Decision Support
for
Supply Chain Design

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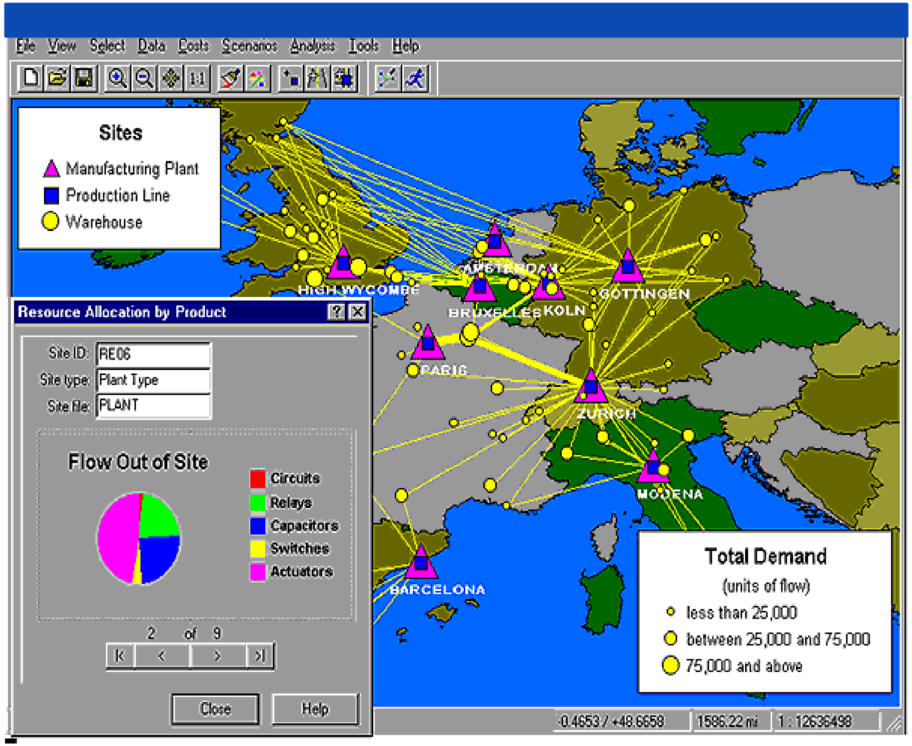
Outline

- Strategic decision support
  - An introduction
- Location analysis under economies of scale
  - Economies of scale
  - Model description: what happens when demand is uncertain
  - A case from Gilde
- Results
  - Computational results from a case with slaughterhouse location
  - Presentation of software

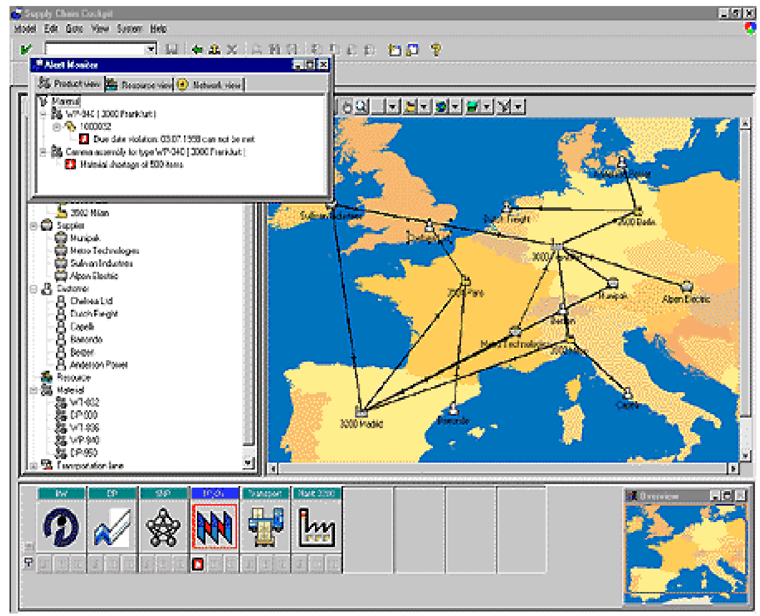
Strategic Decision Support

- Looks at the structure of the supply chain
- Distribution centers, warehouses, plants
  - Optimal number
  - Location
  - Size
- Balances purchase, production- and distribution cost
- Resource allocation at an aggregated and long term level
- Determine best distribution channels
  - Strategic Vehicle Routing
  - Partners, Vehicles, Routes, Functions



Warehouses, example of tactical planning

- Multiperiod inventory models
- Synchronizing inventory towards
  - Production plan
  - Actual production
  - Supply Chain
  - Deliveries
- Demand mapping
- Demand planning and marketing
- Inventory optimization
  - Adaptive inventory management vs security buffer



Strategic decision support software

- What do you need to get it working?

Data for Network Design and supply chain planning

1. A listing of all products
2. Location of customers, stocking points and sources
3. Demand for each product by customer location
4. Transportation rates
5. Warehousing costs
6. Shipment sizes by product
7. Order patterns by frequency, size, season, content
8. Order processing costs
9. Customer service goals

Aggregating Customers

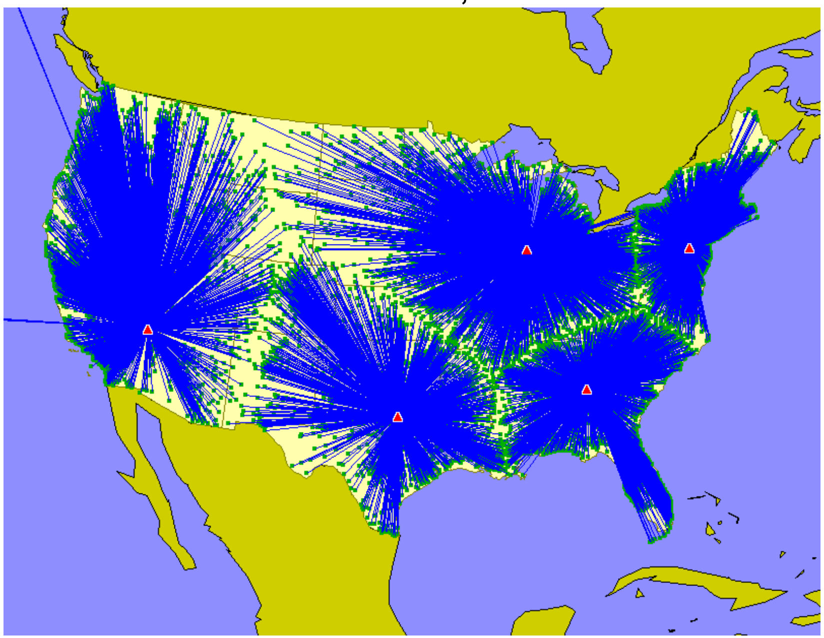
- Customers located in close proximity are aggregated using a grid network or clustering techniques. All customers within a single cell or a single cluster are replaced by a single customer located at the centre of the cell or cluster.

  We refer to a cell or a cluster as a customer zone.

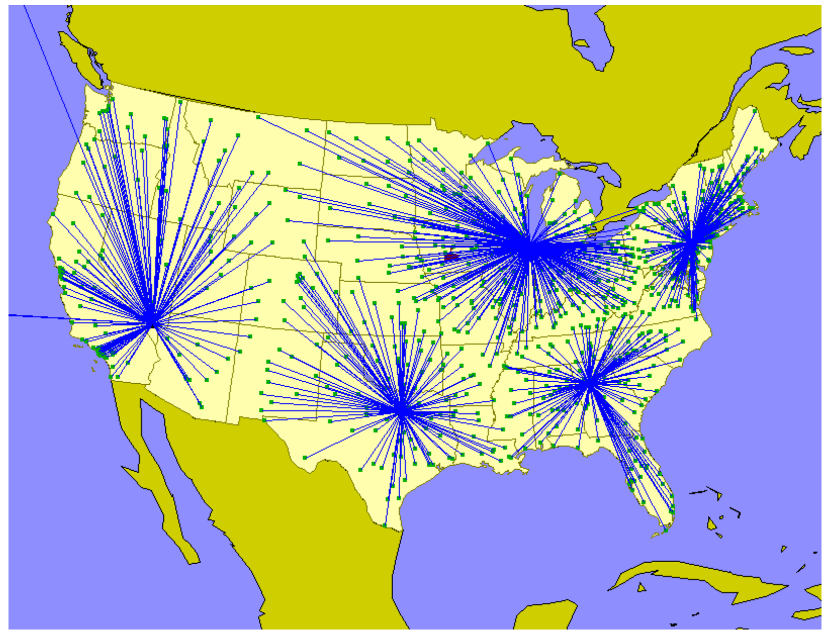
- Why?
  - The cost of obtaining and processing data
  - The form in which data is available
  - The size of the resulting location model
  - The accuracy of forecast demand

Comparing Output

Total Cost:$5,796,000
Total Customers: 18,000



Total Cost:$5,793,000
Total Customers: 800



Cost Difference < 0.05%

Product Grouping

- Companies may have hundreds to thousands of individual items in their production line

  1. Variations in product models and style

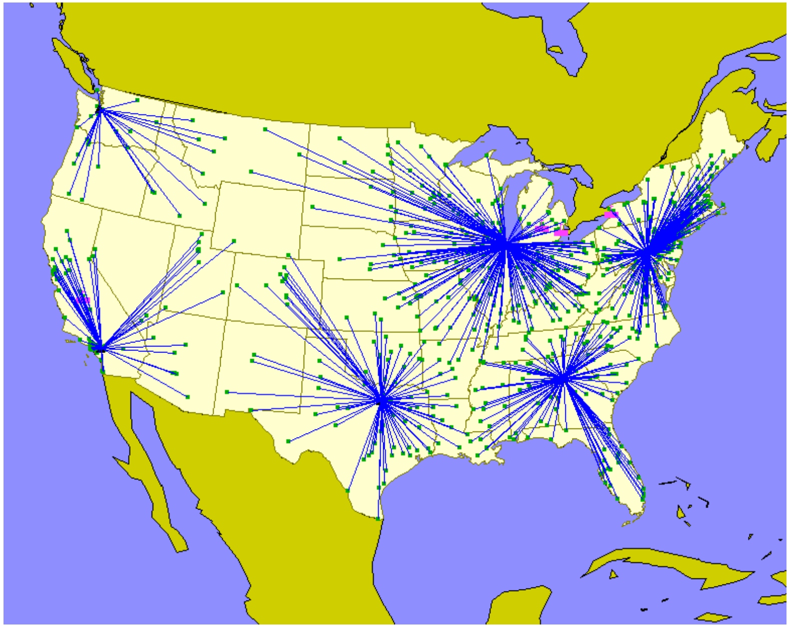
  2. Same products are packaged in many sizes

- Collecting all data and analyzing it is impractical for so many product groups

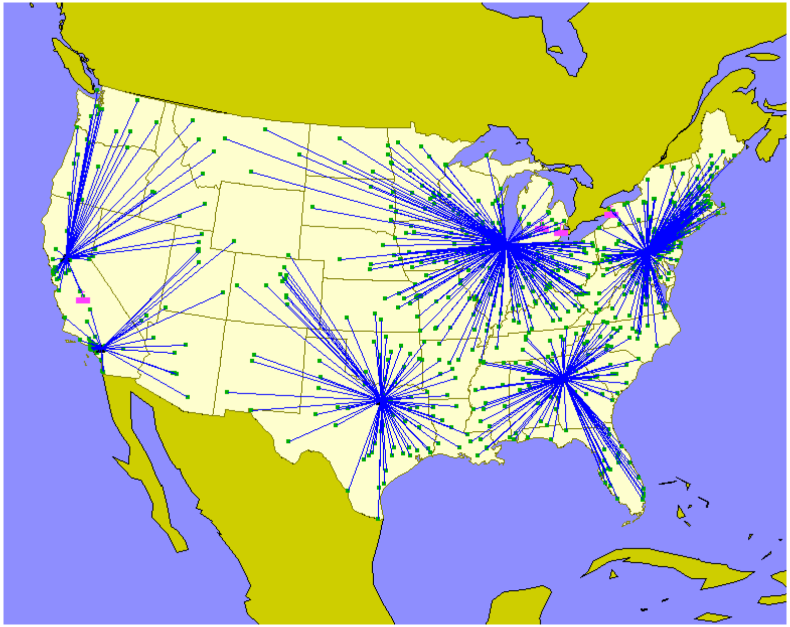
- Aggregate the products by similar logistics characteristics
  - Weight
  - Volume
  - Holding Cost

Sample Aggregation Test: Product Aggregation

Total Cost:$104,564,000
Total Products: 46



Total Cost:$104,599,000
Total Products: 4



Cost Difference: 0.03%

A location model with economies of scale

Facility location under economies of scale

- The long run total cost function of the facilities have economies of scale
- Where should we build facilities ?
- Location-allocation problem
- In addition to the facility costs we have to consider transportation costs
- We look at the situation where all facilities make the same single product

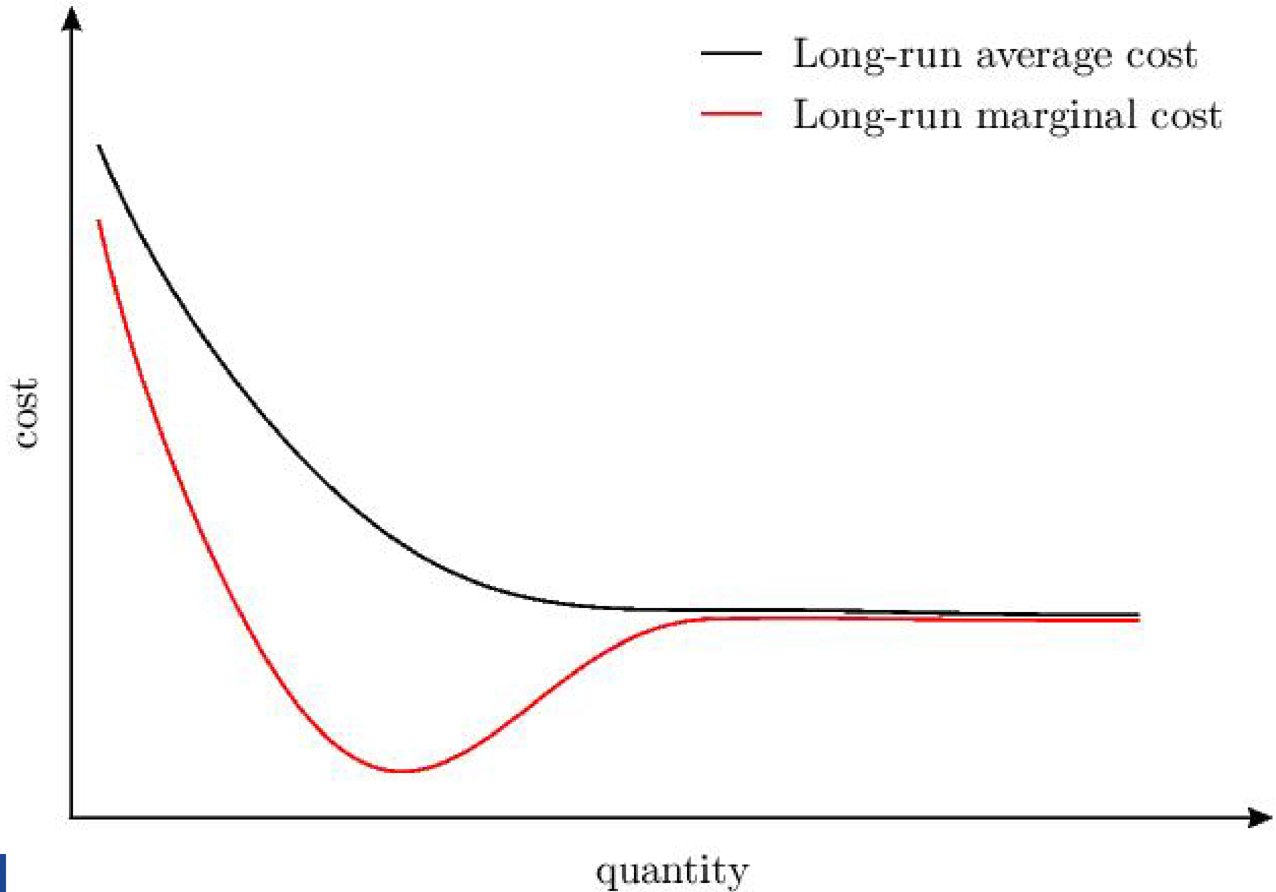
The Long Run Total Cost function of facilities

- Includes:
  - Fixed costs
    - Capital cost, Personal, Insurance
  - Variable costs
    - Energy, Personnel, Water, Cleaning, Repairs, Classification, Material, Waste Management

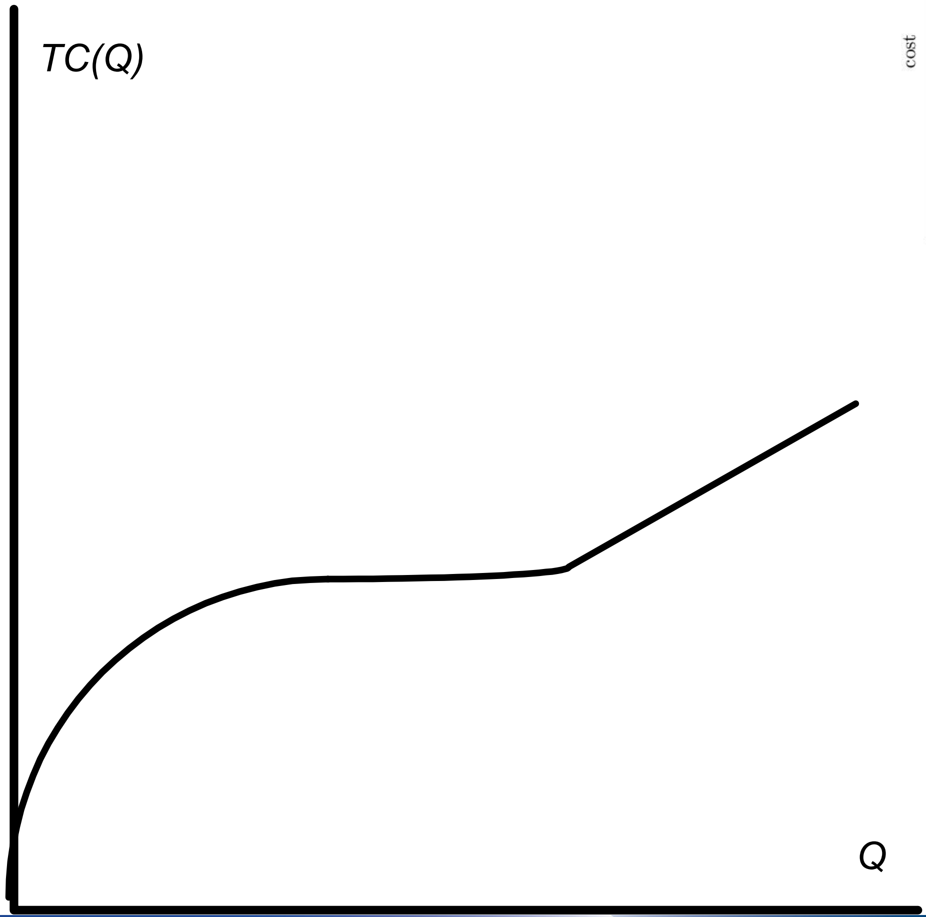
- Average cost: Total cost broken down to cost per unit
- Marginal cost: The cost of producing an additional unit

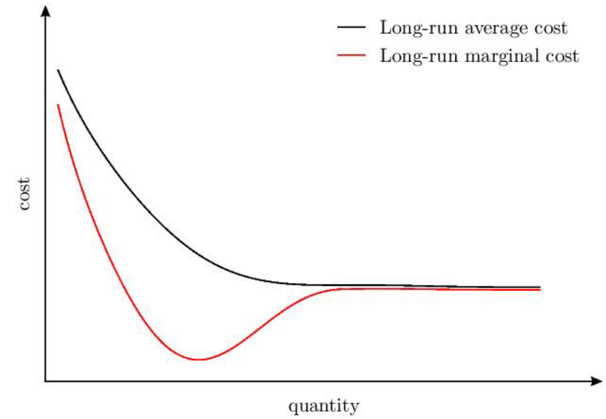
- Economies of scale: Average cost *AC(q)* is decreasing in *q*

Economies of Scale

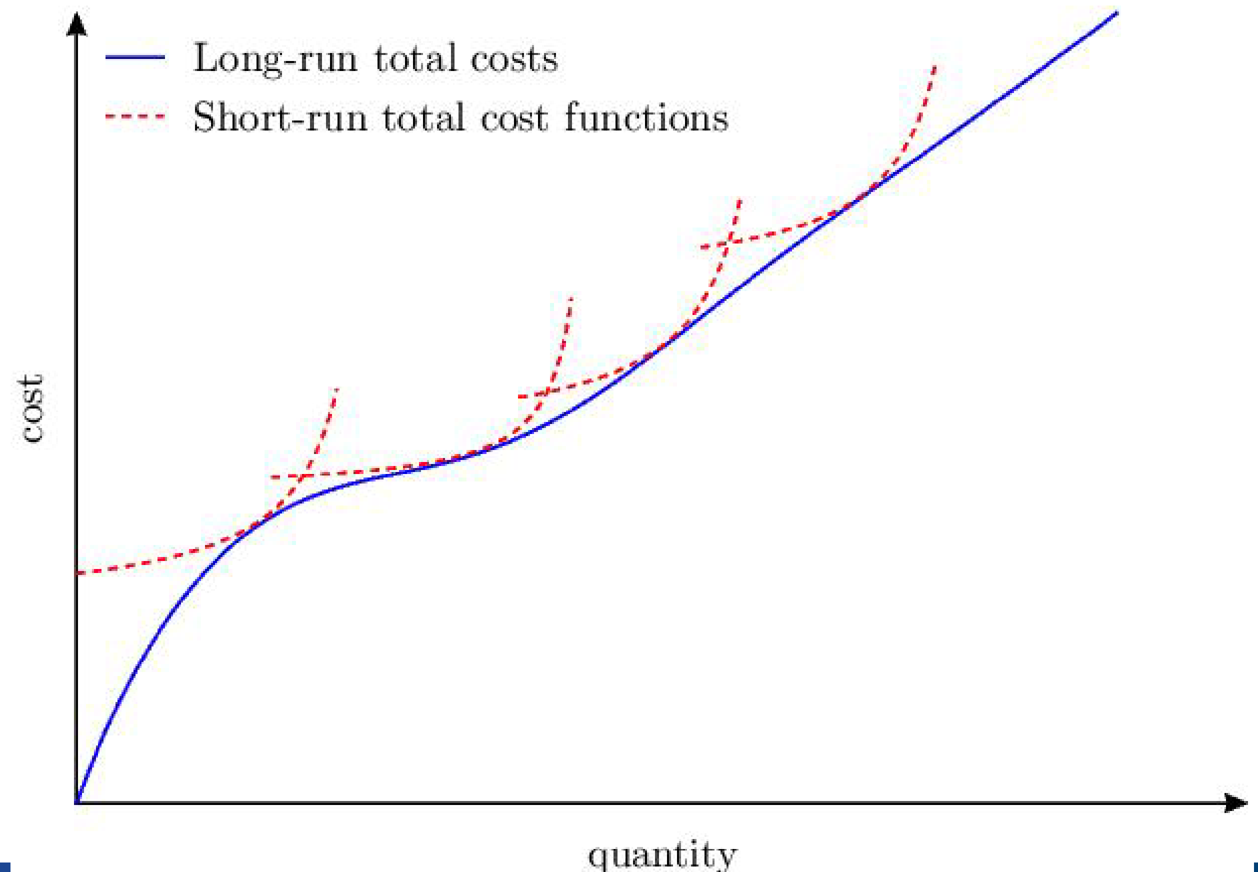


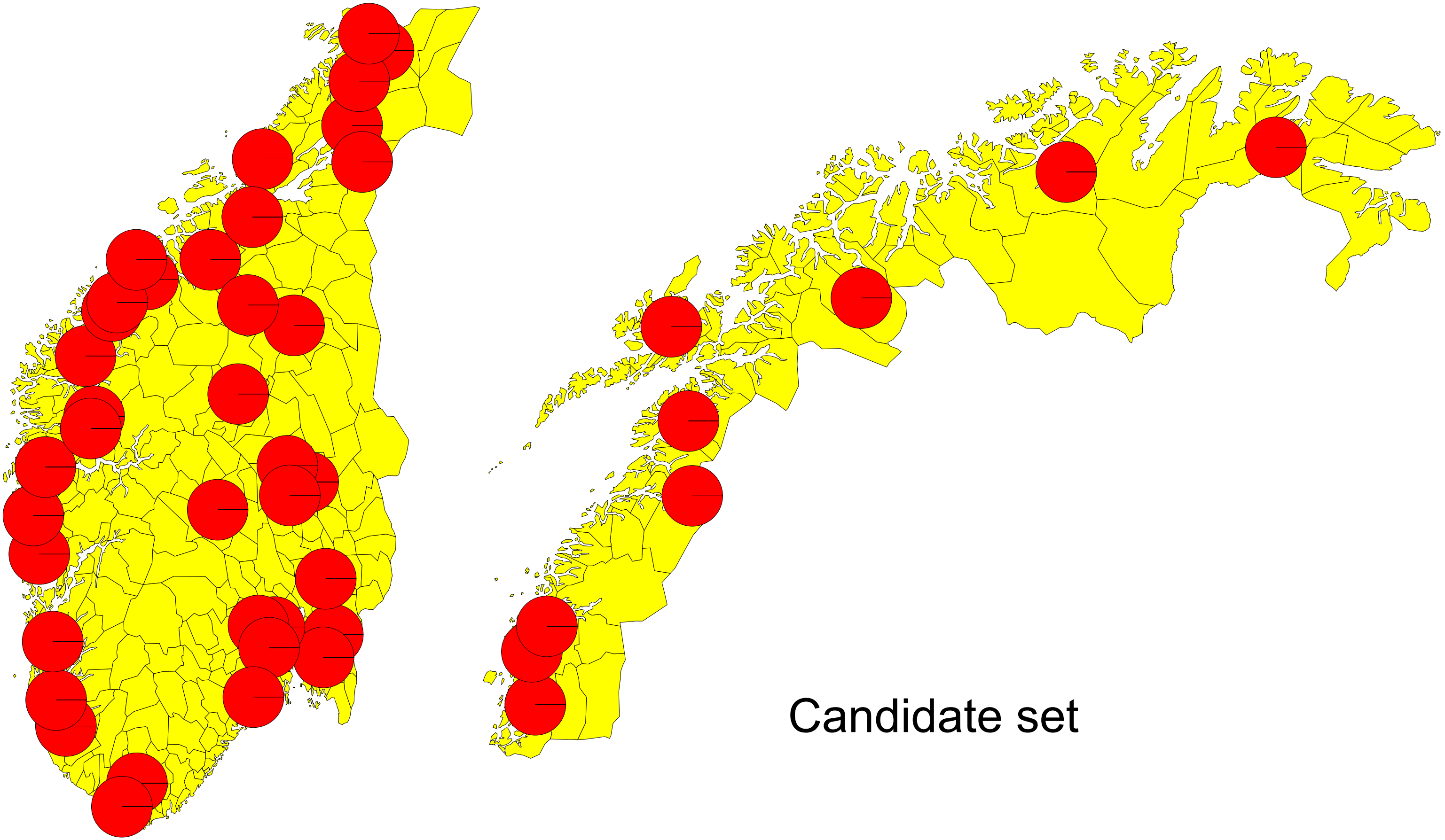
Economies of Scale:
Long run total cost curve





Long-Run vs. Short-Run Costs





Candidate set

What happens when demand is uncertain?

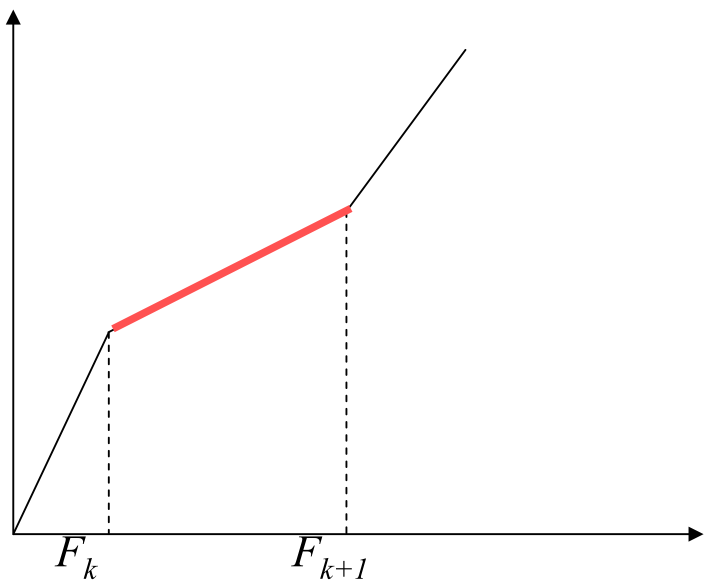
- First stage decision (Today)
  - Choice of facility location an capacity based on long run cost curve
    - And thereby picking the short run cost function
  - Demand is given by a discrete probability distribution through scenarios
  - Minimize the expected cost of operating the facilities, given that demand is uncertain at time of investment

- Second stage decision (At a later point in time….)
  - Realized demand is now known with certainty
  - Allocate demand to facilities
  - Each facilitiy has a short run cost function based on the design capacity from the first stage

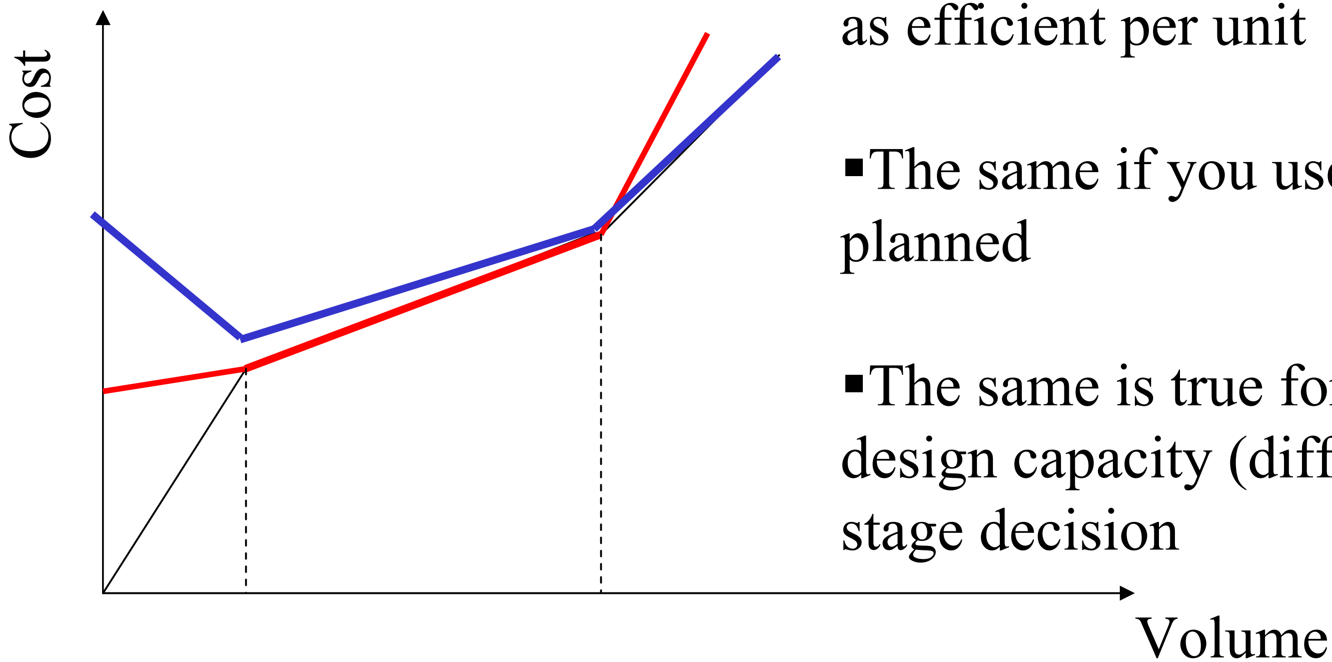
First Stage Problem: The investment decision

For each location alternative

- Should I build a facility?
- What should the design capacity be?



Second Stage Problem: The allocation of demand to facilities

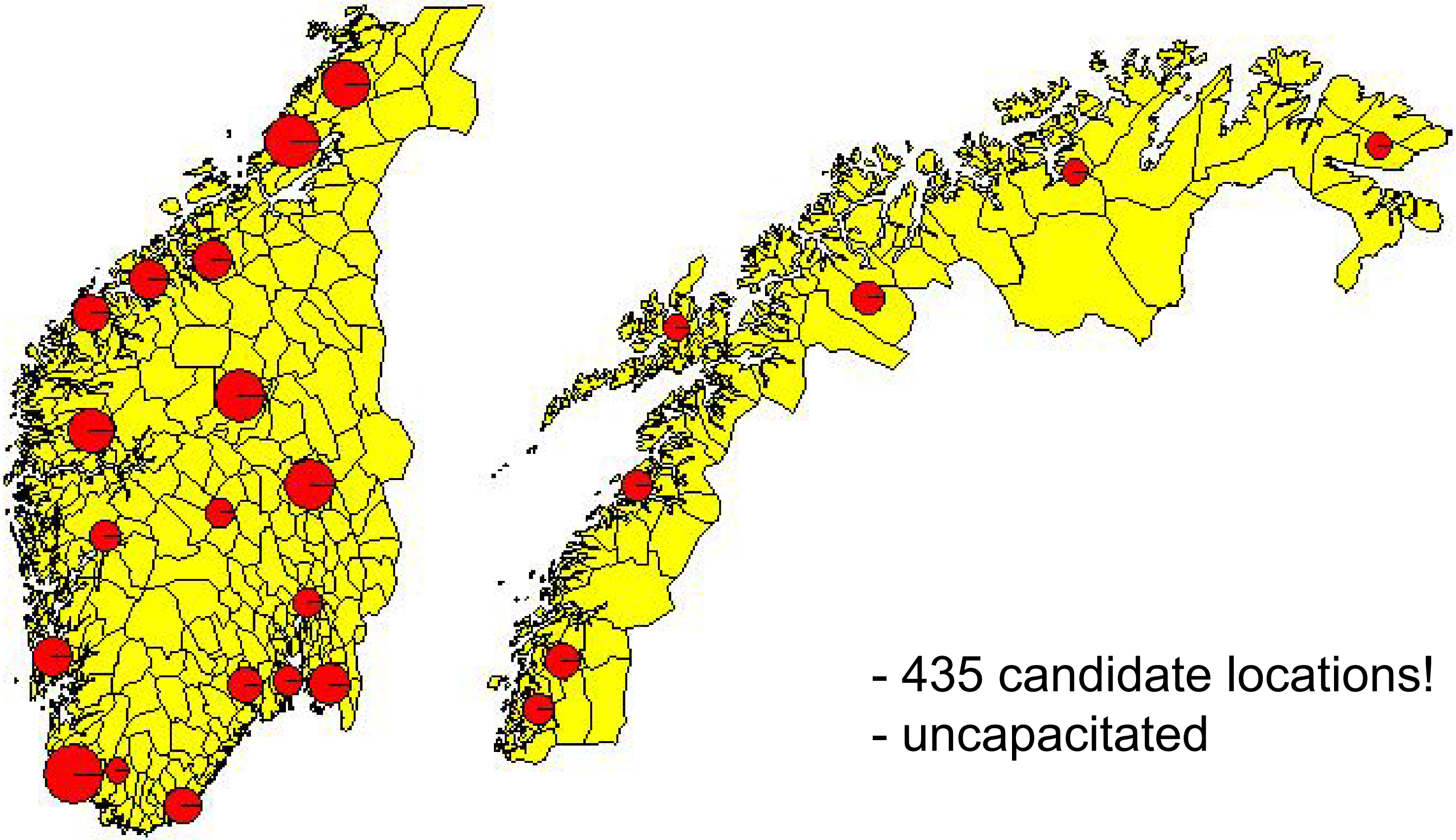


- The design capacity is given
- If you use more capacity it is not as efficient per unit
- The same if you use less than planned
- The same is true for a different design capacity (different first stage decision

Real life case

- Slaughterhouse location analysis for the Norwegian meat co-operative
- Had approximately 25 slaughterhouses for cattle
- What would be the optimal number and locations if they were free to replace them today (using the animal populations they are currently serving)?
  - location
  - size
- Requirements
  - all demand (from farmers) should be met
  - no animal should stay more than 8 hours in the car on its way to the slaughterhouse

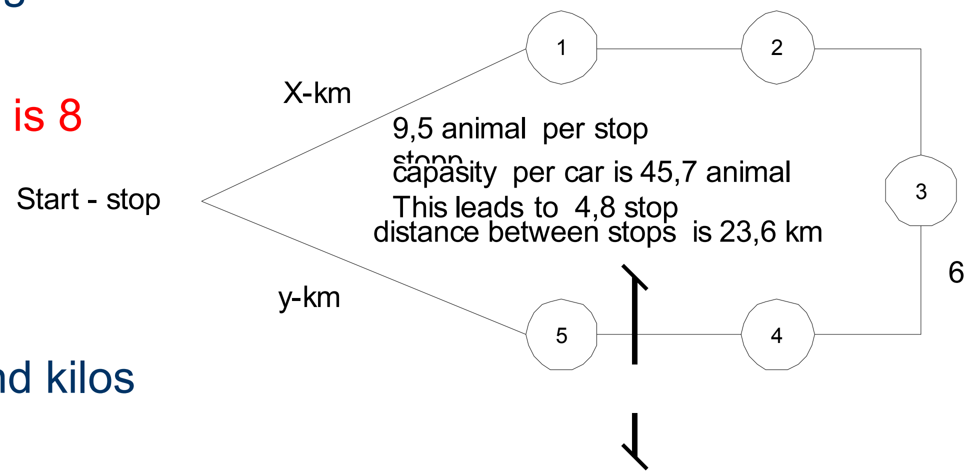
Original locations



- 435 candidate locations!
- uncapacitated

Transportation Time and Cost Estimates

- Time
  - Time between slaughterhouse and region
  - Time on roundtrip within region
  - Terminal time
  - Max limit for transportation is 8 hours

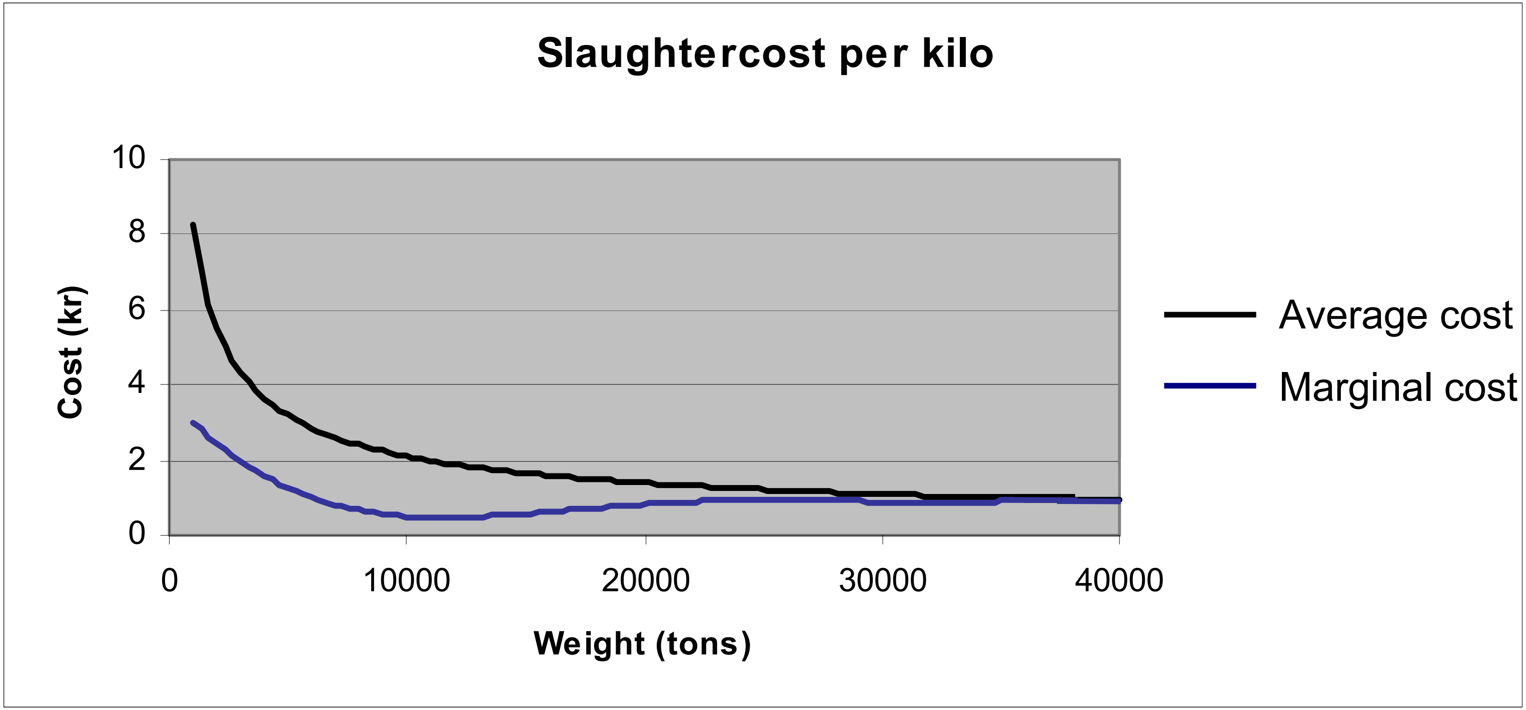


- Cost
  - Linear in travel distance and kilos

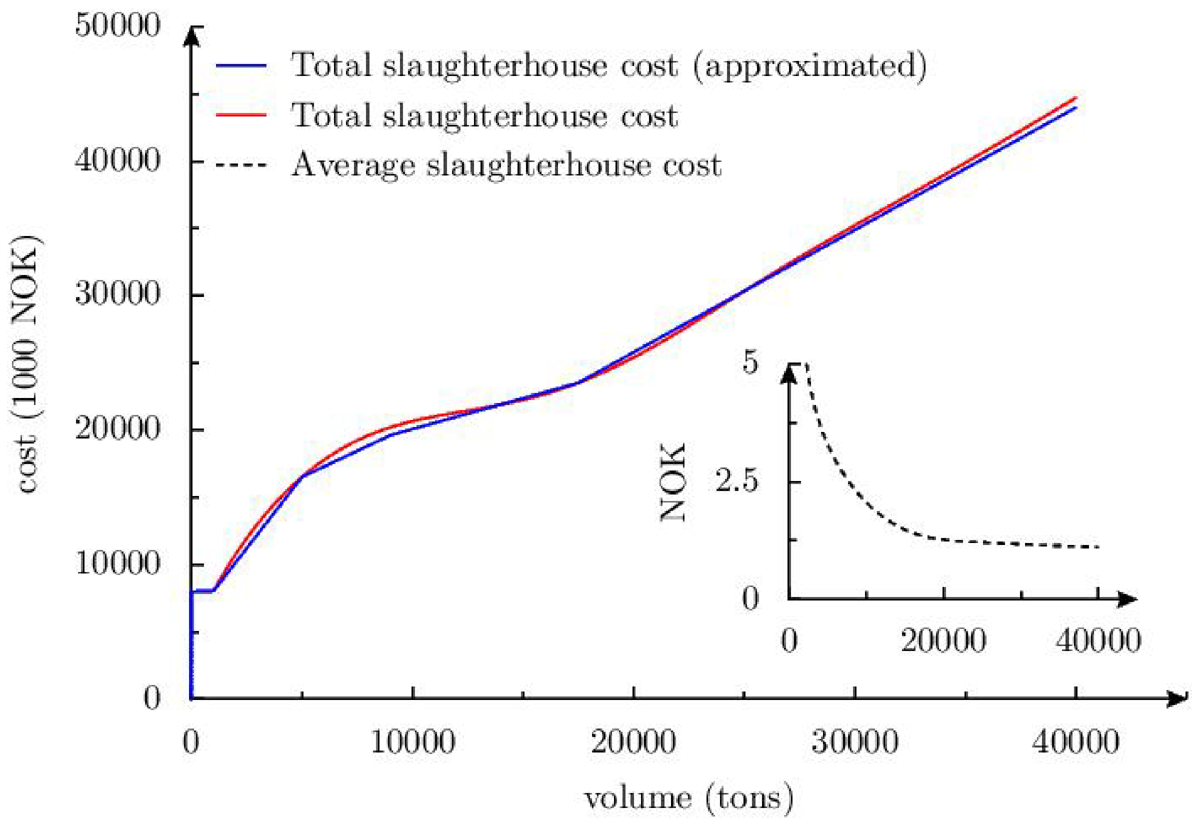
- Both time and cost depend on the size of the car used
  - Two car types

Slaughterhouse Costs

- Nonlinearities in the objective function
- Economies of scale in slaughterhouses



Linearization of the long run total cost curve



The problem instances

- 435 possible location points for facilities
- 420 locations with stochastic demand

- Data generated to test the algorithm based on real-world animal population:
  - We use the animal population from 2002 as mean demand and generate test problems by sampling scenarios from a normal distribution

- Different data sets with 100 scenarios
  - Uncorrelated demand in the regions (420 stoch. variables)
  - Perfectly correlated demand in the regions (1 stoch. variable)
  - Low standard deviation
  - High standard deviation

- Also did some tests with 10 scenarios

Model Size of the Problem Instance

- For the given problem instance with 435 locations, 10 scenarios, 6 linepieces in the first stage , and 3 linepieces in the second stage:
  - 1 999 695 Variables
  - 35 233 Constraints

- Pentium Xeon 3.2 GHz, 6 Gb ram, linux.

Model Size of the Problem Instance

- For the given problem instance with 435 locations, 6 linepieces in the first stage, and 3 linepieces in the second stage:
  - Deterministic: ≈ 35,900 variables, 1,290 constraints,
  - 10 scenarios: ≈ 440,500 variables, 35,000 constraints,
  - 100 scenarios: ≈ 4,381,150 variables, 346,500 constraints,
- Pentium Xeon 3 GHz, 6 Gb RAM, Linux kernel 2.6.11

- Runtime:
  - 1 scenario ≈ 40min
  - 10 scenarios ≈ 3h 40min
  - 100 scenarios ≈ 38h 15min

- Optimality Gap approx. 5%

Typical Results

Location	Expected Value		10 Scenarios		100 Scenarios	
	k	exp. weight	*k*	exp. weight	*k*	exp. weight
Rølingen	5	16549	6	16360	6	16476
Gjesdal	5	12598	5	12760	5	13063
Jondal	2	1000	2	1000	2	1000
Jølster	5	14545	6	13357	6	14167
Trondheim	5	17559	6	19090	6	19035
Vikna	3	2244	3	2255	3	2298
Rana	3	2814	3	2828	3	2882
Hamarøy	3	2077	3	2086	3	2126
Kåfjord	3	1558	3	1568	3	1597
Unjargga-Nesseby	2	424	2	427	2	435
Exp. cost	241844000		244885000		247163000	
			EVS: +∞		EVS: +∞	

Results

Expected value problem

V	S	K	LB	UB	Gap (1500)	Gap	Runtime [hh:mm]
3000	1	5	240258	249751	4,52%	3.76%	0:46
3000	1	6	232791	245496	5,92%	5.18%	0:50

Uncertain demand

V	S	K	LB	UB	Gap (1500)	Gap	Runtime [hh:mm]
3000	10	5	183897	197636	7,1%	6.95%	3:39
3000	10	6	183892	202100	10,82%	9.01%	4:13
3000	100	5	235071	264081		10.99%	38:53