An Introduction to Agent-based Modeling and Simulation (part III)

Dr. Emiliano Casalicchio
casalicchio@ing.uniroma2.it

Download @
www.emilianocasalicchio.eu
(talks & seminars section)

Outline

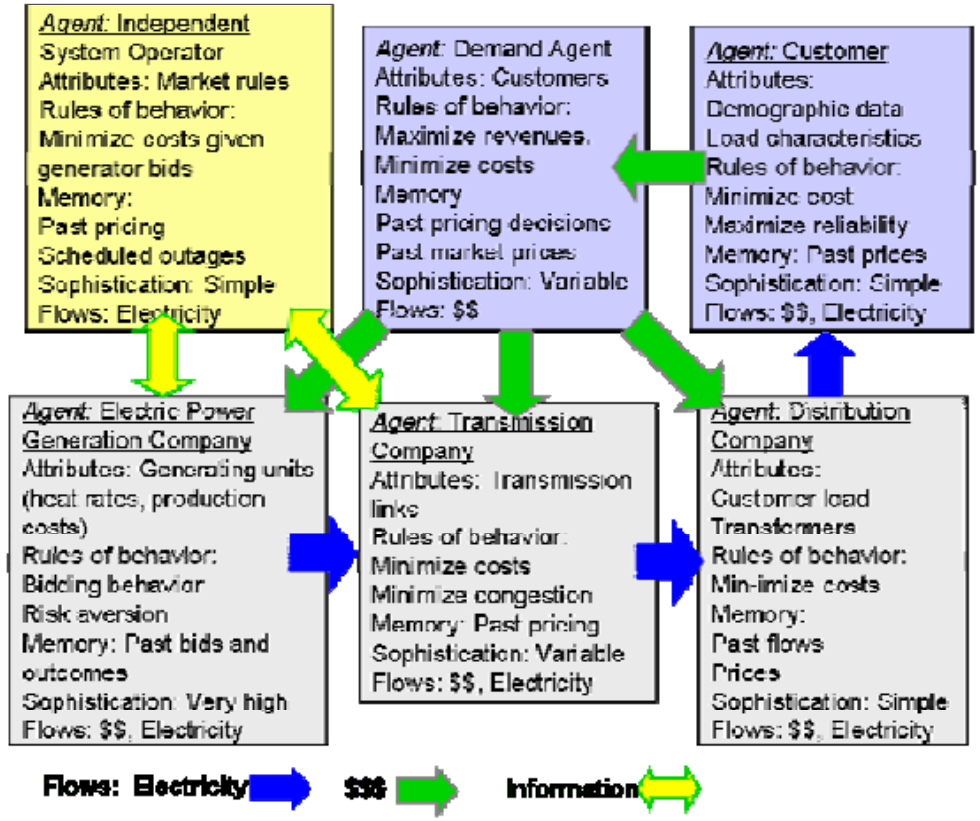
- Part1: An introduction to Agent-based Modeling and Simulation (ABMS)
  - Motivation
  - What is an agent
  - The need for ABMS
  - Background on ABMS
  - Why and when ABMS
- Part 2:
  - ABMS applications
  - How to do ABMS
- **Part 3:**
  - **Electricity market, supply chain example**
  - **ABMS in Workflows and BP re-engineering**

EMCAS: Electricity Market Complex Adaptive System

- It is a large-scale agent based simulation model of the electric power market designed
  - to investigate market restructuring and deregulation.
  - to understand the implications of the coming competitive market in Illinois on electricity prices, availability, and reliability
- It is an example of an agent-based model that has been successfully applied to a real-world policy issue and provided information that would otherwise have not been available using any other modeling approach.

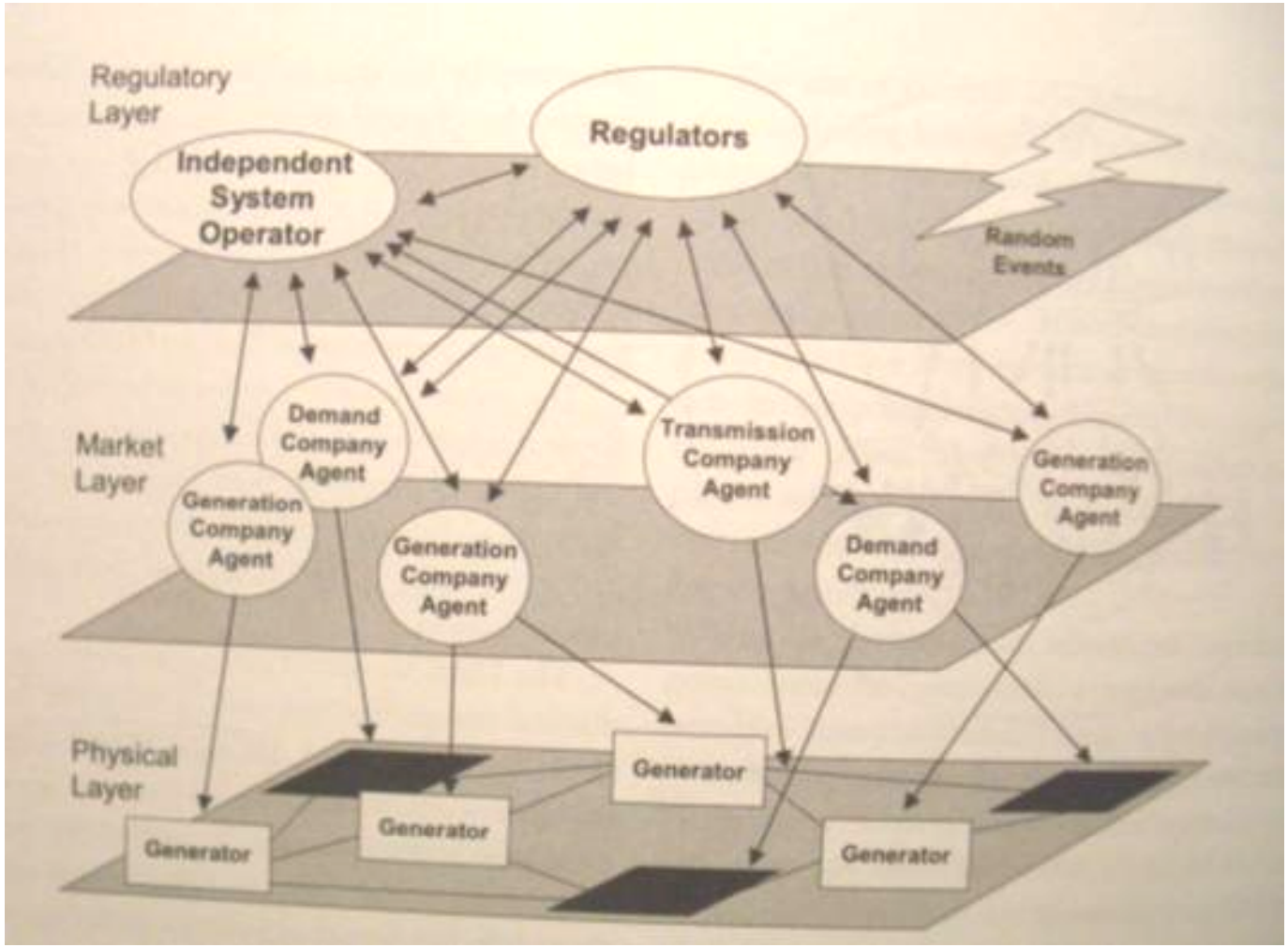
EMCAS Agents

- The agents in EMCAS represent the participants in the restructured electricity market
- Different types of agents capture the heterogeneity of restructured markets, including
  - generation companies,
  - demand companies,
  - transmission companies,
  - distribution companies,
  - independent system operators,
  - consumers.



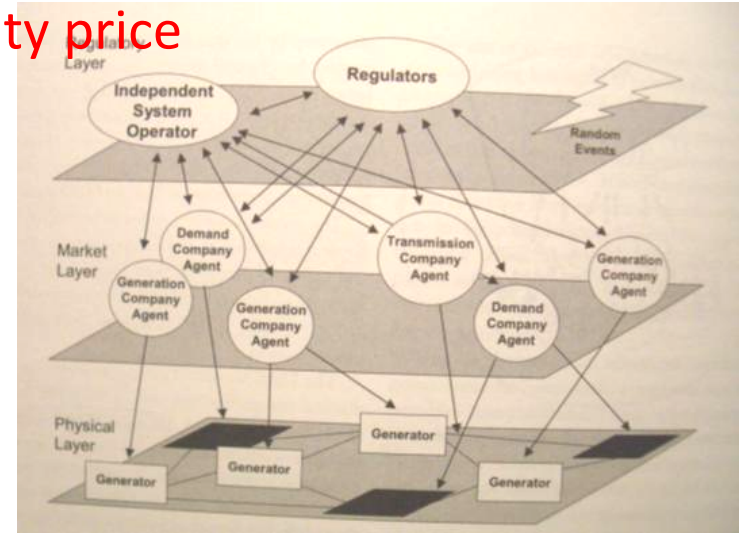
- The agents perform diverse tasks using specialized decision rules.

EMCAS agents



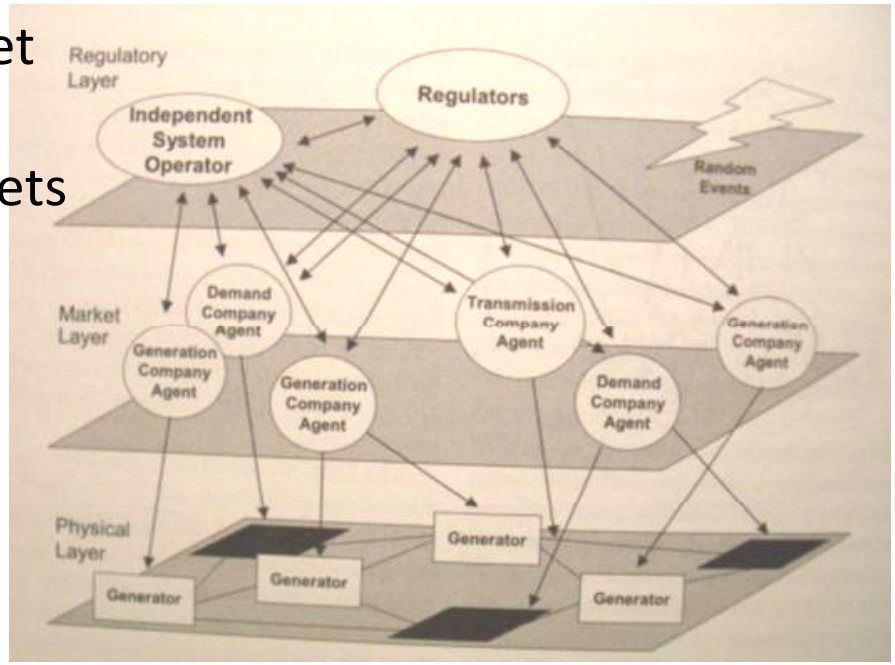
The power grid model

- The electric power grid is not considered an agent because PURELY PASSIVE with no individual activity or memory
  - Transfer electric power between the various agents and passive components within the system
  - The grid provide an high power backbone
  - The grid configuration match the real physical grid being studied (data from national published state sources)
  - The power grid has several thousand components (power lines, transformers, etc…)
  - The physical components are grouped into electrical buses (or tap point)
  - Each tap point has its own hourly unique electricity price



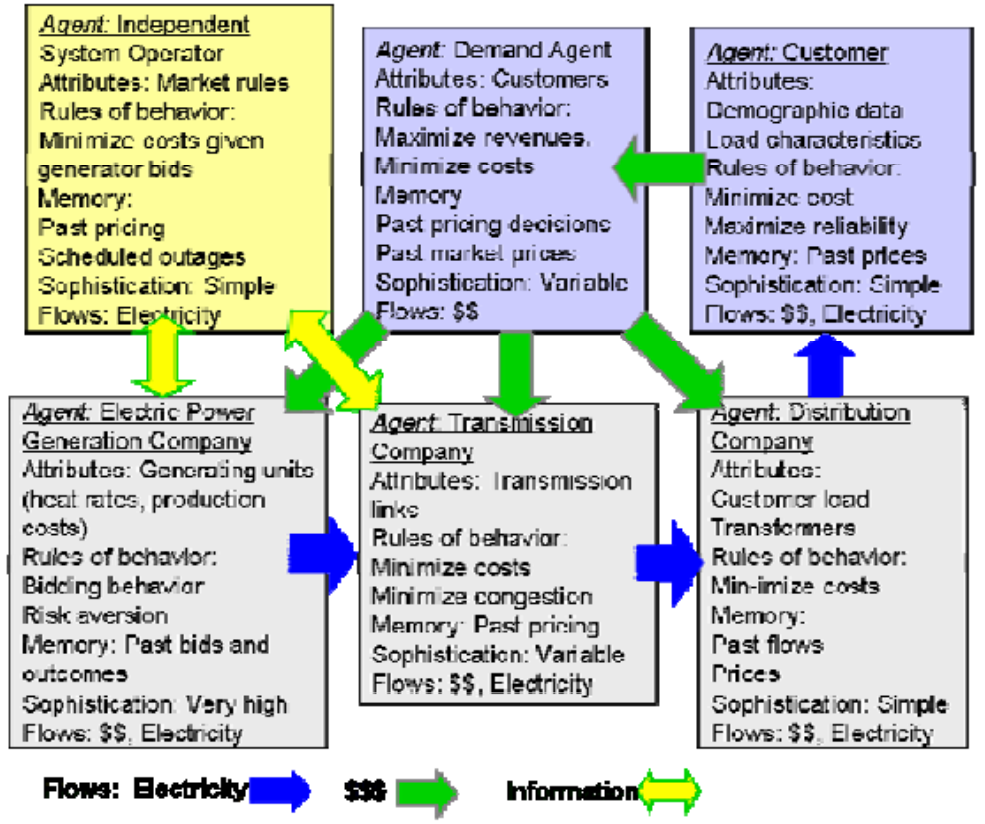
Generation Companies agents

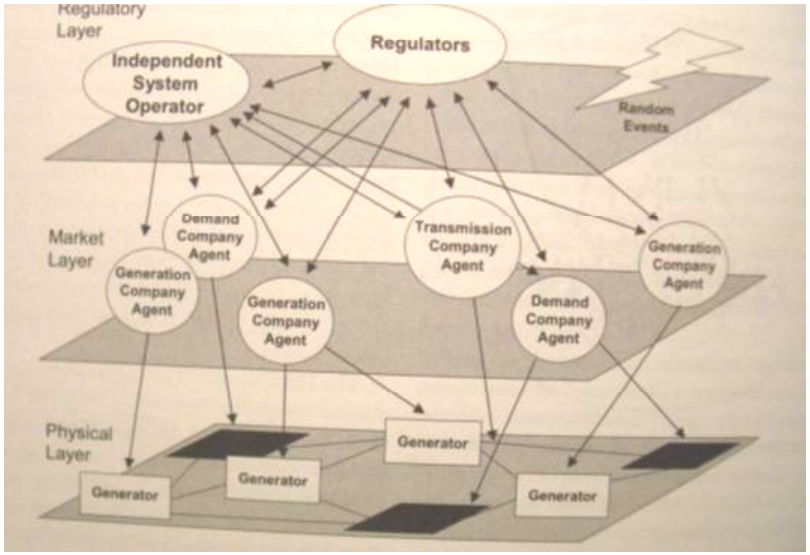
- Own and operate individual portfolios of generators
- Produce power that is sold to distribution companies
- Are modeled as adaptive agents. Adaptive features include
  - The use of complex statistics to project potential future market prices
    - Used to estimate the future prices at each of the electricity tap points where a company can buy or sell power
  - The use of heuristics to develop bidding portfolio
    - To determine the price for their individual generation bids
    - To determine the their individual cost of production
- There are six power generation markets
  - Privately negotiated bilateral power market
  - Publicly cleared spot market
  - Four publicly cleared backup service markets
- The markets differs by
  - Time availability
  - Trade options and futures



Transmission Company agents

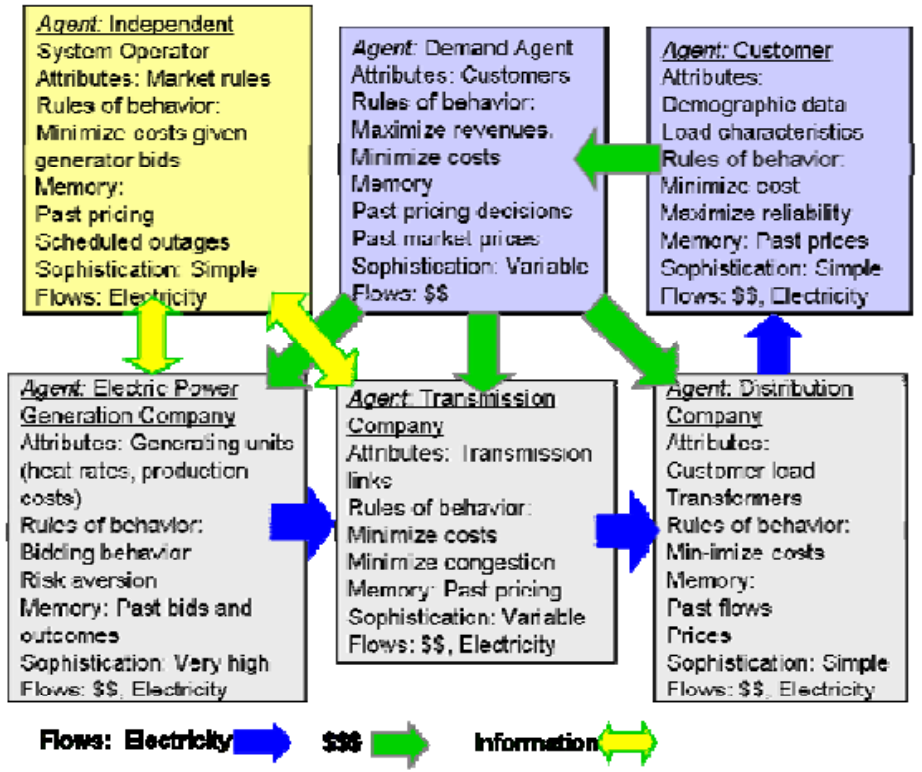
- Deliver power from supplier to retailer
- Are paid in different way
  - Fixed fee (per unit of shipped power) determined by government regulatory body
  - Open or sealed transmission service bidding
  - Hourly value for each transmission line base on the price arbitrage difference between power grid taps.
- They work in the power generation markets
  - Privately negotiated bilateral power market, Publicly cleared spot market, publicly cleared backup service markets
- The want to maximize their profits

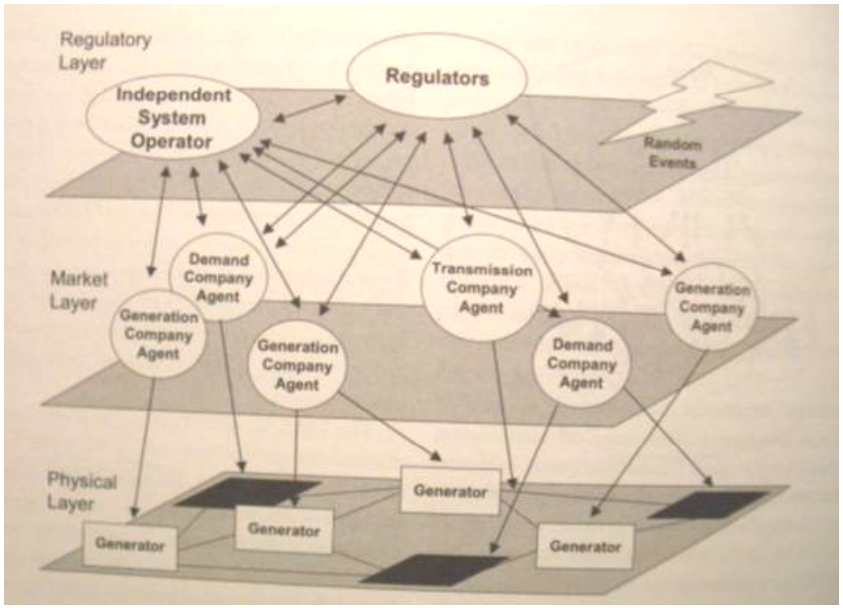




Distribution Company agents

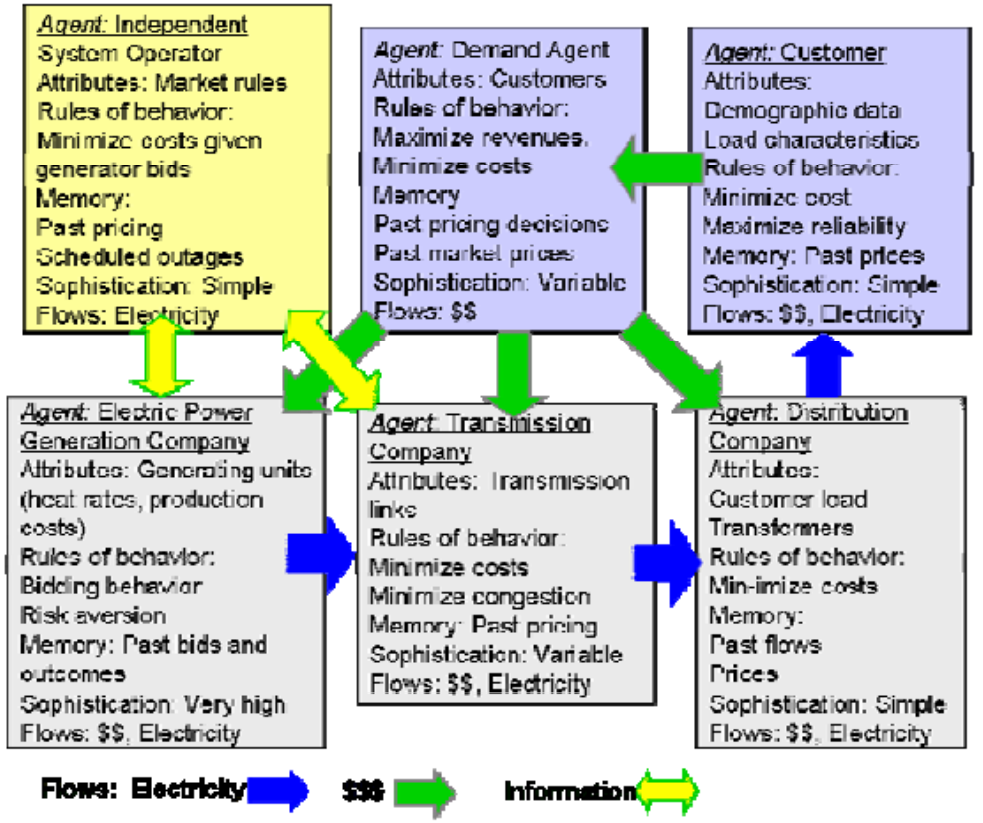
- Are electric power retailer
- Buy wholesale power from generation companies and from intermediate brokers
- Are paid by customers or other distribution companies
- They work in the power generation markets
  - Privately negotiated bilateral power market, Publicly cleared spot market, publicly cleared backup service markets
- The want to maximize their profits

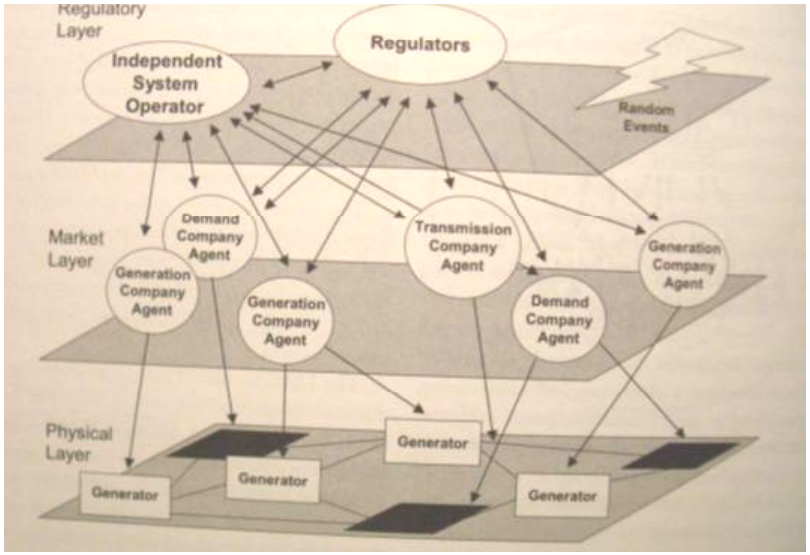




Independent System Operator agents

- Are high regulated private firm or government agencies
  - Acts as a clearing house for pooled bidding
  - Are charged with maintaining the overall stability of the power grid
  - Handle pool market payment clearing
- Charge distribution companies
  - for the operations fees needed to buy reserve power
  - any cost necessary to exercise the options in times of crisis.



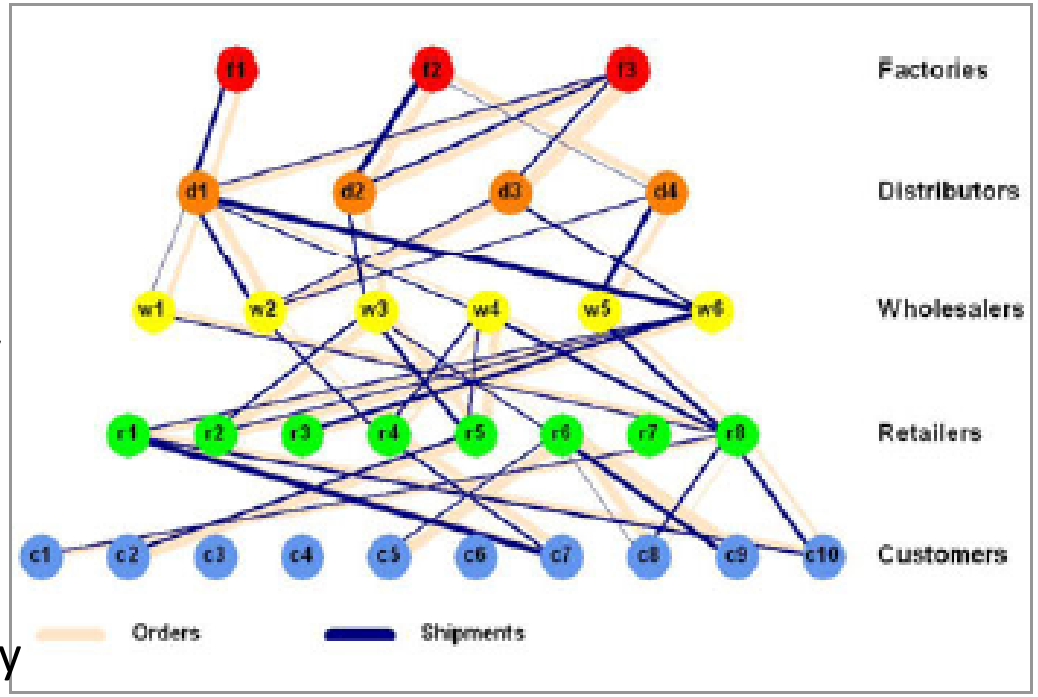


The Supply Chain Example

- A supply chain consists of five stages:
  - factories,
  - distributors,
  - wholesalers,
  - and retailers

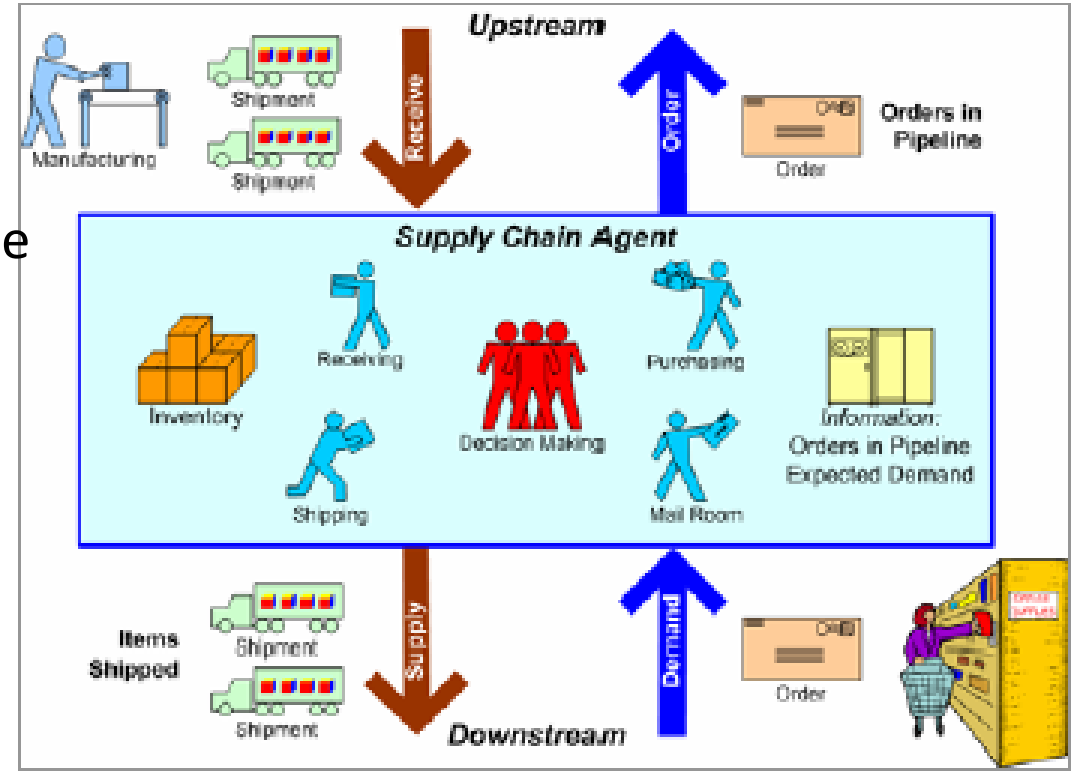
who respond to customers' demand.

- Multiple agents of each type exist at each stage forming a network of supply chain agents
- Agents only have access to local information
  - No agent has a global view of the supply chain or is in a position to optimize the system as a whole
  - Agents adopt decision rules that only consider this local information in making their decisions.

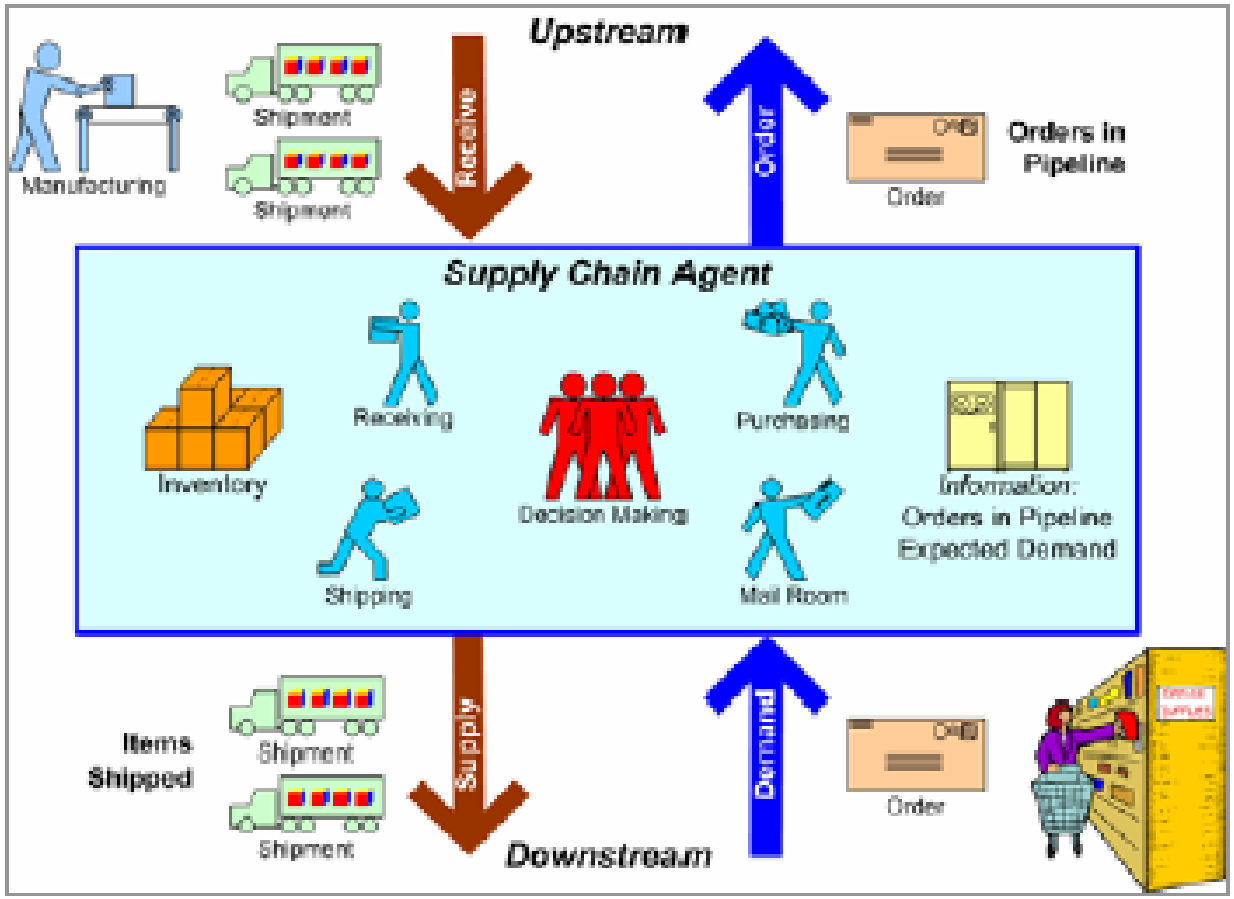


Assumptions

- Various simplifying assumptions for this example
  - we ignore suppliers,
  - there is only one commodity,
  - no transformation of goods is made
  - no assembly of materials into products is required
  - Are not included the flows of payments and the complexities of pricing, negotiation, and financial accounting that this would entail
- Are included the flows of goods and information in the form of orders between stages (agents) as well as physical shipments

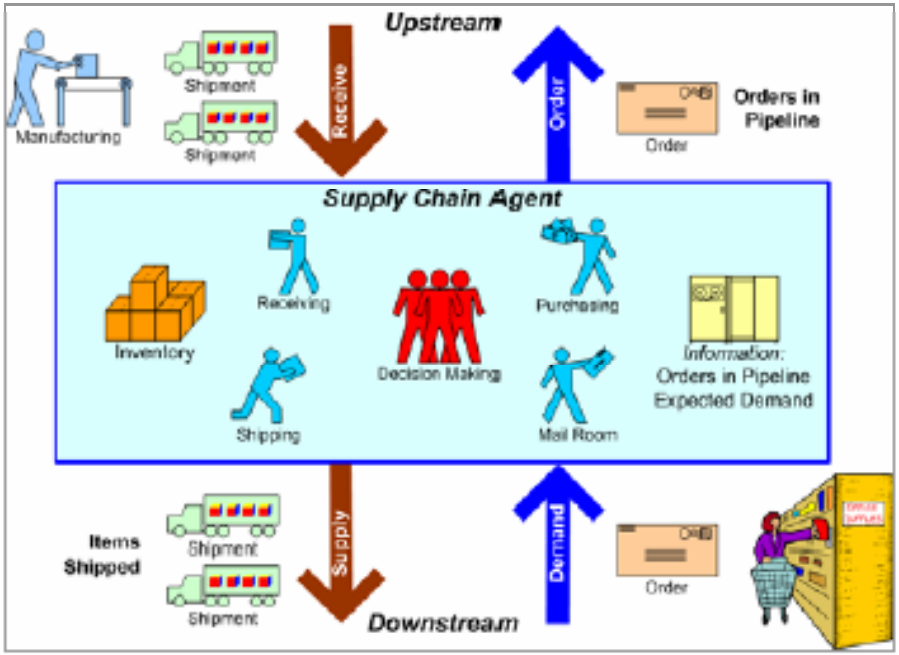


Agents behavior



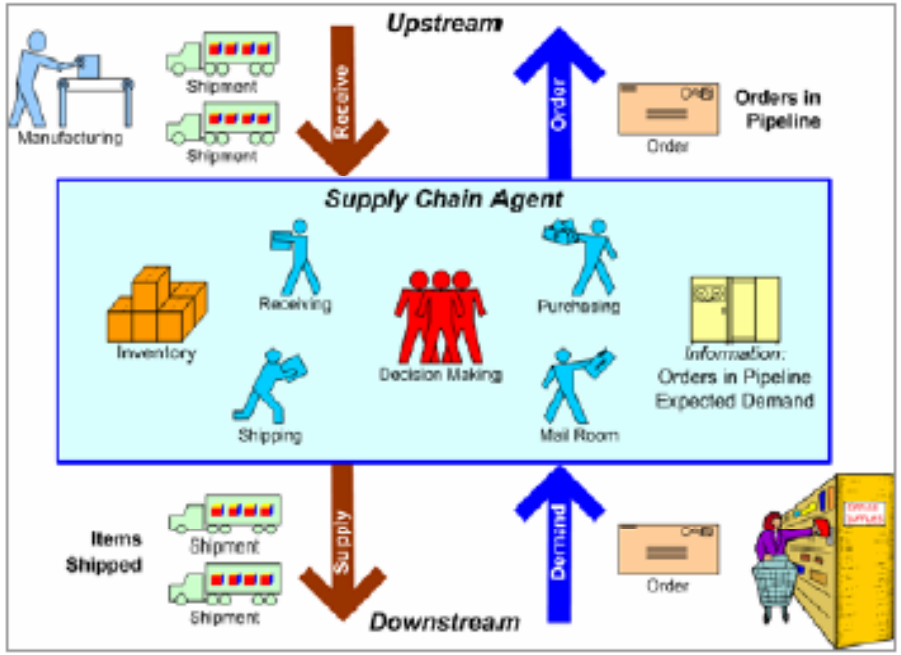
Agents behavior (cont)

1. The customer places an order with the retailer.
2. The retailer fills the order immediately from its respective inventory if it has enough inventory in stock
    1. if the retailer runs out of stock, the customer's order is placed on backorder and filled when stock is replenished



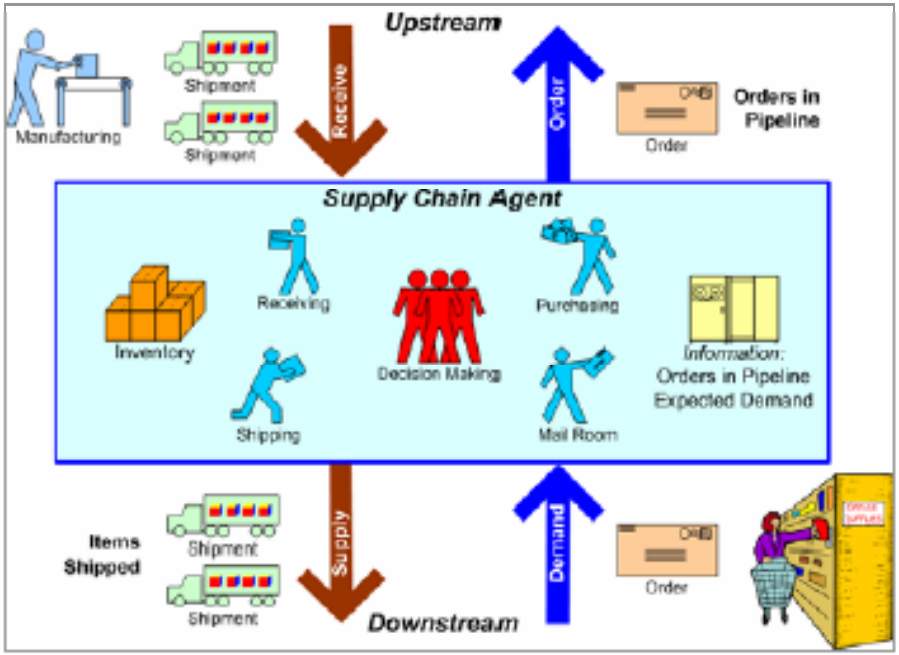
Agent behavior (cont)

3. The retailer receives a shipment from the upstream wholesaler in response to previous orders.
    1. The retailer then decides how much to order from the wholesaler based on an “ordering rule.” The ordering decision is based in part on how much the retailer expects customer demand will be in the future.
    2. The retailer estimates future customer demand using a “demand forecasting” rule.
    3. The retailer then orders items from the wholesaler to cover expected demand and any shortages relative to explicit inventory or pipeline goals.



Agent behavior (cont)

4. each Wholesaler receives a shipment from the upstream distributor, forecasts future demand by the downstream retailer, and places an order with the distributor. This process continues up the chain to the factory who decides on how much to put into new production.

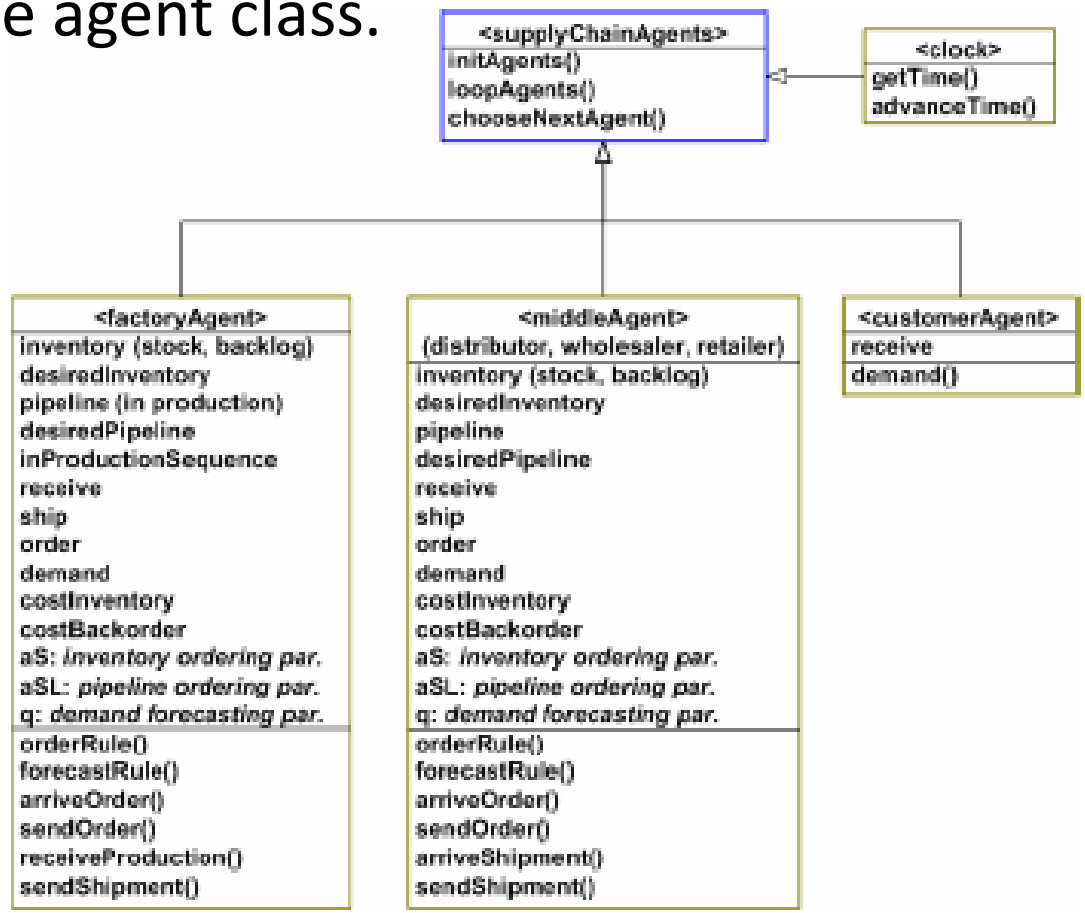


Agent's goals

- The goal of the supply chain agent, other than customers, is
  - to manage their inventory in such a way as to minimize their costs through judicious decisions based on how much to order each period.
  - When inventories are too low and there is a danger of running out of stock, agents order more;
  - when inventories are too large and agents incur high inventory holding costs, agents order less. Besides the inventory holding charge, agents incur a backorder charge when they receive an order and cannot immediately fill it because they are out of stock.
  - Each agent strikes a delicate balance between having too much inventory, which runs up inventory holding costs, and too little inventory, which puts the agent at a greater risk of running out of stock and incurring excessive backorder charges.

Building the supply chain agent model: step 1

- One begins developing an ABS model by identifying the agent types and other objects (classes) along with their attributes
- Each agent class is represented by a set of attributes and methods that operate on the agent class.

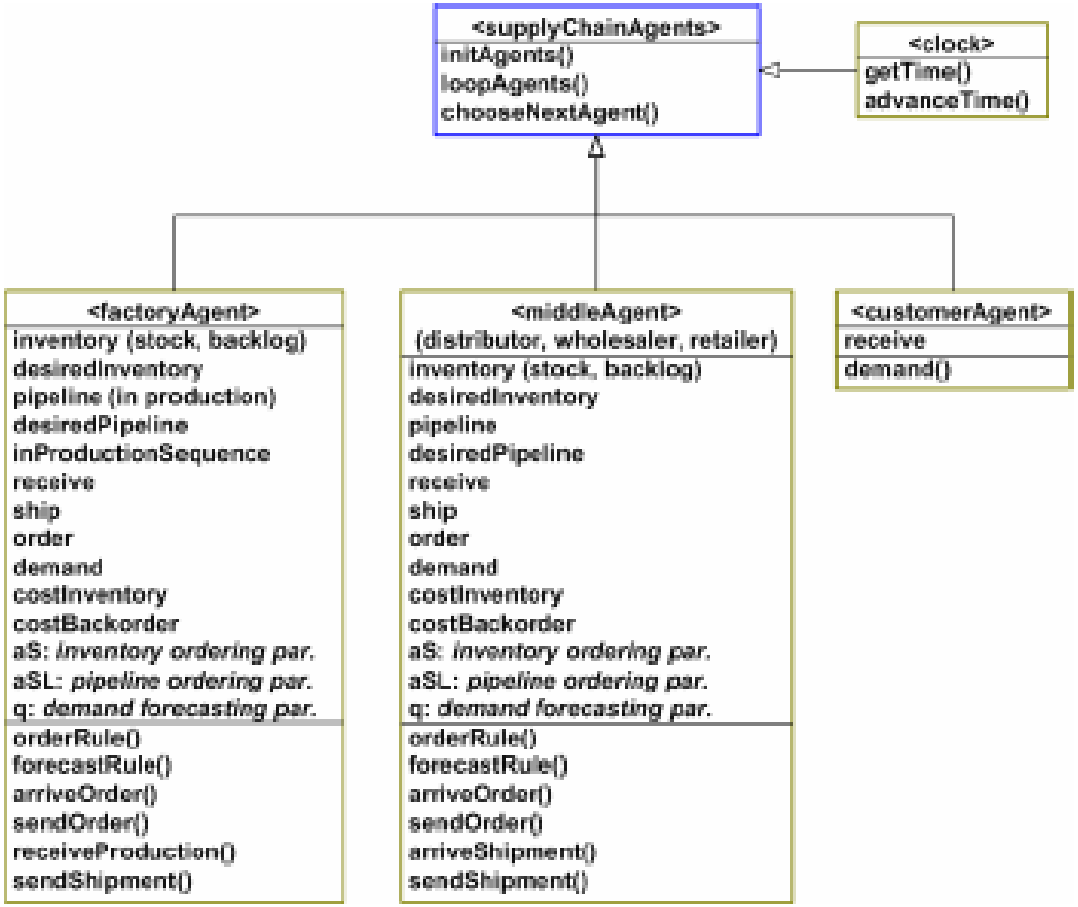


Building the supply chain agent model: Step 2

- Determine the environment in which the agents live and interact .
- the environment consists of external (non-agent) factors that influence agent behavior. For example
  - variable could be the labor rate and its dependence on geographic locale, which could also be included as an agent attribute.

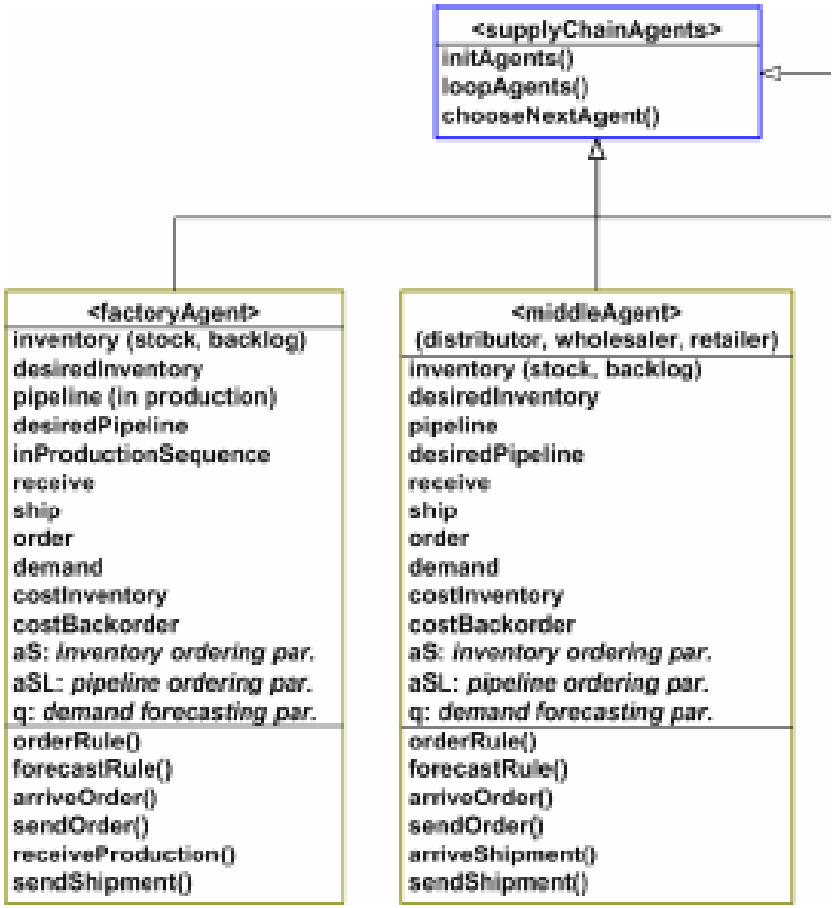
Building the supply chain agent model: Step 3

- Specifies the methods by which agent attributes are updated during the simulation in response to
  - agent-to-agent interactions or
  - agent interactions with the environment



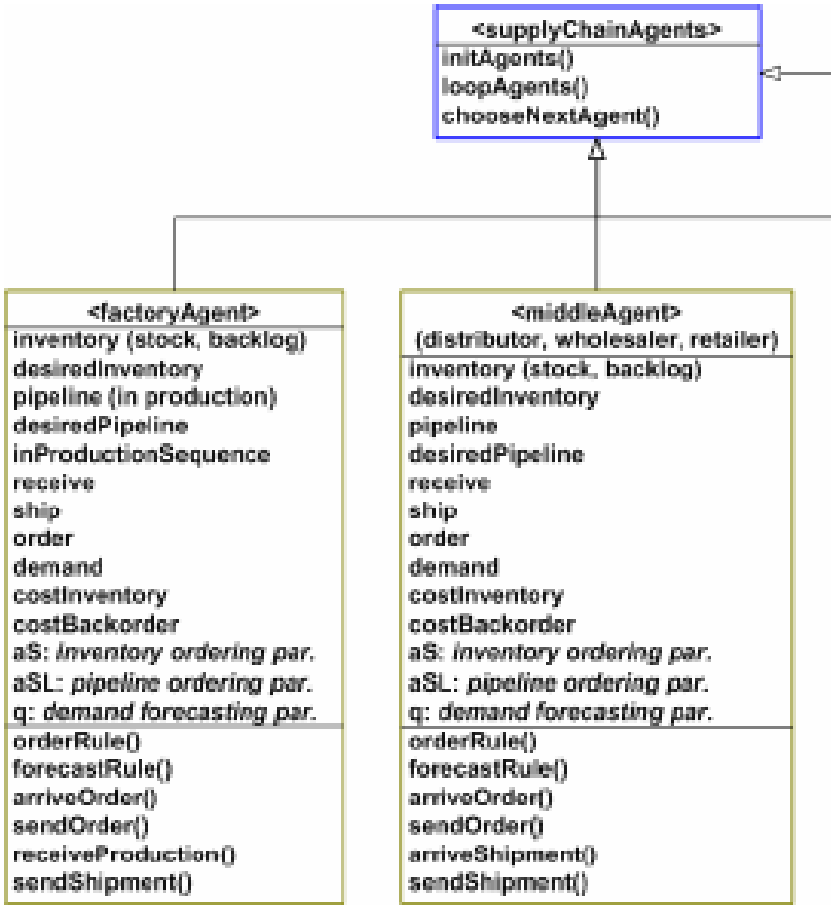
Step 3 (cont)

- In the supply chain model, the inventory level is an attribute of each agent.
  - Inventory is updated when orders and shipments are received and sent.
- Agent methods that embody processing of orders and shipments include:
  - *arriveOrder(), sendOrder(), arriveShipment(), and sendShipment().*
  - These methods would be applied to the agents upon receipt of an order or shipment and affect the values of agent attributes.
- Methods that more directly embody the agent's behavioral decision rules
  - a rule for determining how much to order and from whom at any point in time, embodied in the procedure *orderRule(),*
  - a rule for forecasting demand, embodied in the procedure *forecastRule()*



Building the supply chain agent model: Step 4

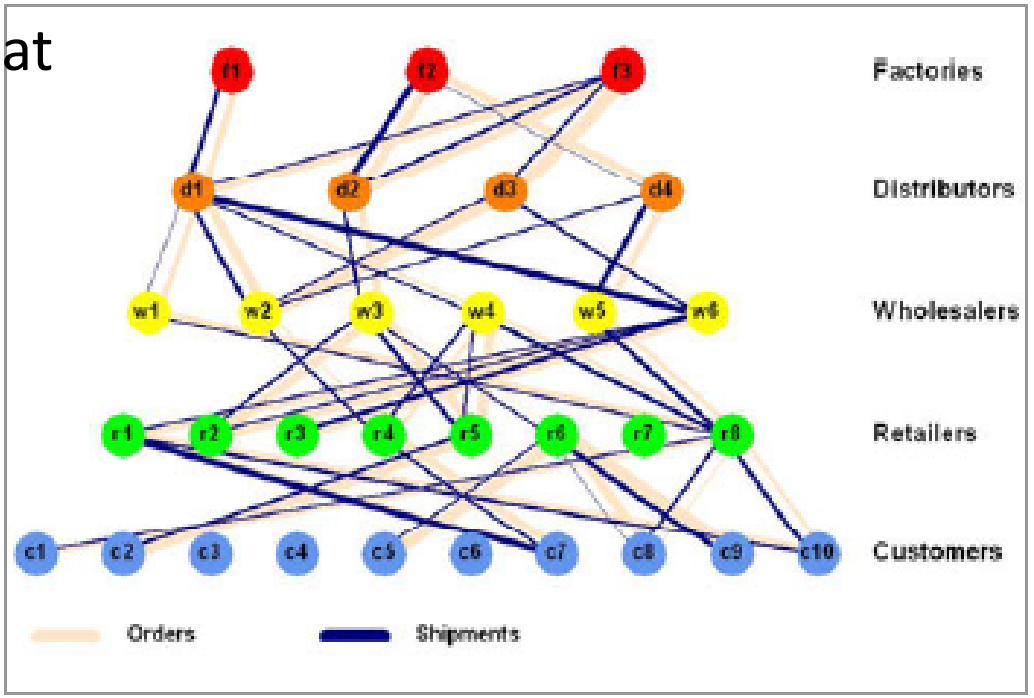
- Adds the methods that control
  - which agents interact,
  - when they interact, and
  - how they interact
- For example, one may develop a procedure for selecting
  - which agents to interact with based on a bidding process in which, for example, the least-costly factory agent is selected from among all factory agents by a distribution agent placing an order.
  - The *agent selection procedure* could be invoked at every time period or when inventory levels reach specified thresholds.
- The *agent interaction procedure would consist of placing an order with the selected* agent at the determined time.



Step 4 (cont)

- In addition to agents, the supply chain model consists of agent relations.
- If agents are the nodes in the supply chain, agent relations are the links or edges in the network.
- Each agent relation involves two agents.
  - the factory-distributor relation includes the attributes of the number of items in-transit from factory to distributor and the order in-transit from distributor to factory.
- Agent relations also have methods that operate on them just as agents have
  - *getShipments(), getOrders(), getUpstreamAgent(), and getDownstreamAgent()*

are useful methods for agent relations.



Building the supply chain agent model: Step 5

- Implementation
  - writing an object-oriented program using, for example, the Java or C++ programming languages
  - using a higher-level agent-based toolkit