Application of MATSim to the Area of Urban Lyon

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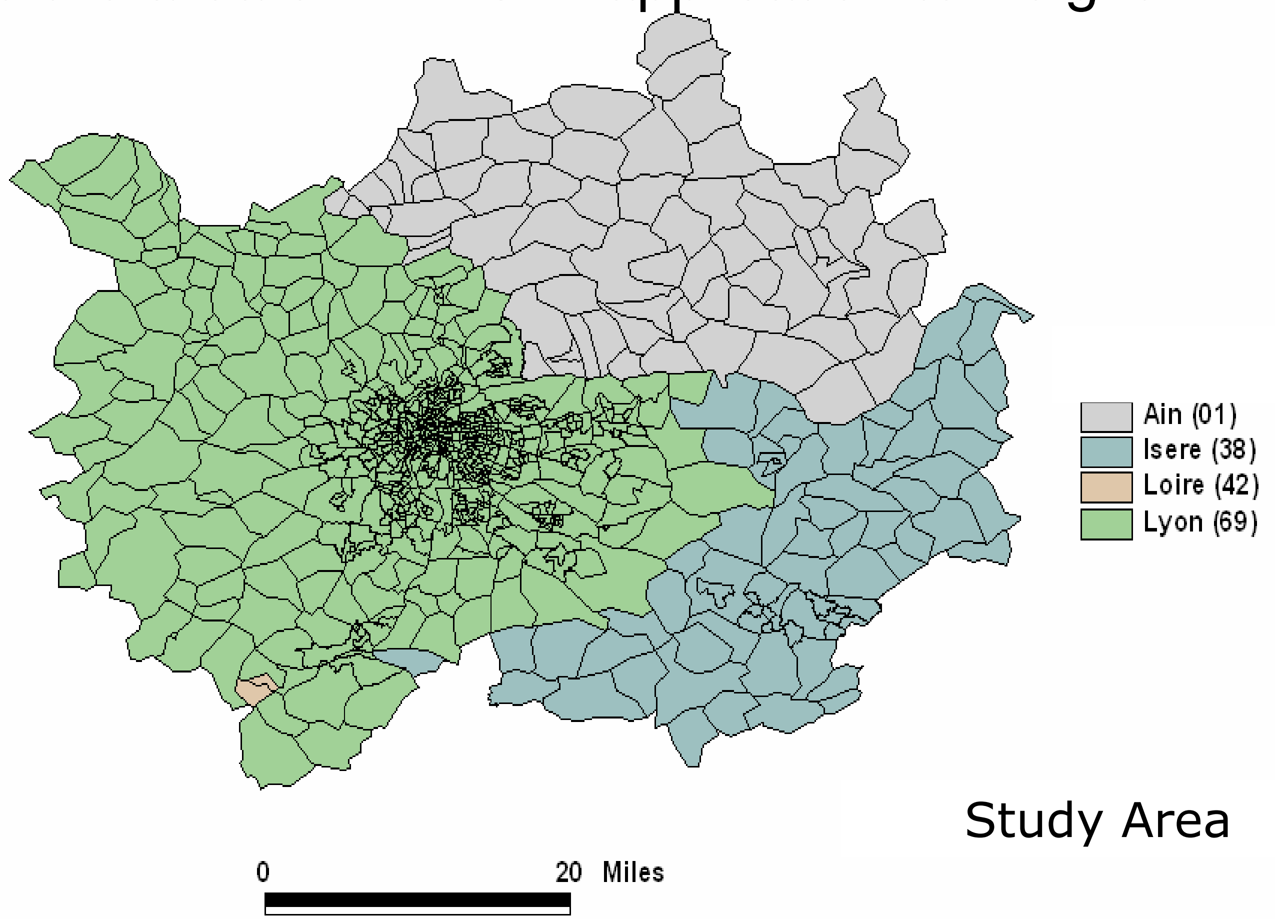
Objective

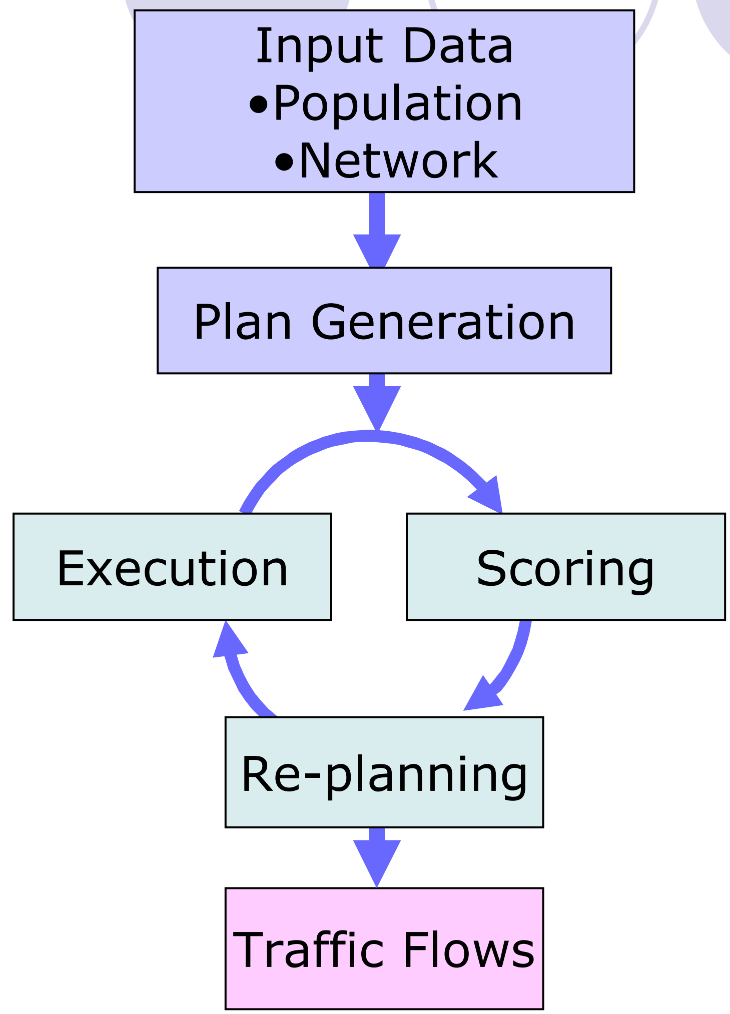
- To apply the available multi-agent simulation model (MATSim) to passenger transport in Lyon area.
- To extend the area of MATSim application to freight transport



Study Area

Model Structure

1. Preparing Input data
2. Plan generation
3. Plan execution by traffic flow simulation
4. Scoring plan, re-planning, re-execution
5. Final results on traffic flows



MATSim overall model structure

Source: Balmer M. (2007) Dissertation

Preparing Synthetic Household Population

Synthetic House Hold Population

- Database
  - *Lyon household trip survey (Enquête Ménages Déplacements Lyon 2006)*
    - Total 11,229 households include 27,573 persons
    - Household information: number of people, number of cars, income, etc.
    - Person information: age, sex, employment etc.
    - Person travel information: origin, destination, purpose, mode, departure time, etc.
  - *Household database (INSEE database)*
    - *Total 662,249 households include 1,609,067 persons*
    - Age group of head
    - Job status of head
    - Number of people in household
    - Number of actives in household
    - Number of cars
  - *Other aggregate socio-economic databases*
    - Household income level distribution
    - Total number of workers living in zones
    - Total number of population by age and sex
    - Etc.

Attributes needed to estimate

- Household attributes
  - Income level
  - Internet at home
  - Parking
  - Etc.
- Person attributes
  - Age, sex
  - Employment type
  - Education level
  - Driving license
  - Monthly public transportation ticket
  - Work at home
  - Daily activity chain and modes

IPF Technique

Formulation

$$P^{t}_{i1,i2,..im} = C_m P^{t-1}_{i1,i2,..im} / \sum_{all\ m} P^{t-1}_{i1,i2,..im}$$

where,

t	*iteration t,*
m	*dimension m,*
$i1, i2,..im$	*cell i in matrix,*
$P^{t}_{i1,i2,..im}$	*proportion in cell i at iteration t,*
C_m	*fixed sum in dimension m,*

P^t_{11}	P^t_{12}	P^t_{1n}	R_1
......	....	......	R_2
⋮			
⋮			
P^t_{1n}		P^t_{mn}	R_m
C_1	C_2	C_n	

Correlation

Odd ratio for multi-dimension matrix,

$$\phi = \frac{(P_{i1,i2,..im})(P_{i1...iJ+c1..ik+c2...im})}{(P_{i1..iJ+c1..ik...im})(P_{i1..iJ...iK+c2...im)}}$$

Odd ratio for two-dimension matrix,

$$\phi = \frac{P_{1,1}P_{2,2}}{P_{1,2}P_{2,1}}$$

IPF Procedure

- *Step 1*:
  - iteration t=0, set initial cells, to the value given from survey data and set all zero cells to 0.2
  - Fix marginal totals, to the value from the given total from aggregate data sources.
- *Step 2*:
  - calculate cell values at iteration t for each matrix dimension as:

$$p^{t}_{i_1,i_2,\ldots,i=k,..i_m} = T_k\, p^{t-1}_{i_1,i_2,\ldots,i=k,..i_m} / \sum_{all\ k} p^{t-1}_{i_1,i_2,\ldots,i=k,..i_m}$$

  - Repeat the same to all dimensions.
- *Step 3*:
  - get the maximum difference between iterations as:

$$conv = \max[p^{t}_{i_1,i_2,\ldots,i=k,..i_m} - p^{t-1}_{i_1,i_2,\ldots,i=k,..i_m}]$$

  - stop when convergence is reached, $conv <= 0.5$

Example Calculation

- Calculation of Income of Household
  - Initial table for zone 10050000 (Amberieux-en-Dombes)

				Income of HH by classes											
#Cars	Age	#NP	UC	5958	9139	11719	14000	16198	18505	21249	25084	32026	more	Sum	Fixed
0	1	1	**0.0**	0.2	129.0	0.2	0.2	38.0	0.2	0.2	6.0	0.2	1.0	175.2	**0.0**
.	.	.	.	.	.	.	.	.	.	.	.	.	.		.
.	.	.	.	.	.	.	.	.	.	.	.	.	.		.
0	5	1	**17.0**	0.2	166.0	0.2	0.2	127.0	0.2	0.2	9.0	0.2	3.0	306.2	**17.0**
0	5	2	**6.0**	10.5	0.2	52.5	0.2	0.2	10.5	0.2	3.0	0.2	1.5	79.0	**6.0**
0	5	3	**0.0**	1.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	3.6	**0.0**
0	5	4	**0.0**	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.0	**0.0**
0	5	5	**0.0**	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.0	**0.0**
1	1	1	**7.0**	0.2	66.0	0.2	0.2	99.0	0.2	0.2	32.0	0.2	8.0	206.2	**7.0**
1	1	2	**4.5**	30.7	0.2	59.2	0.2	0.2	43.5	1.3	10.5	0.2	10.5	156.5	**4.5**
1	1	3	**2.0**	18.0	27.0	1.6	20.2	0.2	0.2	5.4	1.6	3.6	0.2	78.0	**2.0**
1	1	4	**4.6**	10.9	23.3	2.3	10.5	0.2	2.1	0.2	0.2	0.2	0.2	50.1	**4.6**
.	.	.	.	.	.	.	.	.	.	.	.	.	.		.
2	2	2	**9.0**	9.0	0.2	39.9	0.2	0.2	73.5	2.6	70.5	0.2	55.3	251.6	**9.0**
2	2	3	**38.0**	19.8	77.2	4.8	151.0	1.6	20.0	129.6	19.6	68.4	25.8	517.8	**38.0**
2	2	4	**128.8**	15.3	135.2	82.7	305.5	55.2	279.1	15.0	189.9	9.2	60.9	1148.0	**128.8**
2	2	5	**119.0**	110.5	112.5	169.6	83.4	97.4	25.8	100.6	14.4	38.9	0.2	753.3	**119.0**
2	3	1	**1.0**	0.2	0.2	0.2	0.2	9.0	0.2	0.2	14.0	0.2	11.0	35.4	**1.0**
2	3	2	**31.5**	15.0	0.2	130.3	0.2	0.2	181.5	0.2	193.5	1.3	149.8	672.2	**31.5**
2	3	3	**56.0**	9.6	81.0	0.2	210.8	0.2	128.0	23.4	119.6	25.2	49.2	647.2	**56.0**
.	.	.	.	.	.	.	.	.	.	.	.	.	.		.
			Sum	1210.4	2047.9	1967.6	1368.3	1260.0	1786.6	562.5	1557.4	291.8	842.3		
			Fixed	**49.18**	**111.63**	**107.71**	**100.73**	**101.41**	**75.19**	**84.23**	**87.23**	**93.85**	**75.06**		

Example Calculation

- Calculation of Income of Household
  - Final table for zone 10050000 (Amberieux-en-Dombes)

				Income of HH by classes											
#Cars	Age	#NP	UC	5958	9139	11719	14000	16198	18505	21249	25084	32026	more	Sum	Fixed
0	1	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
0	5	1	17.0	0.0	6.3	0.0	0.0	10.1	0.0	0.0	0.4	0.0	0.2	33.8	17.0
0	5	2	6.0	0.6	0.0	4.1	0.0	0.0	0.6	0.0	0.3	0.1	0.2	11.8	6.0
0	5	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0	5	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0	5	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	1	1	7.0	0.0	1.4	0.0	0.0	4.5	0.0	0.0	0.7	0.0	0.3	13.7	7.0
1	1	2	4.5	0.7	0.0	1.7	0.0	0.0	0.9	0.1	0.4	0.0	0.6	8.4	4.5
1	1	3	2.0	0.2	0.5	0.0	0.4	0.0	0.0	0.3	0.0	0.4	0.0	4.0	2.0
1	1	4	4.6	0.7	2.3	0.2	1.1	0.0	0.1	0.0	0.0	0.1	0.0	9.2	4.6
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2	2	2	9.0	0.2	0.0	1.2	0.0	0.0	1.6	0.2	2.5	0.0	3.3	14.7	9.0
2	2	3	38.0	0.5	2.7	0.2	5.6	0.1	0.5	11.8	0.7	14.2	1.7	74.3	38.0
2	2	4	128.8	1.1	14.0	7.6	32.9	12.0	18.9	4.0	21.0	5.6	11.6	246.0	128.8
2	2	5	119.0	7.7	11.7	15.6	9.0	21.3	1.8	26.8	1.6	23.6	0.0	238.0	119.0
2	3	1	1.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.4	1.6	1.0
2	3	2	31.5	0.4	0.0	4.9	0.0	0.0	5.1	0.0	8.8	0.3	11.8	51.2	31.5
2	3	3	56.0	0.4	5.6	0.0	15.0	0.0	5.7	4.1	8.7	10.1	6.2	105.8	56.0
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			Sum	49.18	111.63	107.71	100.73	101.41	75.19	84.23	87.23	93.85	75.06		
			Fixed	49.18	111.63	107.71	100.73	101.41	75.19	84.23	87.23	93.85	75.06		

IPF Technique

- Advantage of IPF technique
  - Control the final result to be as same as the fixed value obtained from aggregate data sources
  - Maintain the correlation structure from the initial input
  - Less bias from travel survey data comparing with other technique
    - the distribution is distorted to be fitted with the fixed value
    - extend the distribution to cover the area that might be neglected from travel survey

Results

- Activity chain with modes in percent

Act-Chain	Work-Full	Act-Chain	Work-Par	Act-Chain	Retire	Act-Chain	Student	Act-Chain	Others
HcWcH	16.64	HcWcH	6.98	HcLcH	8.25	HpEpH	13.12	HcScH	5.06
HcWcHcWcH	4.15	HpWpH	3.83	HwSwH	7.49	HwKwH	4.78	HcLcH	4.73
HpWpH	3.88	HcWcHcWcH	2.40	HcScH	7.11	HcKcH	4.23	HwSwH	4.47
HcWcHcLcH	1.83	HcScH	1.71	HwLwH	5.03	HwKwHwKwH	4.22	HwLwH	2.71
HcWcScH	1.56	HcAcWcAcH	1.55	HwSwHwLwH	2.45	HwEwHwEwH	3.36	HpSpH	1.59
HcWcLcWcH	1.34	HwWwH	1.45	HpLpH	2.09	HwEwH	3.01	HwAwHwAwH	1.54
HcAcWcH	1.17	HcLcH	1.45	HcCcH	1.46	HcEcH	2.55	HwAwHwAwHwAwHwAwH	1.52
HcWwLwWcH	1.07	HcAcWcH	0.99	HcScScH	1.42	HcKcHcKcH	1.81	HpLpH	1.26
HwWwH	1.05	HcWcScH	0.97	HcScHcLcH	1.39	HcLcH	1.67	HcMcH	1.15
HwWwHwWwH	0.97	HcWcHcLcH	0.88	HpSpH	1.24	HpEpHpEpH	1.64	HpCpH	1.02
HcWcWcWcH	0.96	HcWcHcAcH	0.79	HcLcHcLcH	1.22	HpEpHcLcH	1.36	HcAcHcAcHcAcHcAcH	0.99
HcWcLcH	0.94	HcWcHcScH	0.75	HwSwHcLcH	1.19	HcEpH	1.15	HcLcHcLcH	0.90
HcAcWcAcH	0.92	HwWwHwWwH	0.74	HwSwSwH	1.06	HpEcH	0.92	HcScHcLcH	0.83
HcWcHcScH	0.91	HcScHcLcH	0.71	HwLwHwLwH	0.93	HpEpHwLwH	0.78	HcAcH	0.81
HcScH	0.85	HwSwH	0.64	HcScHcScH	0.84	HcKwH	0.75	HcScScH	0.79
HcWcWcH	0.74	HcWcLcWcH	0.56	HcAcH	0.73	HpEwLwEpH	0.74	HcCcH	0.77
HcLcH	0.71	HwLwH	0.56	HcScLcH	0.73	HcEcHcEcH	0.67	HcLcLcH	0.75
HcWcAcH	0.69	HcWcAcH	0.45	HcScHwLwH	0.67	HwLwH	0.63	HwSwHwLwH	0.74
HcWcHwLwH	0.67	HcAcHcAcH	0.44	HwSwHcScH	0.58	HcKcHcLcH	0.56	HcAcHcAcH	0.66

Trip purpose

H =home
W=work
E =education
S=shopping
L=leisure
K=kindergarten
C =health care
M =maintenance
A =accompany

Mode

c =car
p =public transport
b =bike
m =motorbike
w = walk
u = others

Results

- Plan

```
<?xml version="1.0" encoding="utf-8"?>
<!DOCTYPE plans SYSTEM "http://www.matsim.org/files/dtd/plans_v4.dtd">
<plans name="LyonPOP" xml:lang="de-CH">
<!-- ====================================================================== -->
    <person id="7" sex="m" age="27" license="yes" car_avail="always" employed="yes">
        <knowledge desc="created based on lyon travel survey data">
            <activity type="home">
                <location id="1">
                </location>
            </activity>
        </knowledge>
        <plan selected="yes">
            <act type="home" x="798882" y="2113975" start_time="00:00:00" end_time="24:00:00" dur="24:00:00"/>
            <leg mode="car"/>
            <act type="work" link="0" start_time="00:00:00" end_time="24:00:00" dur="24:00:00"/>
            <leg mode="walk"/>
            <act type="leisure" link="0" start_time="00:00:00" end_time="24:00:00" dur="24:00:00"/>
            <leg mode="walk"/>
            <act type="work" link="0" start_time="00:00:00" end_time="24:00:00" dur="24:00:00"/>
            <leg mode="car"/>
            <act type="home" x="798882" y="2113975" start_time="00:00:00" end_time="24:00:00" dur="24:00:00"/>
        </plan>
    </person>
<!-- ====================================================================== -->
</plans>
```

Results

- Person attributes

```xml

<?xml version="1.0" encoding="utf-8"?>

    <person id="1" household="1" tcl_ticket="no" work_fulltime="yes" pcs="61"
        work_at_home="no" education="coll_CAP_BEP"/>
    <person id="2" household="1" tcl_ticket="no" work_fulltime="no" pcs="81"
        work_at_home="no" education="primaire"/>
    <person id="3" household="2" tcl_ticket="no" work_fulltime="yes" pcs="55"
        work_at_home="no" education="coll_CAP_BEP"/>
    <person id="4" household="2" tcl_ticket="no" work_fulltime="no" pcs="81"
        work_at_home="no" education="primaire"/>
    <person id="5" household="3" tcl_ticket="no" work_fulltime="yes" pcs="54"
        work_at_home="no" education="coll_CAP_BEP"/>
    <person id="6" household="3" tcl_ticket="no" work_fulltime="no" pcs="81"
        work_at_home="no" education="superieurs"/>
```

Results

- Household data

```xml

<?xml version="1.0" encoding="utf-8"?>

<household id="1" persons="1 2" nocars="1" income="25857.0" internet="no"
    habitat="petitColletif" occupation="proprietaire" parking="gratuit"/>

<household id="2" persons="3 4" nocars="2" income="32416.5" internet="yes"
    habitat="individuelIsole" occupation="proprietaire" parking="gratuit"/>

<household id="3" persons="5 6" nocars="2" income="26268.0" internet="yes"
    habitat="grandCollectif" occupation="proprietaire" parking="gratuit"/>
<household id="4" persons="7 8" nocars="1" income="13880.0" internet="no"
    habitat="individuelIsole" occupation="proprietaire" parking="payant"/>
```

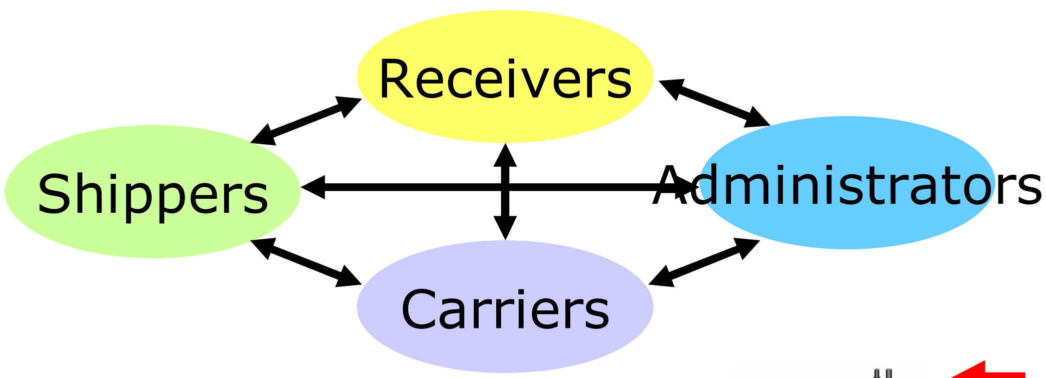
Next step

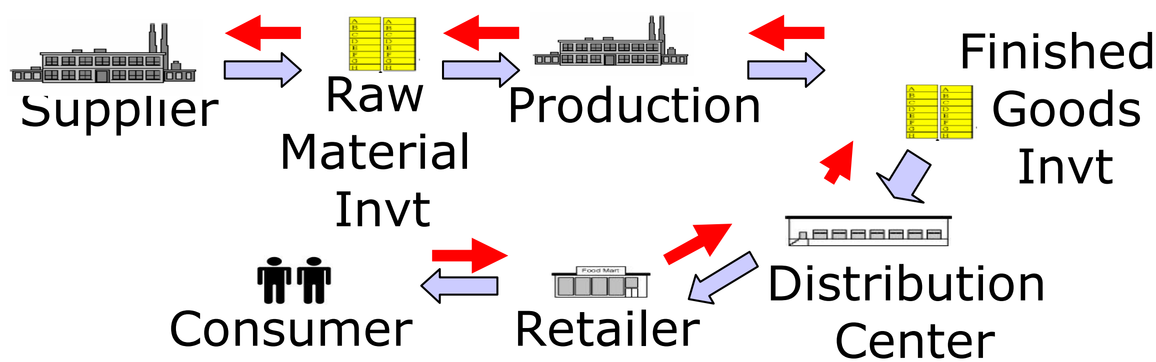
- Adding primary location
- Adding secondary location
- Application of MATSim on Lyon area using the generated Plan on the transport network
  - Results
    - Hourly traffic volume on the network
    - Vehicle Kilometer of Travel (VKT)
    - Etc.

MATSim for freight transport

Characteristics of freight transport

- Freight movement is originated from the movement of commodities through supply chains.
- Freight movement involves very complex linkage among many freight agents.
- Freight movement deals with commodities those vary in value, volume, weight, and shape.

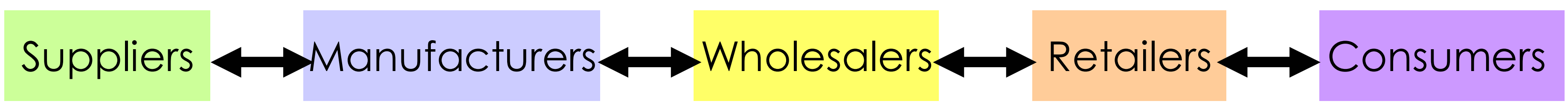




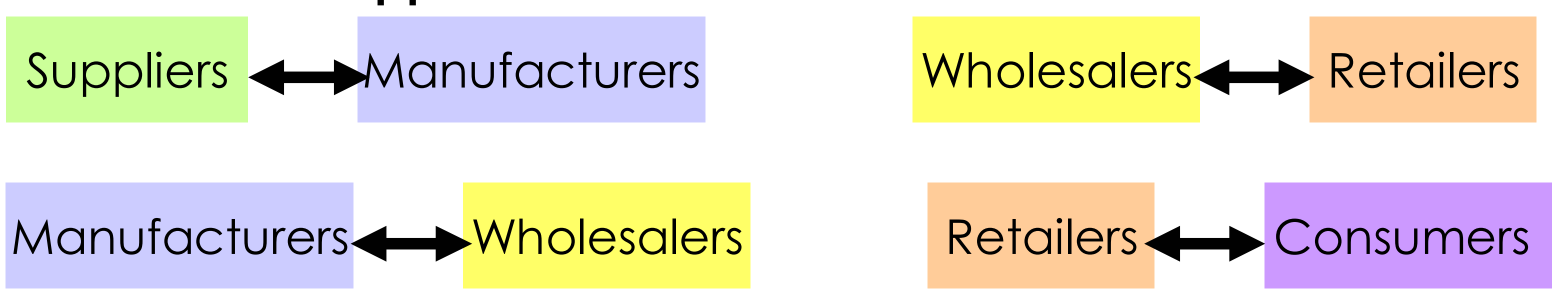
Problem Statement

- The conventional approach can consider only the interaction between each pair of shipper and customer.
- In fact, the behavior of agent is also influenced by the other agents staying in the lower or upper state in the supply chain.
- Simulation based models is found suitable to deal with the interactions in the dynamic system of supply chain.

Actual



Conventional Approach



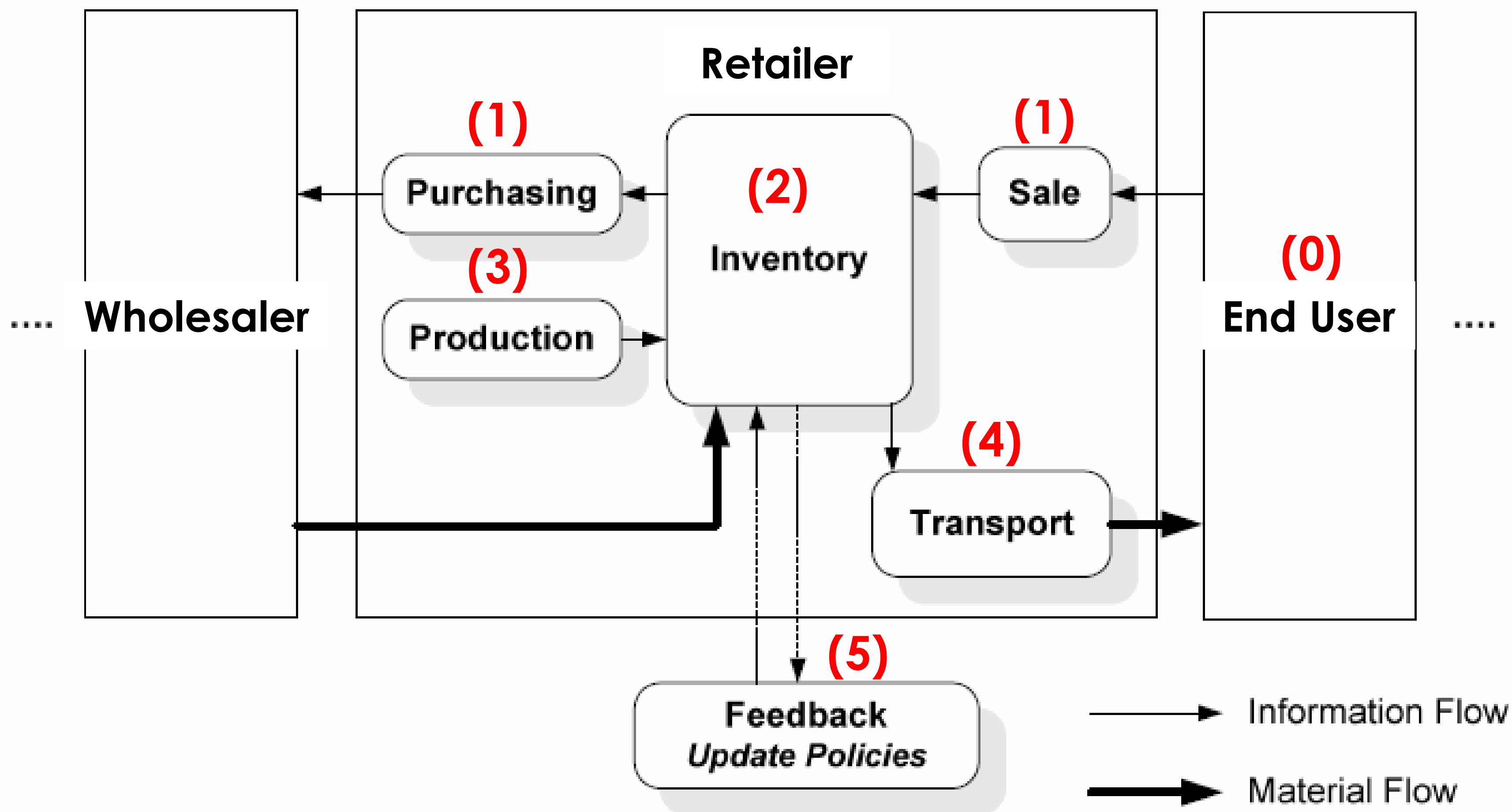
Objective

- To develop a supply chain based simulation model that demonstrates the relationship between commodity flows and traffic flows.

Concept

- The model is a combination of optimization and simulation method.
- The activities of agents are based on minimization of the cost involved in those activities.
- The proposed model simulates everyday the activities of each agent involved in procurement, production, inventory, and distribution.
- The model consists of five modules including:
  - Production Module
  - Sale-Purchasing Decision Module
  - Inventory Module
  - Transportation Module
  - Feedback Module

Model Structure



(0) Demand from End Users

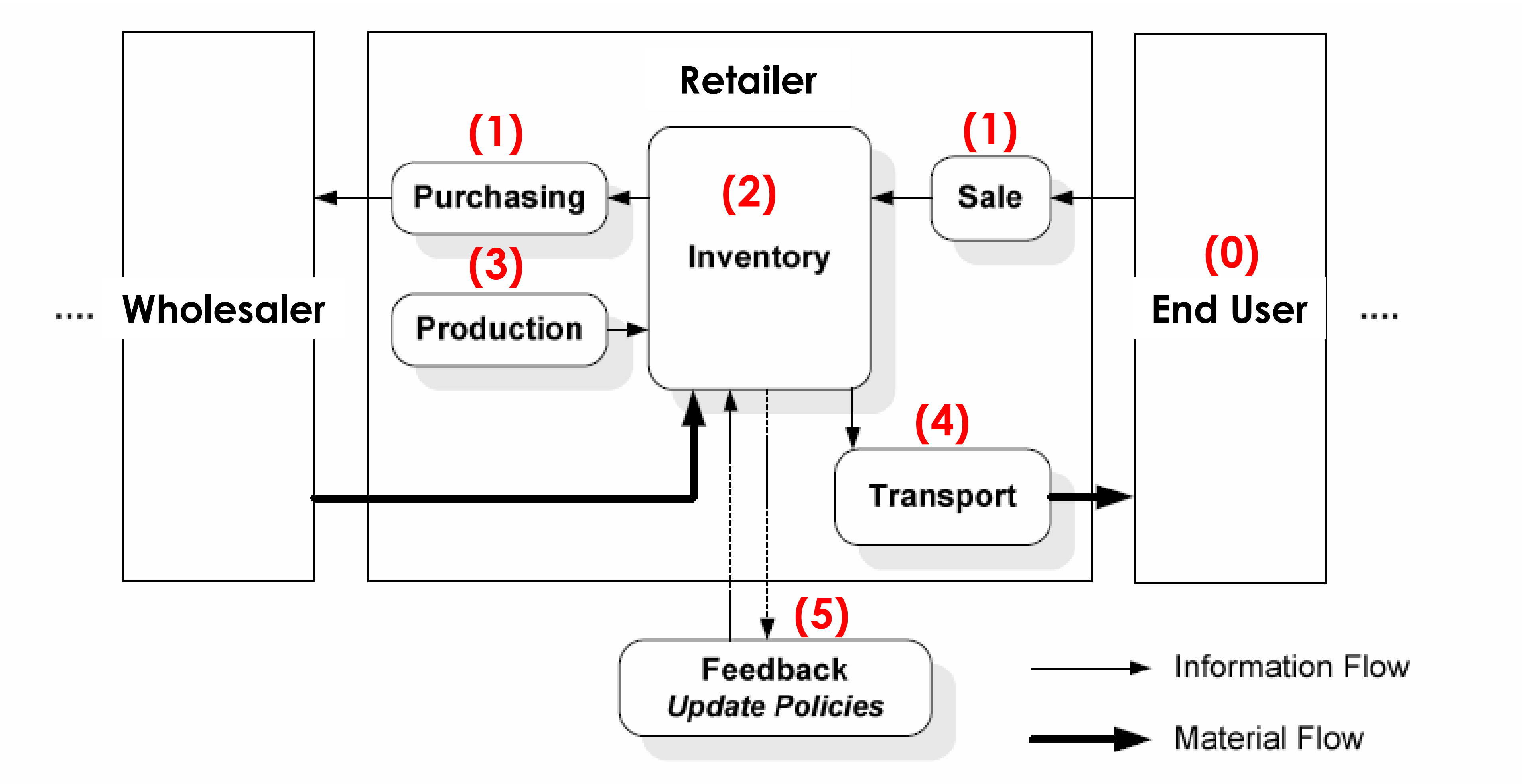
- Assuming that the demand that consumers purchase from retailers is normal distribution with mean and variance obtained from the total demand in the area.

$$d_i^t = N(\bar{d}_i, \varepsilon_i)$$

where,

d_i^t	Daily sale of retailer *i* at time *t*
$\bar{d}_i$	Average daily sale of each retailer
ε_i	Sd. Of daily sale of each retailer

Model Structure



(1) Sale-Purchasing Module

- As a firm can purchase a commodity from many sources; purchasing decision module determines the fraction of commodity to be purchased from each source.
- The purchasing fraction is a multiplication of three parts:
  - distribution channel choice, $P(C)$
  - location choice, $P(z|C)$
  - shipper choice. $P(i|C,z)$

$$P(i) = P(C) \cdot P(z|C) \cdot P(i|C,z), \quad i \in C, z$$

- distribution channel choice, $P(C)$
  - The probability that each industry type is selected
  - Directly calculate from survey data

(1) Sale-Purchasing Module (Cont.)

Location Choice, $P(z|C)$

- Probability that zone *z* is selected
- Using multinomial logit model
- Developed separately by industry type of customer, industry type of shipper, and commodity type

$$P(z|C) = \frac{\exp(\mu^z V_z)}{\sum_{z' \in z} \exp(\mu^z V_{z'})}$$

Utility function: $V_z = f(D_{IJ}, N_I^{C,k}, G_I^k)$

where,

D_{IJ} distance between zone I and J

G_I^k total commodity k generated from zone I

$N_I^{C,k}$ number of firm type C in zone I

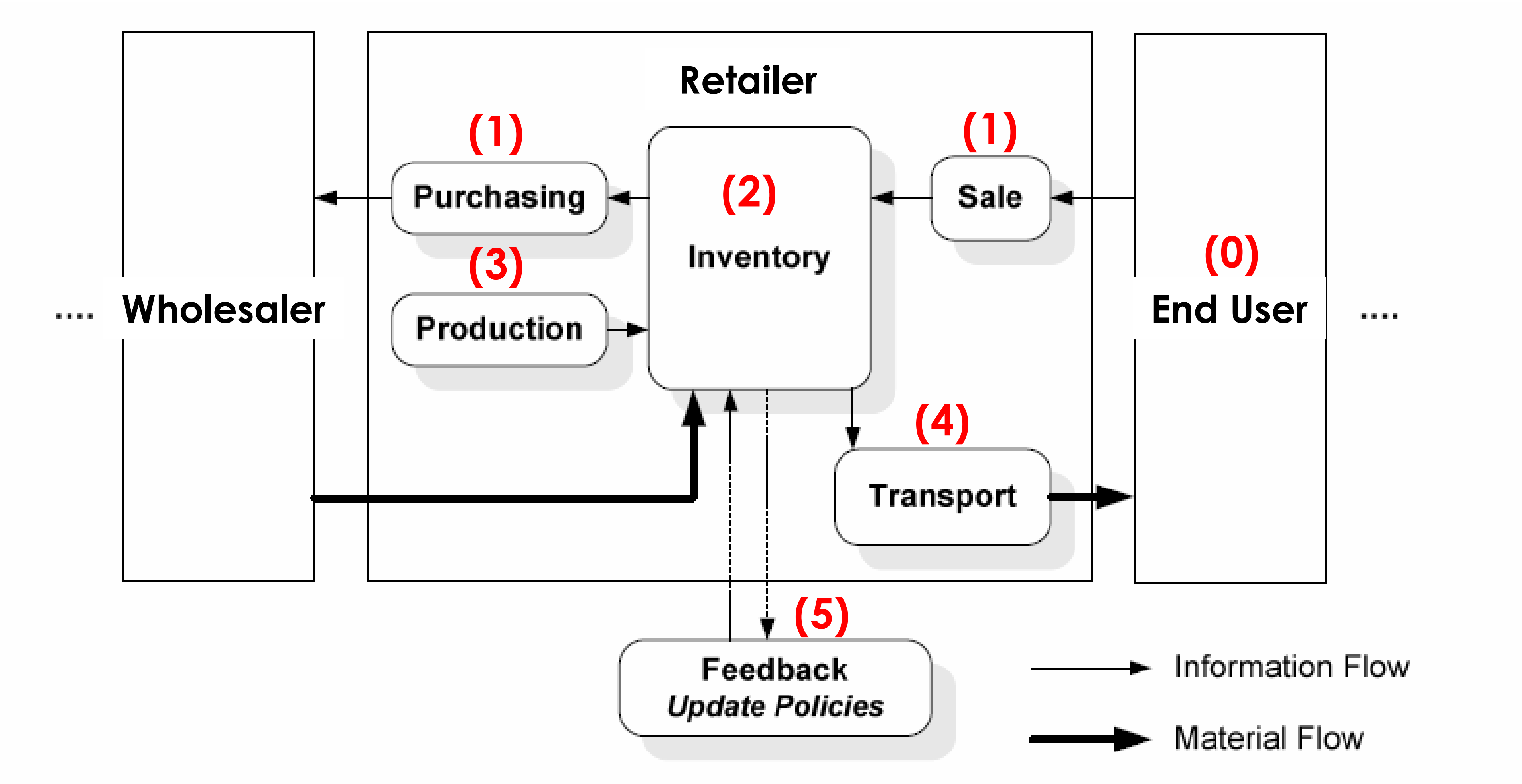
(1) Sale-Purchasing Module (Cont.)

Shipper Choice, $P(i|C,z)$

- Probability that shipper *i* is selected
- Using multinomial logit model
- Derived from the amount of commodity production of each shipper

$$P(i|C,z) = \frac{\exp(G_i)}{\sum_{i' \in i} \exp(G_i)}$$

Model Structure



(2) Inventory Module

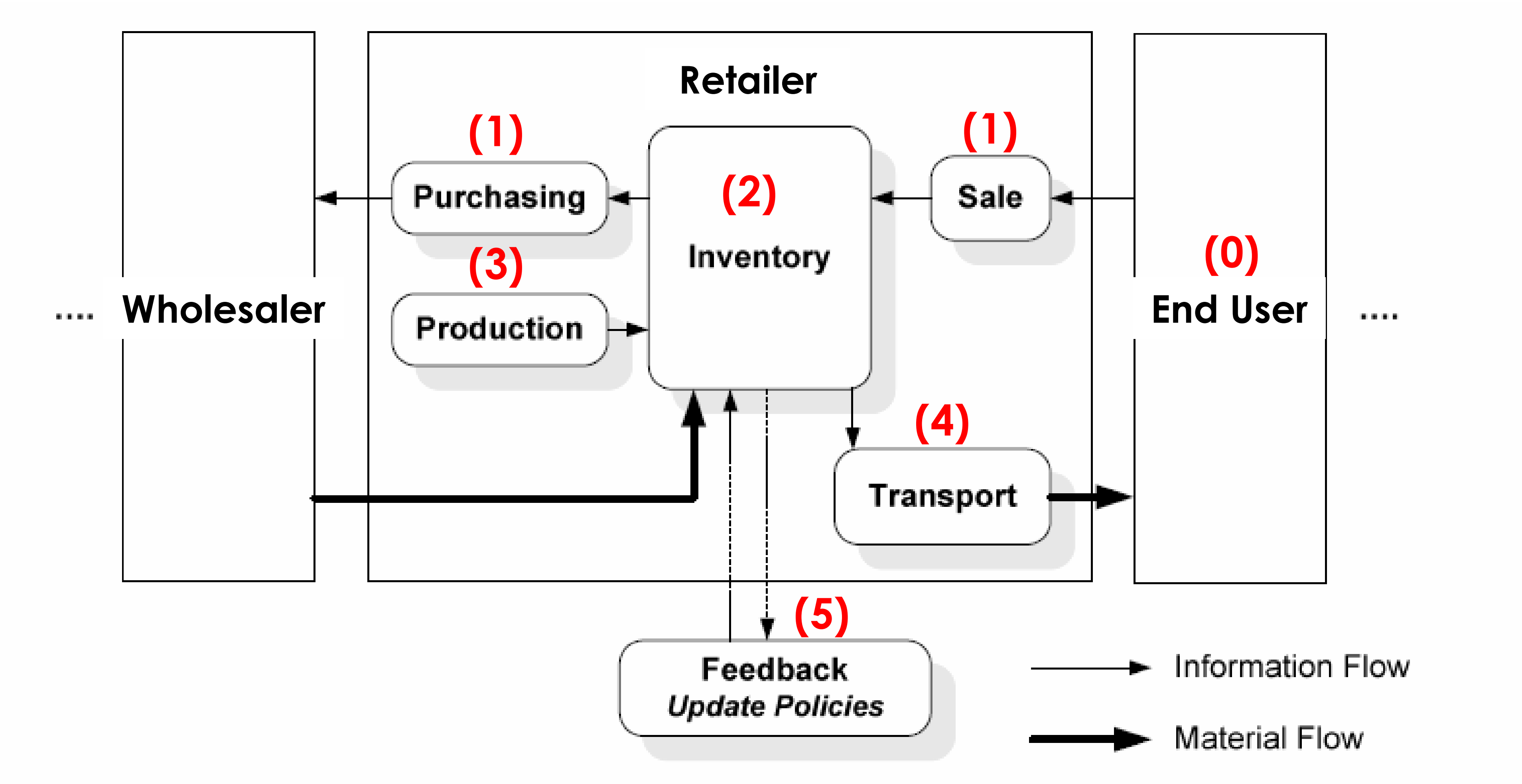
- Inventory module is the main module to decide whether or not the other modules will be activated.
- The decisions of each firm are assumed to minimize the total inventory costs including holding costs, ordering costs, and transportation costs.

$$F_{ij} = \sqrt{\frac{Q_{ij}}{\gamma \cdot D_{ij}}}$$

where,

F_{ij}	ordering frequency of firm *i* requested to firm *j*.
Q_{ij}	monthly commodity purchased by firm *i* from firm *j*.
D_{ij}	distance between firm *i* and firm *j*.
γ	parameter for inventory model.

Model Structure



(3) Production Module

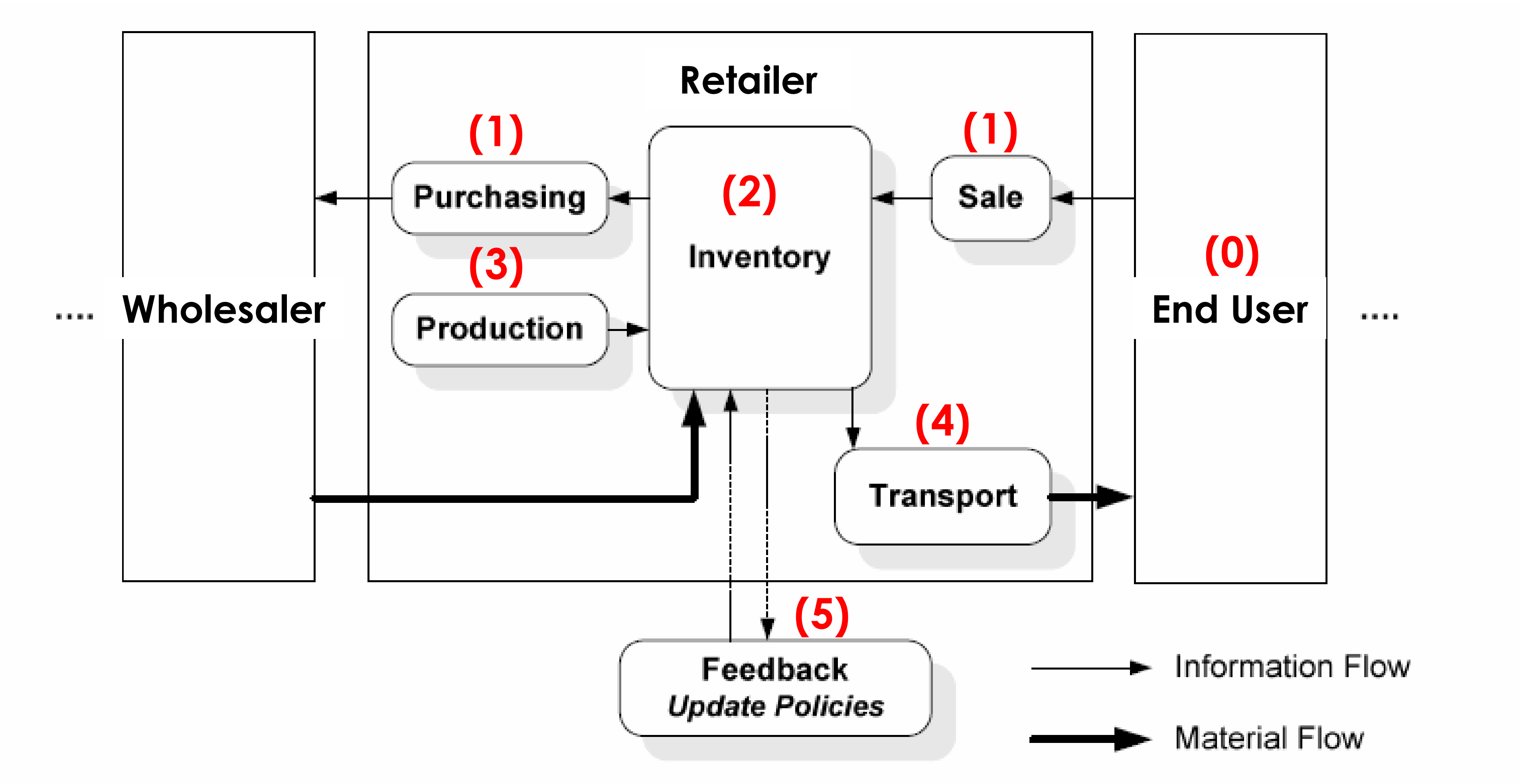
- The average monthly amount of commodities produced by each firm is estimated using regression techniques from the characteristics of firms.
- The variables can be any attributions of the firm, which in this case are number of employees and floor area.

$$G_i = f(x_{1i}, x_{2i}, \cdots, x_{ki})$$

where, G_i monthly amount of produced commodities of firm *i*.

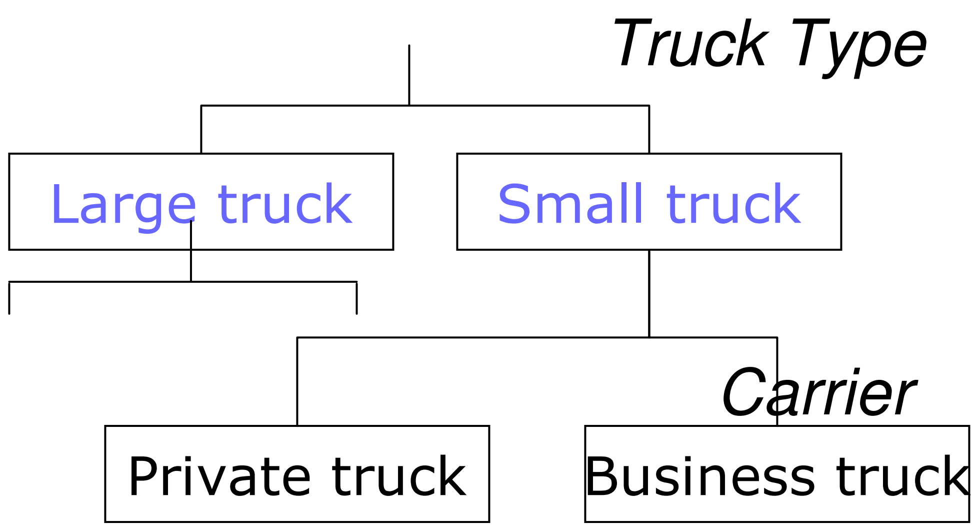
x_{ki} attributions of firm *i*.

Model Structure



(4) Transport Module

- Each time the information flows from customers to shippers, transportation module is activated to distribute the commodities from shippers to their customers.
- Transportation module consists of two sub modules: carrier and vehicle choices and vehicle routing.
- **Carrier and vehicle preference**



(4) Transport Module (Cont.)

- **Vehicle routing**
- provides an order to visit customers.
- The delivery route is decided in the way that minimizes the total route travel time, which is constrained by
  - maximum working hours of a truck driver
  - limited carrying weight of a truck. The total travel time includes the staying time at customer's location for parking, commodity loading and unloading.

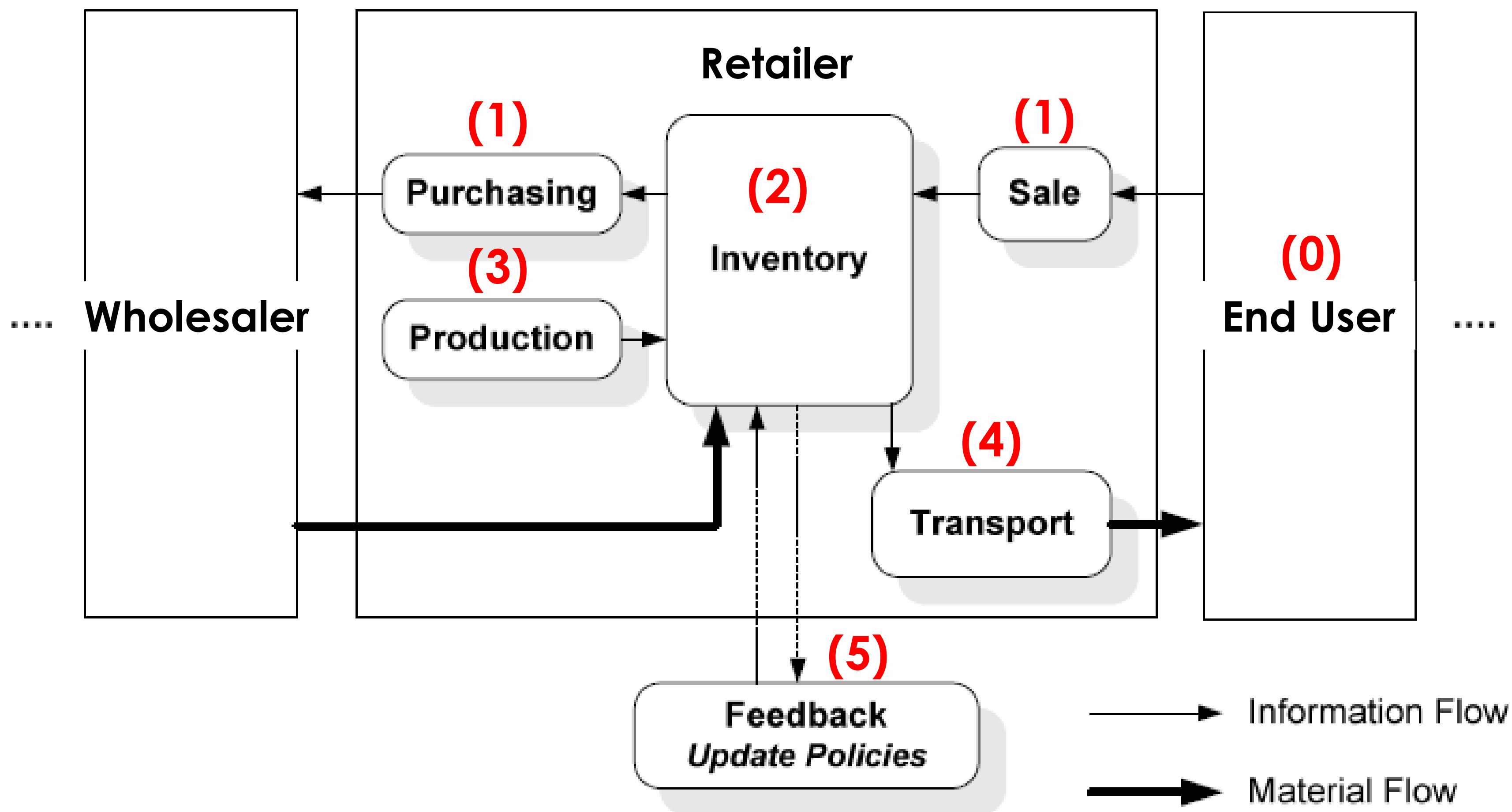
Min $$TC_i = \sum_{m=1}^{n}\sum_{l=1}^{n}((TT_{l,m} + ST_m)\cdot x_{l,m})$$

Subject to

$$\sum_{m=1}^{n} x_{l,m} = 1 \qquad \sum_{m=1}^{n}\sum_{l=1}^{n}((TT_{l,m} + ST_m)\cdot x_{l,m}) \le HR_{\max}$$

$$\sum_{l=1}^{n} x_{l,m} = 1 \qquad \sum_{m=1}^{n}\sum_{l=1}^{n}(L_{l,m}\cdot x_{l,m}) \le WT_{\max} \qquad x_{l,m} \in \{0,1\}$$

Model Structure



(5) Feedback Module

- Firms revise their forecast demand and **decision on production and inventory control**. Based on the new predicted demand, firm will change their production and inventory policies (eg. production rate and ordering frequency).
- **Market share/Consumption pattern** can be changed according to the performance of the firm and its supply chain.

To do

- Adding tools for dealing with firm
  - Production module
  - Sale-Purchase module
  - Inventory module
  - Transport module
  - Feedback module
- Adding transport module with Travel Salesman Problem (TSP)
- Using the available traffic simulation module to get feed back from transport network for updating policies

Thank you for your attention!