

Consumer Direct Grocery Initiatives



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George Shaheen (Webvan):
“We (e-grocers) promise to give back
your Saturday mornings.”

Outline

- Consumer direct & home grocery delivery
- Problem definition
- Relevant literature
- Dynamic routing algorithm
- Sample results
- Future directions



Peapod

PublixDirectsm
..... Online Shopping, Home Delivery



E-Commerce: Consumer Direct



- Huge potential
 - Retailers are seeing online sales growing rapidly (in some cases doubling every 6 to 12 months)
 - Forrester Research expects online purchases by U.S. consumers to grow to \$184 billion by 2004, or 7% of total retail spending
- Huge challenges
 - Marketing: getting and keeping consumers
 - Logistics: getting the goods to the consumer

E-Commerce: Consumer Direct



- New home delivery service models
 - Grocery delivery (WebVan, Peapod)
 - Office supply delivery (Staples)
 - Pharmaceuticals delivery (CVS ProCare)
- Modified existing home delivery service models
 - Cable and phone installation/repair (AT&T)
- Offer value-added service
 - Bringing goods “the last mile” to the customers

E-Grocers

- Online grocery shopping spending

- 1999: \$100 million
- 2000: \$300 million
- 2006: \$11.3 billion



- Online grocery shopping users

- 1998: < 100,000
- 2002: > 6,000,000 (estimated)




What is in it for the retailer?



- ROI (Return on investment)
 - Consumer direct shopping baskets usually average more than \$100 (i.e., profitable customers)
 - Incremental volume
- ROR (Return on relationship)
 - Perfect opportunity to study consumer behavior and gather market research data

What is in it for the consumer?



- The ability to shop when and where you want
- The ability to receive when and where you want
- The ability to purchase multiple categories

- Weekly shopping lists, lists of frequently ordered products, personalized shopping aisles, etc.

However ...



Business Times (10 Jul 2001)

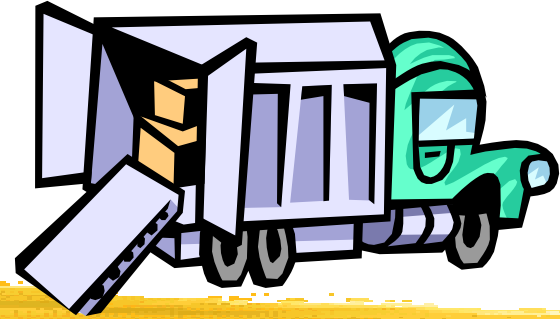
SAN FRANCISCO - The announced closing of the giant Internet grocer Webvan, one of the most heavily financed online retailers, marks the end of one Web business era and opens a hazy horizon for its future.

Bankruptcy of Webvan



- Contributing factors:
 - Independent internet business (not related to existing grocery retailer)
 - Prices being charged to consumers not in line with the cost to the business (i.e., free delivery)
 - Specific consumers were not being successfully targeted

Home Delivery



- Home delivery seems simple:
 - package the order and bring it to the customer
- Home delivery is difficult:
 - unpredictable demand
 - stringent delivery time restrictions (time-starved consumers are the ones most attracted to the convenience of online shopping)
 - costs need to be controlled (small profit margins)

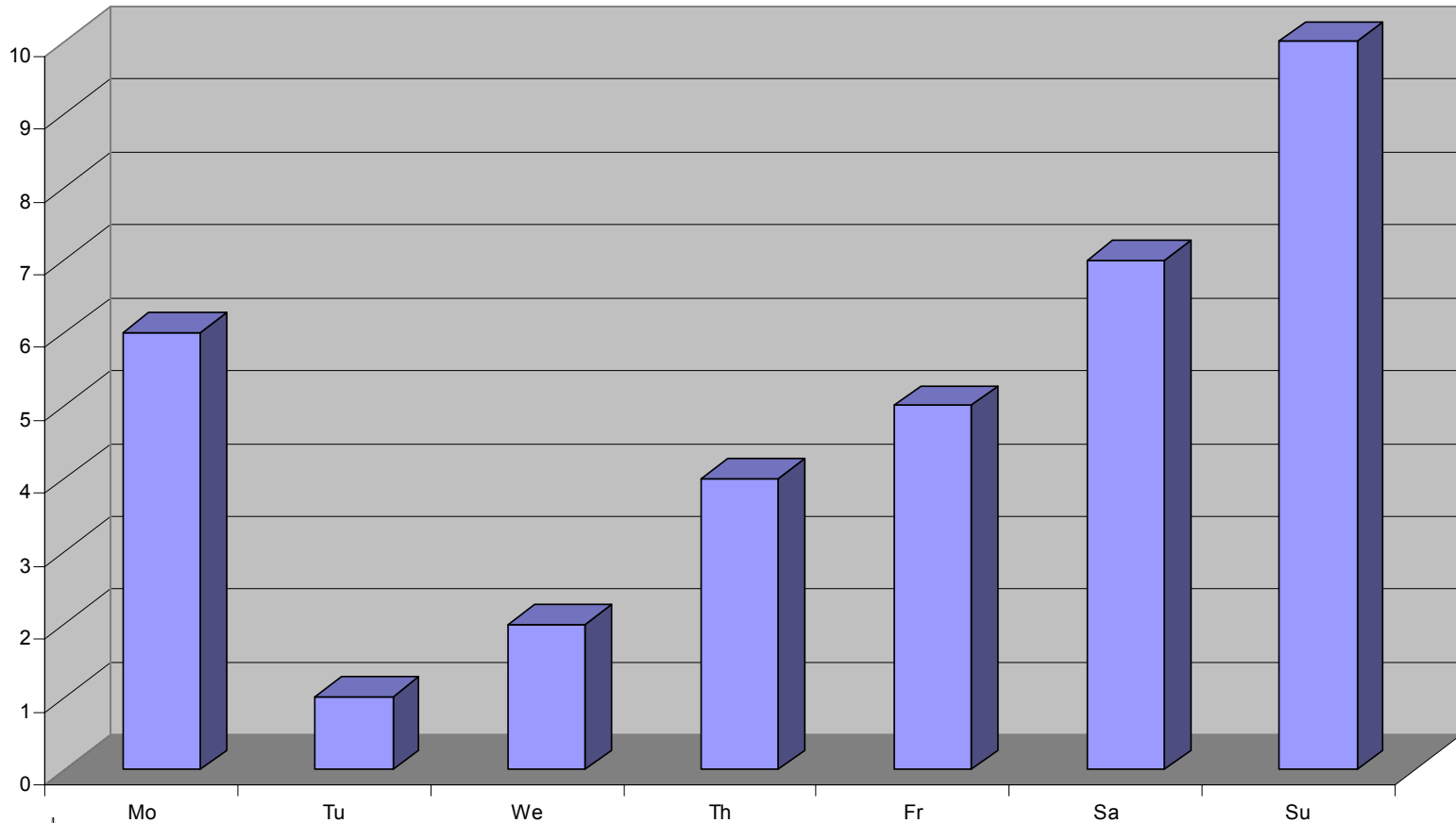
Home delivery lesson



- Unless you can set up an effective and efficient home delivery system, the cost savings promised by e-commerce are being eaten up by high delivery costs

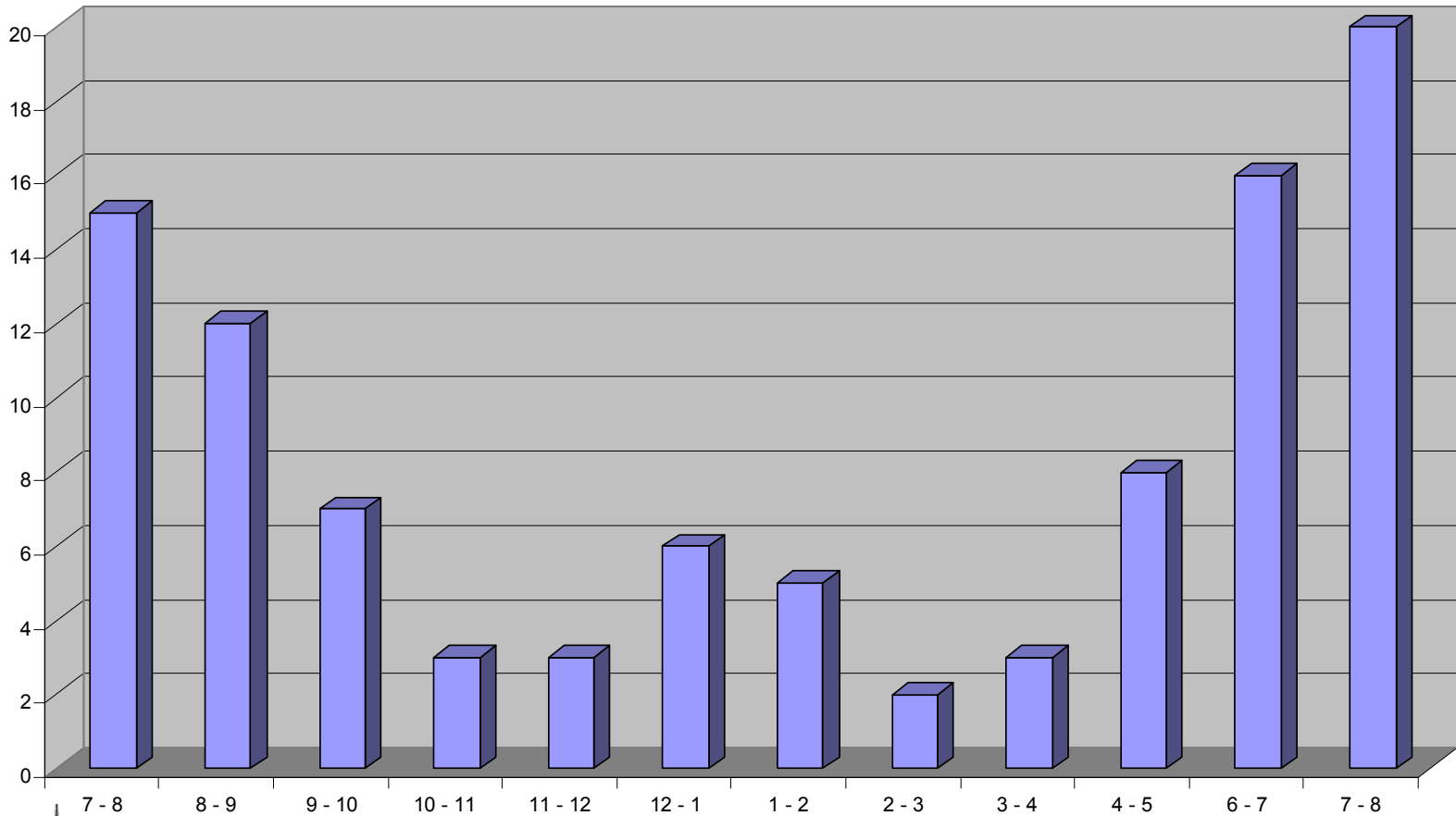
Difficulty – demand variability

Daily demand



Difficulty – demand variability

Timeslot demand



Focus



- Consumer direct process can be divided into three phases
 - Order capture and promise
 - Order picking and assembly
 - Order delivery
- Our focus is on the interaction between *order capture and promise* and *order delivery* for attended deliveries

Focus



- **Can we estimate the impact of an order on the delivery costs, so that we can decide which orders we capture and what delivery times we promise ?**

Time slot management



- Delivery time slot is agreed upon mutually by retailer & consumer
- Delivery time slot has a fixed length, typically a half hour or an hour
- Delivery time slots do not overlap
- Delivery time slots can be selected up to seven days in advance

Time slot management



- Current practice:
 - Accept a fixed number of requests per time slot. When that number is reached the time slot is no longer available for future customers
 - The number of requests to accept per time slot is based on either the number of delivery vehicles or on historic performance

Time slot management



- Observe:
 - The closer the delivery locations are for orders in a given time slot (or consecutive time slots), the easier it will be to schedule the deliveries and the cheaper it will be to carry them out
 - The closer the delivery locations are for orders in a given time slot (or consecutive time slots), the more deliveries can be accepted and effectively handled, which reduces average delivery costs and increases profitability

Key to success



- Integrate:
 - Dynamic routing and scheduling
 - Time slot management
- Dynamically present available delivery time slots based on the customer location and a tentative set of delivery routes

Home Delivery Problem



- We are constructing a set of delivery routes for a specific day in the not too distant future
- Requests from a known set of customers for a delivery on that particular day are coming in in real-time and are considered up to a certain cut-off time T , which precedes the actual execution of the planned delivery routes
- **We have to accept or reject a delivery request as soon as it arrives**

Home Delivery Problem

- At each point in time t , we can compute for each customer i the probability $p_i(t)$ that customer i will place a request for delivery between t and the cut-off time T
- We have a homogeneous set of m vehicles with capacity Q
- Each request, if accepted, consumes d_i of the vehicle capacity and results in a revenue of r_i

Home Delivery Problem



- To improve service, deliveries are guaranteed to take place within a time slot, e.g.,
 - 8:00-9:00, 9:00-10:00, ..., 19:00-20:00
- Each customer has a time slot profile that identifies which time slots are acceptable for delivery
- Each request, if accepted, must be assigned an acceptable time slot

Home Delivery Problem



- Our objective is to maximize profit, i.e., total revenue minus total cost, where we assume that the total cost depends linearly on the total distance traveled in the final set of delivery routes

Literature



- Home grocery delivery
 - Focusing on models for unattended deliveries (Punakivi:2000)
 - Comparing unattended and attended delivery models (Punakivi:2001, Yrjola:2001)

Literature



- Dynamic vehicle routing
 - *Redirect trucks during the execution of their routes to accommodate new orders*
- Stochastic vehicle routing
 - *Minimize expected costs for satisfying realized demand/customers*
- Dynamic fleet management
 - *Decide what freight/loads to accept next*
- Airline revenue management
 - *Evaluate probability of being able to sell a seat in a higher fare class in the future*

Step 1:

Evaluating Feasibility

- How can we determine feasibility of request quickly?
- Insertion heuristics for VRPTW
 - Construct delivery routes for all already accepted orders
 - If the order under consideration can be inserted in the set of routes, then accept it
 - If the order under consideration can be inserted in multiple time slots, choose the time slot where the total costs are lowest

Step 1: Evaluating Feasibility



- Adaptable to randomization (GRASP)
 - Create multiple sets of routes for already accepted orders
 - Better chance for feasible insertion

Step 2:

Evaluating Profitability



- As a request arrives, evaluate how accepting or rejecting impacts expected profit
 - Given already accepted orders
 - Given that additional orders may materialize in the future

Step 2:

Evaluating Profitability

- Compute expected profit with and without this request (opportunity cost)
- Conceptually:
 - Look at every possible realization of future demands
 - Calculate probability of each realization occurring
 - Find the most profitable set of routes **without** the request but with all accepted requests and any future requests
 - For each acceptable time slot, find the most profitable set of routes **with** the request in that time slot

Step 2:

Evaluating Profitability



- With these, we can compute
 - Expected profit without request and with request in each time slot
 - If expected profit without request is larger than all with request, then reject
 - Otherwise, guarantee delivery during time slot associated with the highest expected profit

- Computationally intractable !

Pragmatic Approach

- Approximate the conceptual approach by solving a modified VRPTW involving
 - the accepted deliveries
 - the proposed delivery
 - all deliveries that may or may not be realized
- Adjust the revenue and the capacity requirements of deliveries that have not yet materialized, i.e.,
 - $d_i = p_i(t) d_i$
 - $r_i = p_i(t) r_i$

Pragmatic Approach



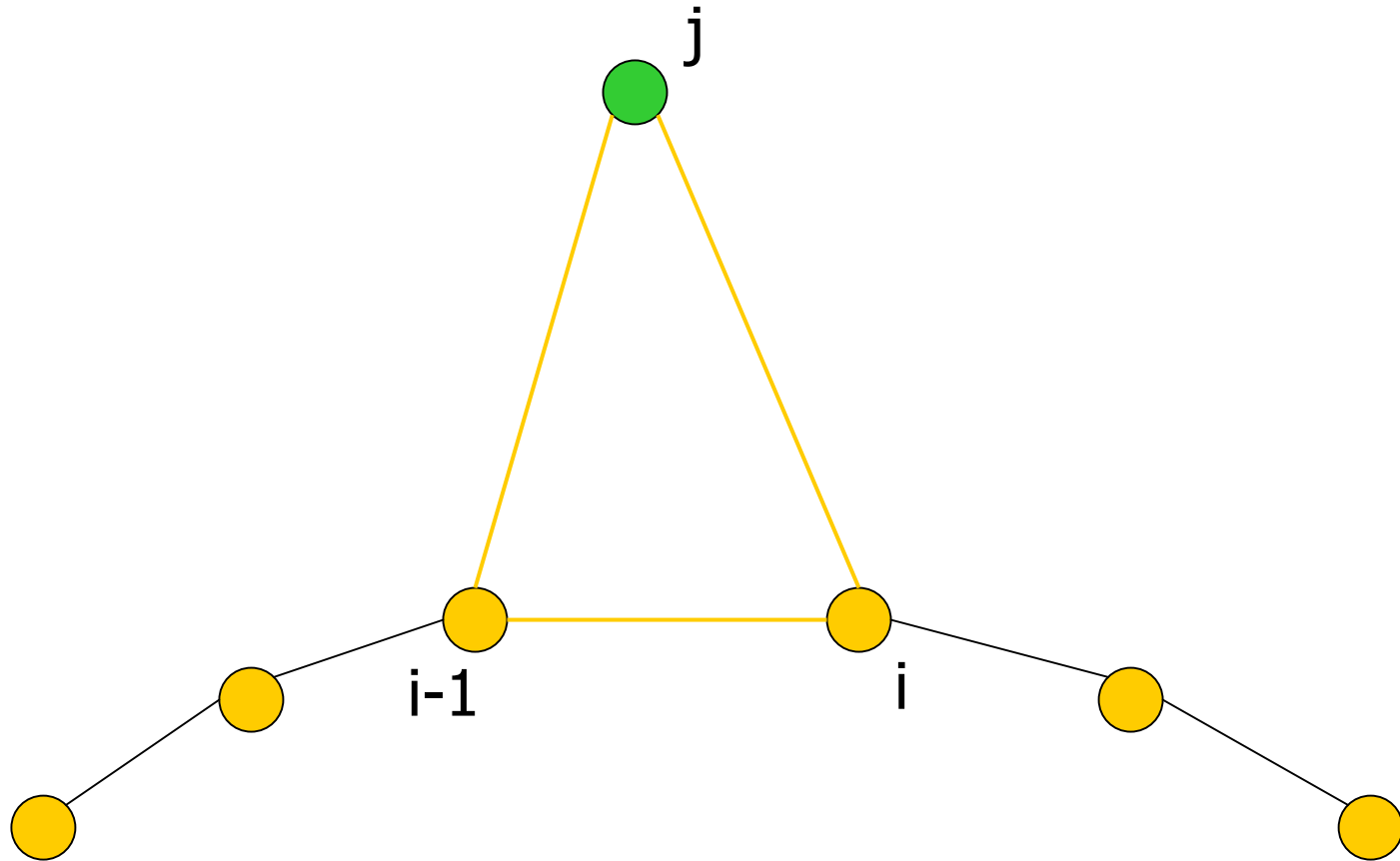
- Choose which deliveries to include so as to maximize profit given the limited capacity and time
- If the request under consideration is included, it signifies that it is more valuable to accept it than to wait for future requests to materialize
- If the request under consideration is included, then accept it in the proper time slot; if the request under consideration is not included, then reject it

Insertion heuristic

- Phase I:
 - Insert all customers with accepted requests
- Phase II:
 - Insert customers with unrealized requests



Insertion



Insertion costs

- Profit
 - $r_j - (c_{i-1,j} + c_{j,i} - c_{i-1,i})$
- DSR criterion – discounted revenue
 - $p_j r_j - (c_{i-1,j} + c_{j,i} - c_{i-1,i})$

Insertion costs

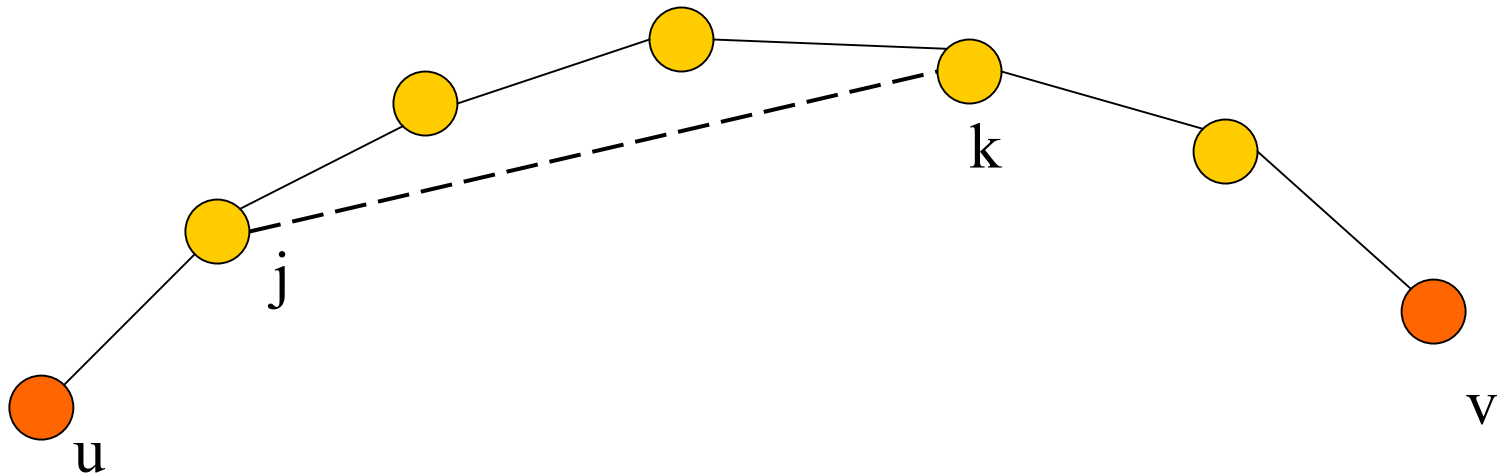


- DSR criterion ignores that j will only be between $i-1$ and i if **both** are realized and accepted
- Modify expected costs relative to two already accepted deliveries u and v
- Compute expected cost of path between u and v **with** and **without** j

Insertion costs

- PATH criterion – probabilistic path length

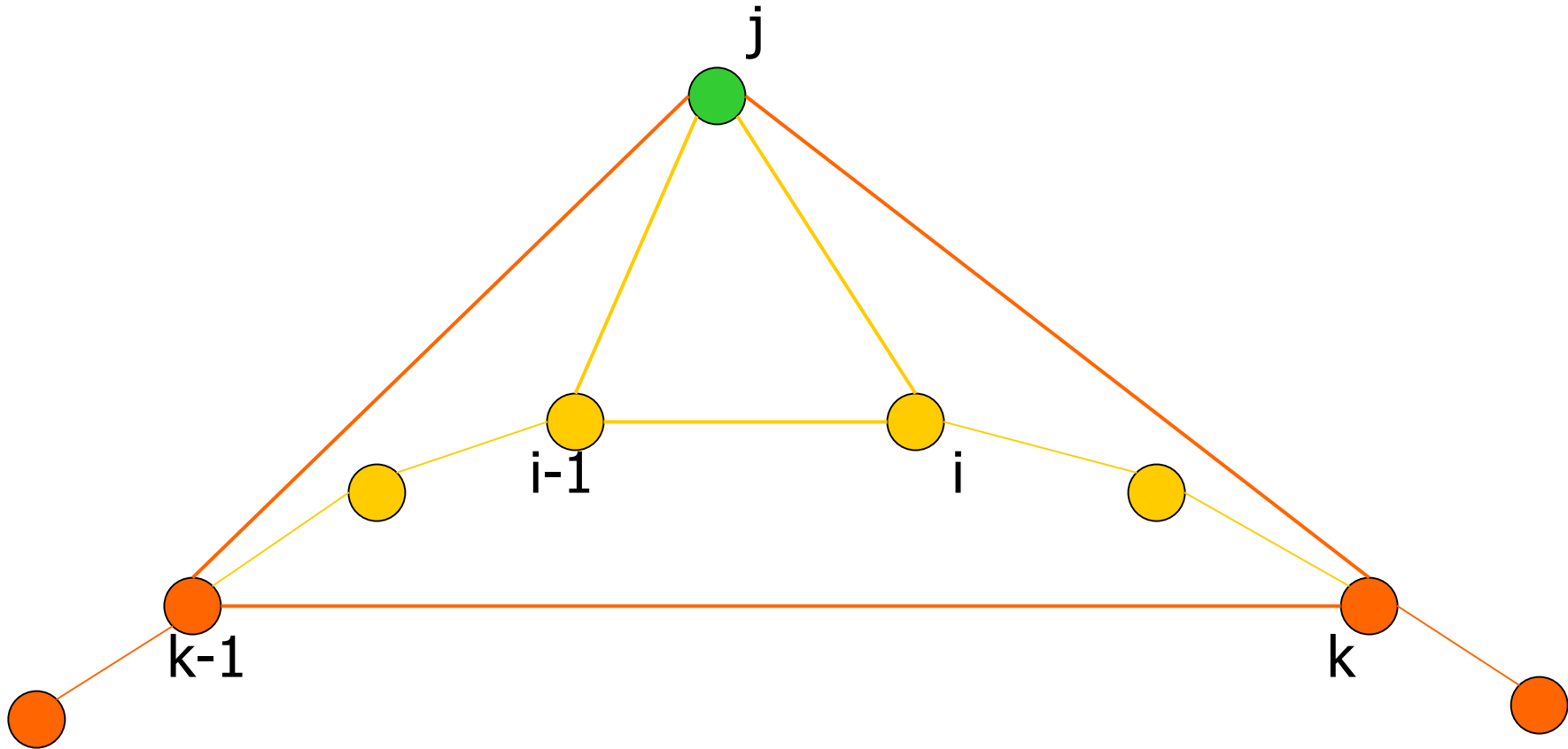
$$\sum_{j=u, \dots, v-1} \sum_{k=u+1, \dots, v} d_{j,k} p_j p_k \prod_{l=j+1, \dots, k-1} (1 - p_l)$$



Insertion costs

- DIFF criterion – consider optimistic and pessimistic insertion costs
 - Optimistic (nearest neighbors)
 - $v_1 = c_{i-1,j} + c_{j,i} - c_{i-1,i}$
 - Pessimistic (nearest accepted neighbors)
 - $v_2 = c_{k-1,j} + c_{j,k} - c_{k-1,k}$
 - Value
 - $p_j(t) r_j - (v_2 - p_{i-1}(t) p_i(t) (v_2 - v_1))$

Insertion



Insertion Costs

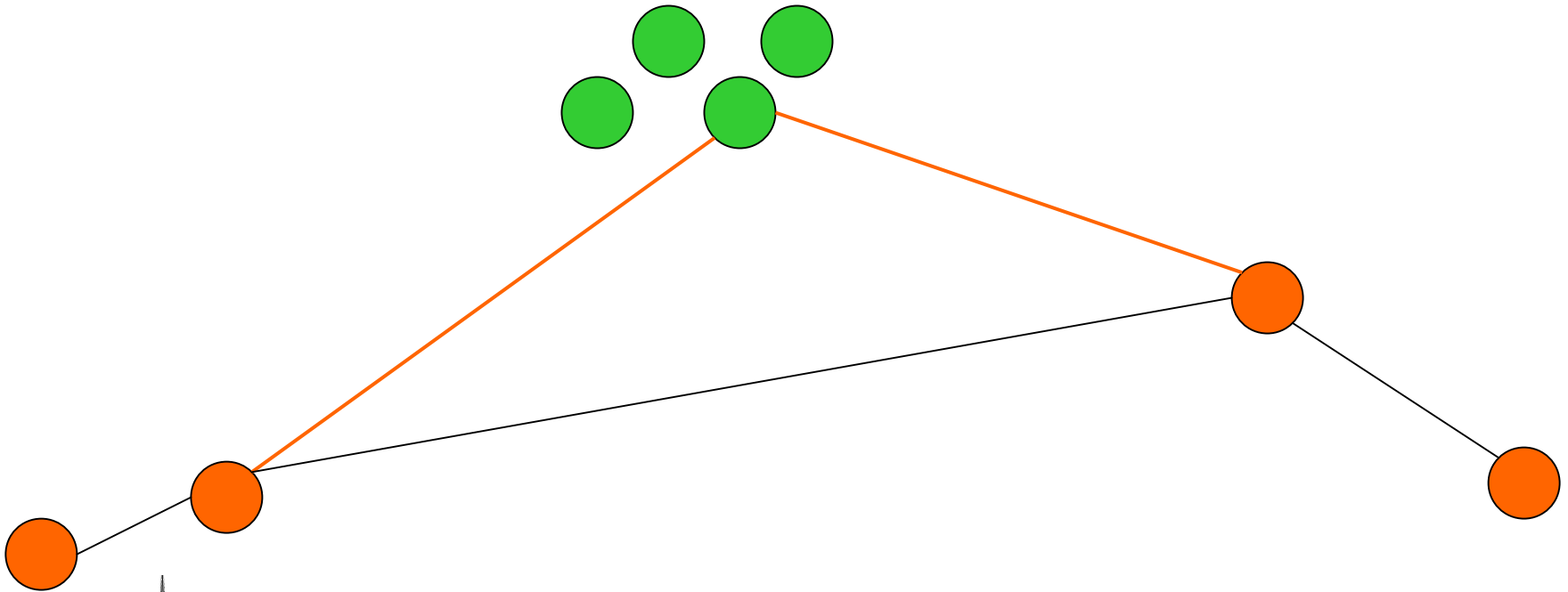


- RAD criterion – capture synergy of nearby customers in computing expected revenue
 - $R(j)$ represents region surrounding j
 - $R(j)$ only contains unrealized customers
 - How large to define $R(j)$?
- Capacity Considerations
 - Size of delivery discounted by probability of delivery

Insertion costs

- Synergies between nearby customers

$$\sum_{k \in R(j)} p_k r_k - (c_{i-1,j} + c_{j,i} - c_{i-1,i})$$



Computational Experiments

- Test through simulation
 - Request probability modeled as linearly declining towards cutoff time T , i.e., $p_i(t) = (T-t)/T$
 - Instances with 100 customers
 - Evaluate requests as they arrive over time
 - Averages from 10 instances over a dense grid and 10 instances over a sparse grid
 - Can compare to delivery routes with perfect information (BEST)
 - Can compare to delivery routes for status quo (SLOT), where the number of accepted deliveries in a time slot is based on the average distance between customers

Basic Experiment

- Identical revenues: \$40
- Identical probabilities: 24%
- Single vehicle with capacity 24
- Time slot profiles with 2 slots
- Region is 5% of grid dimension

PROB	DEC TYPE	MAX TIME	STOPS	REV	COST	FAIL	PROFIT
0.24	BEST	0.00	23.90	956.00	273.01	0.00	682.99
0.24	SLOT	0.01	20.40	816.00	305.76	0.00	510.24
0.24	DYN	0.02	23.90	956.00	296.72	0.00	659.27
0.24	DSR	0.43	23.90	956.00	285.07	0.00	670.93
0.24	PATH	9.25	23.70	948.00	281.33	0.00	666.67
0.24	RAD	0.88	23.90	956.00	287.08	0.00	668.92
0.24	DIFF	0.51	22.70	908.00	265.74	0.00	642.26

- DYN significantly outperforms SLOT
- Profit based methods fairly close to BEST
- PATH takes significantly longer

Increasing Expected Demand – Sparse Grid

PROB	DEC TYPE	MAX TIME	STOPS	REV	DIST	FAIL	PROFIT
0.24	BEST	0.00	21.20	848.00	431.92	0.00	416.08
0.24	SLOT	0.01	19.80	792.00	568.86	0.60	223.14
0.24	DYN	0.02	<u>23.10</u>	924.00	588.64	0.00	<u>335.36</u>
0.24	DSR	0.31	18.10	724.00	380.77	0.00	343.23
0.24	PATH	1.63	16.20	648.00	323.20	0.00	<u>324.80</u>
0.24	RAD	0.36	19.30	772.00	395.65	0.00	376.35
0.24	DIFF	0.36	14.00	560.00	269.04	0.00	290.96
0.32	BEST	0.00	23.30	932.00	418.89	0.00	513.11
0.32	SLOT	0.02	21.60	864.00	622.69	0.90	241.31
0.32	DYN	0.02	24.00	960.00	605.35	0.00	<u>354.65</u>
0.32	DSR	0.28	23.00	920.00	476.17	0.00	443.83
0.32	PATH	1.85	21.50	860.00	421.40	0.00	<u>438.60</u>
0.32	RAD	0.43	22.30	892.00	464.19	0.00	427.81
0.32	DIFF	0.32	18.90	756.00	361.86	0.00	394.14
0.40	BEST	0.01	24.00	960.00	373.61	0.00	586.39
0.40	SLOT	0.05	22.70	908.00	645.62	1.10	262.38
0.40	DYN	0.05	24.00	960.00	609.58	0.00	<u>350.42</u>
0.40	DSR	0.46	24.00	960.00	483.79	0.00	476.21
0.40	PATH	2.20	23.20	928.00	432.79	0.00	<u>495.21</u>
0.40	RAD	0.45	23.90	956.00	494.06	0.00	461.94
0.40	DIFF	0.30	22.00	880.00	403.39	0.00	476.61
0.48	BEST	0.00	23.90	956.00	341.26	0.00	614.74
0.48	SLOT	0.01	22.50	900.00	627.46	1.50	272.54
0.48	DYN	0.02	24.00	960.00	634.94	0.00	<u>325.06</u>
0.48	DSR	0.31	24.00	960.00	466.32	0.00	493.68
0.48	PATH	1.73	23.20	928.00	410.55	0.00	<u>517.45</u>
0.48	RAD	0.41	24.00	960.00	486.41	0.00	473.59
0.48	DIFF	0.30	23.40	936.00	443.49	0.00	492.51

Changing Window Width – Sparse Grid

30.00	0.48	BEST	0.00	23.70	948.00	392.25	0.00	555.75
30.00	0.48	SLOT	0.01	20.50	820.00	590.90	2.50	229.10
30.00	0.48	DYN	0.02	24.00	960.00	632.71	0.00	327.29
30.00	0.48	DSR	0.18	22.90	916.00	449.66	0.00	466.34
30.00	0.48	PATH	0.69	22.40	896.00	432.75	0.00	463.25
30.00	0.48	RAD	0.22	23.20	928.00	475.27	0.00	452.73
30.00	0.48	DIFF	0.18	21.50	860.00	410.56	0.00	449.44
60.00	0.48	BEST	0.00	23.90	956.00	341.26	0.00	614.74
60.00	0.48	SLOT	0.02	22.50	900.00	627.46	1.50	272.54
60.00	0.48	DYN	0.02	24.00	960.00	634.94	0.00	325.06
60.00	0.48	DSR	0.23	24.00	960.00	466.32	0.00	493.68
60.00	0.48	PATH	1.66	23.20	928.00	410.55	0.00	517.45
60.00	0.48	RAD	0.30	24.00	960.00	486.41	0.00	473.59
60.00	0.48	DIFF	0.25	23.40	936.00	443.49	0.00	492.51
120.00	0.48	BEST	0.00	24.00	960.00	265.35	0.00	694.65
120.00	0.48	SLOT	0.01	23.90	956.00	595.36	0.10	360.64
120.00	0.48	DYN	0.02	24.00	960.00	507.35	0.00	452.65
120.00	0.48	DSR	0.25	24.00	960.00	383.54	0.00	576.46
120.00	0.48	PATH	5.18	24.00	960.00	364.73	0.00	595.27
120.00	0.48	RAD	0.39	23.90	956.00	360.94	0.00	595.06
120.00	0.48	DIFF	0.32	24.00	960.00	395.38	0.00	564.62
180.00	0.48	BEST	0.00	24.00	960.00	213.35	0.00	746.65
180.00	0.48	SLOT	0.01	24.00	960.00	527.90	0.00	432.10
180.00	0.48	DYN	0.01	24.00	960.00	457.29	0.00	502.71
180.00	0.48	DSR	0.27	24.00	960.00	340.19	0.00	619.81
180.00	0.48	PATH	9.45	24.00	960.00	322.52	0.00	637.48
180.00	0.48	RAD	0.56	24.00	960.00	352.10	0.00	607.90
180.00	0.48	DIFF	0.40	24.00	960.00	337.78	0.00	622.22

Initial Insights



- Dynamic feasibility evaluation can be very valuable
- Importance of evaluating profitability increases with expected demand
- Importance of evaluating profitability decreases with customer density
- The width of the time slot can have substantial impact on profits
- The number of slots in the profile can have substantial impact on profits

Initial Insights



- More, smaller vehicles are better than fewer, larger ones to match capacity with time slots
- PATH and RAD perform well on dense grids; RAD does not perform as well on sparse grids
- PATH may be too time consuming; DIFF may be a good substitute

Future Directions



- Observe:
 - The closer the delivery locations are for orders in a given time slot (or consecutive time slots), the easier it will be to schedule the deliveries and the cheaper it will be to carry them out
 - The closer the delivery locations are for orders in a given time slot (or consecutive time slots), the more deliveries can be accepted and effectively handled, which reduces average delivery costs and increases profitability

Future Directions



- Dynamically present and **price** available delivery time slots based on the customer location and a tentative set of delivery routes to encourage cost-effective delivery routes

Future Directions



- To even out the distribution of demand, time slots will be accompanied by incentives (discounts) to encourage customers to choose particular delivery windows (which are better from a scheduling perspective) or to accept wider delivery windows (which give more flexibility in scheduling the delivery)
- The incentives will be based on calculations that reflect how well a delivery at the customer's location in the specific time-slot fits into the tentative schedule

Future Directions



- Possible approach
 - When a customer comes online, compute a set of delivery plans:
 - A set of delivery routes (and thus expected revenue) assuming that the customer is rejected
 - For each time slot, a set of delivery routes (and thus expected revenue) assuming that the customer is accepted in that particular time slot

Future Directions



- Possible approach (cont.)
 - The difference in expected revenue between accepting the customer in a particular time slot and rejecting the customer establishes an opportunity value
 - A simple rule for providing incentives is as follows:
 - All time slots with a non-positive opportunity value are listed as unavailable
 - For all time slots with a positive opportunity value provide a discount that is $x\%$ of the value

Example

<i>Time slot</i>	<i>Value</i>	<i>Incentive</i>	<i>Adjusted value</i>
1	-10	N/A	
2	-10	N/A	
3	-5	N/A	
4	3	0.3	2.7
5	8	0.8	7.2
6	16	1.6	14.4
7	10	1.0	9.0
8	5	0.5	4.5
9	5	0.5	4.5
10	3	0.3	2.7

Home Delivery Problem with Incentives



- Price each time slot dynamically – providing an incentive to encourage or discourage selection of different feasible and acceptable time slots
- Modify the time slot profile so that it specifies how much a customer is willing to pay for a delivery in a given time slot

Home Grocery Delivery

Please imagine that a home-delivered grocery company exists which truly offers exceptional value. Their prices are no higher than conventional stores, they have a huge selection, their quality is superb, and from the marbling of their meat to the ripeness of their fruit, customers always feel assured that they'll receive exactly what they want. Their system for ordering, whether by phone or over the Internet is fast and easy, and customers can pay by credit card or be billed. Their staff is courteous, they never charge for delivery, and to cap it all off, their delivery is so convenient that their driver always arrives the following day at precisely the time the customer desires, even if that's early in the morning or late in the evening. Now, presuming you have a choice to either use this company's service or go to the store yourself, which do you think that you'd generally prefer to do?

- (a) Use this company's service = 34%
- (b) Go to the store yourself = 66%

Home Grocery Delivery



Now, assuming that everything about the proceeding company's service is the same EXCEPT that you could never be sure at what time the next day your groceries would arrive: which do you think that you'd generally prefer to do?

- (a) Use this company's service = 25%
- (b) Go to the store yourself = 75%

Home Grocery Delivery



Now, please assume that for no additional charge, this company can loan you a secure delivery box. The box could be located wherever you like such as at the side of your house or outside of your apartment: and even though you could never be sure at what time the next day your groceries would arrive, you could indeed be sure that your box would keep your order safe and fresh. Given such a box, which do you think you'd generally prefer to do?

- (a) Use this company's service = 60%
- (b) Go to the store yourself = 39%

Home Grocery Delivery



Now, please assume this same delivery box could be used to receive a variety of goods from many different companies: for services like pickup and delivery laundry or even to return unwanted goods. Assuming that the cost for such goods and services is no higher than what you would expect to pay at a store, do you think that your use of home delivered goods and services would be likely to increase?

(a) Yes = 74%

(b) No = 26%