A location and design study was done in 1992 and the building was completed in two phases – the last in 1995.

WHY Nike selected Laakdal from several available locations in Europe?

1. Nike's main business objective was to service 75% of its customers in less than 24 hours. Because of its proximity to major customer markets. Laakdal was a natural choice.
2. Proximity to ports of entry for footwear and apparel manufactured overseas, the road network in and around Laakdal, and access to major highways were superb.
3. Because its citizens are required to go to school until at least age of 18, Belgium has an educated workforce.
4. Other factors also favored Laakdal.

In practice, many factors have an important impact on location decisions. The relative importance of these factors depends on whether the scope of a particular location problems is international, national, statewide, or communitywide.

Example:

If we are trying to determine the location of a manufacturing facility in a foreign country, factors such as;

- Political stability,
- Foreign exchange rates,
- Business climate,
- Duties, and
- Taxes

play a role.

If the scope of the location problem is restricted to few communities, the factors like;

- Community services,
- Property tax incentives,
- Local business climate, and
- Local government regulations

are important.

2.3.4. Factors that affect Location Decisions

- Proximity to source of raw materials,
- Cost and availability of energy and utilities,
- Cost, availability, skill and productivity of labor,
- Government regulations at the federal, state, county and local levels,
- Taxes at the federal, state, county and local levels,
- Insurance,

- Construction costs and land price,
- Government and political stability,
- Exchange rate fluctuation,
- Export and import regulations, duties and tariffs,
- Transportation system,
- Technical expertise,
- Environmental regulations at the federal, state, county and local levels,
- Support services,
- Community services – schools, hospitals- recreation and so on,
- Weather,
- Proximity to customers,
- Business climate,
- Competition-related factors.

<u>Example:</u>

Suppose that the Waterstill Manufacturing Company has narrowed its choice down to two locations, city A and city B. all cost calculations have been made and there is no clear-cut distinction. In fact, for simplicity, assume that all costs are equal at the two locations. How can the decision be made?

<u>Step 1:</u> make a list of all important factors. Noncost factors in plant location:

(1) Nearness to market
(2) Nearness to unworkerked goods
(3) Availability of power
(4) Climate
(5) Availability of water
(6) Capital availability
(7) Momentum of early start
(8) Fire protection
(9) Police protection
(10) Schools and colleges
(11) Union activity
(12) Churches and religious facilities
(13) Recreational opportunities
(14) Housing
(15) Vulnerability to air attacks
(16) Community attitude
(17) Local ordinances
(18) Labor laws
(19) Future growth of community
(20) Medical facilities
(21) Employee transportation facilities

<u>Step 2:</u> assign relative point values for each of the factor for specific company and plant to be located. Therefore, maximum point values for each factor:

Factor-Value	*Factor-Value*	*Factor-Value*
1 - 280	8 - 10	15 - 10
2 - 220	9 - 20	16 - 60
3 - 30	10 - 20	17 - 50
4 - 40	11 - 60	18 - 30
5 - 10	12 - 10	19 - 30
6 - 60	13 -20	20 - 10
7 - 10	14 - 10	21 - 20

<u>Step 3:</u> assign degrees and points within each factor. Usually, from 4 to 6 degrees are used with linear assignment of points between degrees.

Degrees and points for factor 16 (community attitude):

Degrees		*Point Assignment*
0	Hostile, bitter, noncooperative	0
1	Parasitic in nature	15
2	Noncooperative	30
3	Cooperative	45
Maximum	Friendly and more than cooperative	60

At this point Waterstill has its evaluation scheme completely defined, so it now must assign each of the two locations (A and B) degrees and corresponding points for each factor. The hypothetical results are;

	CITY A		CITY B	
Factor	*Degree*	*Points*	*Degree*	*Points*
1	Maximum	280	3	168
2	4	176	4	176
3	2	12	4	24
4	0	0	4	24
5	4	8	2	4
6	3	36	4	48
7	2	4	1	2
8	Maximum	10	2	4
9	4	16	2	8
10	2	8	3	12
11	3	36	3	36
12	2	6	2	6
13	3	15	Maximum	20
14	4	8	0	0
15	1	2	2	5
16	3	45	2	30
17	2	20	4	40
18	3	23	1	8
19	0	0	3	18
20	1	2	1	2
21	4	12	2	8
Total		719		643

Waterstill now can compare these results with the cost calculations and make a decision. City A has a total point value of 719 compared to 643 for City B. City A would probably be preferred since all cost calculations were assumed equal.

It is often extremely difficult to find a single location that meets all these objectives at the desired level. For example, a location may offer a highly skilled labor pool, but construction and land costs may be too high.

Similarly, another location may offer low tax rates and minimal government regulations but may be too far from the raw materials source or customer base.

Thus, facility location problem is to select a site (among several available alternatives) that optimizes a weighted set of objectives.

If we examine the inputs required to produce a product or provide a service, two things stand out:

- People, and
- Raw materials.

For a location to be effective, it must be in close proximity to relatively less expensive, skilled labor pools and raw materials sources.

Example:

- One of the reasons for electronics and software companies locating in Silicon Valley is availability of highly skilled computer professionals.
- Similarly, many U.S. companies are opening manufacturing facilities in Mexico and Far East to take advantage of lower labor wage rates. Many companies look for labor pools with higher productivity, a strong work ethic, and absence of unionization.

With respect to raw materials, some industries find it more important to be close to raw materials sources than others. These tend to be industries for which raw materials are bulky or otherwise expensive to transport. Companies that have implemented just-in-time (JIT) strategies are likely to be located near inventories and thereby reduce costs. Other inputs that have an impact on location decisions are cost and availability of energy and utilities, land prices and construction costs.

In addition to the input-related factors, one output-related factor plays an important role in the evaluation of location – proximity to customers. This factor is important because the product's shelf life may be short, the finished product may be bulky or may require special care during transportation, and duties and tariffs may be high, necessitating that the facility location be close to the market area.

2.4. Techniques for Discrete Space Location Problems

Our focus is on the single-facility location problem.

The single facility for which we seek a location may be;

- The only one that will serve all the customers,
- An addition to a network of existing facilities that are already serving customers.

1. Qualitative Analysis
2. Quantitative Analysis
3. Hybrid Analysis

2.4.1. Qualitative Analysis

Qualitative Analysis => Location Scoring Method

This is a very popular, subjective decision-making tool that is relatively easy to use.

Qualitative Analysis consists of these steps:

Step 1: List all the factors that are important – that have an impact on the location problem.

Step 2: Assign an appropriate weight (typically between 0 and 1) to each factor based on the relative importance of each.

Step 3: Assign a score (typically between 0 and 100) to each location with respect to each factor indentified in step 1.

Step 4: Compute the weighted score for each factor for each location by multiplying its weight by the corresponding score.

Step 5: Compute the sum of the weighted scores for each location and choose a location based on these scores.

Example:

A payroll processing company has recently won several major contracts in the Midwest region of the United States and Central Canada, and wants to open a new, large facility to serve these areas. Because customer service is so important, the company wants to be as near its "customers" as possible. A preliminary investigation has shown that Minneapolis, Winnipeg, and Springfield are the three most desirable locations, and the payroll company has to select one of these. Using the location scoring method (Qualitative Analysis), determine the best location for the new payroll processing facility.

Solution:

A through investigation of each location with respect to eight important factors generated the raw scores and weights listed in the table below.
Table 1: Factors and weights for three locations:

		Score		
Weight	Factor	Minneapolis	Winnipeg	Springfield
0.25	Proximity to customer	95	90	65
0.15	Land and construction prices	60	60	90
0.15	Wage rates	70	45	60
0.10	Property taxes	70	90	70
0.10	Business taxes	80	90	85
0.10	Commercial travel	80	65	75
0.08	Insurance costs	70	95	60
0.07	Office services	90	90	80

Steps 1, 2, and 3 have been completed. That is, all the factors that are important (which have an impact on the location decision) are listed. Appropriate weights (typically between 0 and 1) are assigned to each factor based on the relative importance of each. A score (typically between 0 and 100) is assigned to each location with respect to each factor identified above.

We now need to compute the weighted score for each location-factor pair, add these weighted scores and determine the location based on the scores.

Table 2: Weighted scores for the three locations:

	Weighted Score		
Factor	Minneapolis	Winnipeg	Springfield
Proximity to customer	23.75	22.50	16.25
Land and construction prices	9.00	9.00	13.50
Wage rates	10.50	6.75	9.00
Property taxes	7.00	9.00	7.00
Business taxes	8.00	9.00	8.50
Commercial travel	8.00	6.50	7.50
Insurance costs	5.60	7.60	4.80
Office services	6.30	6.30	5.60
Sum of Weighted Scores	78.15	76.65	72.15

From the analysis in the table above, it is clear that Minneapolis is the best location on the subjective information.

Although step 5 calls for the location decision to be made solely on the basis of the weighted scores, those scores were arrived at in a subjective manner, and hence a final location decision must also take into account objective measures such as transportation costs, loads and operation costs.

2.4.2. Quantitative Analysis

Several quantitative techniques are available to solve the discrete space, single-facility location problem. Each is appropriate for a specific set of objectives and constraints.

e.g. the so-called minimax location model is appropriate for determining the location of an emergency service facility (such as a fire station, police station, hospital), where the objective is to minimize the maximum distance travelled between the facility and any customer.

If the objective is to minimize the total distance travelled, the transportation model is appropriate.

That is, we have *m* plants in a distribution network that serves *n* customers. Due to an increase in demand at one or more of these n customers, it has become necessary to open an addition plant. The new plant could be located at *p* possible sites. To evaluate which of the *p* sites will minimize distribution (transportation) costs, we can set up *p*

transportation models, each with n customers and $m+1$ plants, where $(m+1)^{th}$ plant corresponds to the new location being evaluated.
Solving the model will tell us not only the distribution of goods from the $m+1$ plants (including the new one from the location being evaluated) but also the cost of distribution.

The location that yields the least overall distribution cost is the one where the new facility should be located.

Example:

Seers Inc. has two manufacturing plants at Albany and Little Rock that supply Canmore brand refrigerators to four distribution centers in Boston, Philadelphia, Galveston and Raleigh. Due to an increase in the demand for this brand or refrigerators that is exported to last for several years, Sears Inc. has decided to build another plant in Atlanta or Pittsburgh.

The unit transportation costs, expected demand at the four distribution centers and the maximum capacity at the Albany and Little Rock plants are given in the following table. Determine which of the two locations, Atlanta o Pittsburgh, is suitable for the new plant Seers Inc. wishes to utilize all of the capacity available at its Albany and Little Rock locations. Costs, demand and supply capacity information:

Factors and weights for the three locations	**Demand**					
	Location	***Boston***	**Philadelphia**	**Galveston**	**Raleigh**	**Supply Capacity**
	Albany	10	15	22	20	250
	Little Rock	19	15	10	9	300
	Atlanta	21	11	13	6	No Limit
	Pittsburgh	17	8	18	12	No Limit
	Total	200	100	300	280	

Solution:

Manufacturing Plants
- Albany
- Little Rock
- +
- New Plant in Atlanta? or in Pittsburgh?

Distribution Centers
- Boston
- Philadelphia
- Galveston
- Raleigh

Maximum capacity of the new plant required at either location is 330 because the capacity at Albany and Little Rock is to be fully utilized.

Total demand $= 200 + 100 + 300 + 280 = 880$
Total supply $= 250 + 300 + \chi = 550 + \chi$
$550 + \chi = 880$
$\chi = 330$

(I) Transportation model with plant in Atlanta

Transportation model with plant in Atlanta	**Demand**				
	Location	***Boston***	**Philadelphia**	**Galveston**	**Raleigh**	**Supply Capacity**
	Albany	10	15	22	20	250
	Little Rock	19	15	10	9	300
	Atlanta	21	11	13	6	330
	Total	200	100	300	280	880

Distribution pattern is as follows:

Location	Demand: Boston	Philadelphia	Galveston	Raleigh	Supply Capacity
Albany	10 200	15 50	22	20	~~250~~ ~~50~~
Little Rock	19	15	10 300	9	~~300~~
Atlanta	21	11 50	13	6 280	~~330~~ ~~50~~
Total	200	100	300	280	880

$$\text{Total Cost} = (200\times 10) + (50\times 15) + (50\times 11) + (300\times 10) + (280\times 6)$$
$$= \$7980$$

(II) Transportation model with plant in Pittsburgh

Transportation model with plant in Pittsburgh	**Demand**				
	Location	***Boston***	**Philadelphia**	**Galveston**	**Raleigh**	**Supply Capacity**
	Albany	10	15	22	20	250
	Little Rock	19	15	10	9	300
	Pittsburgh	17	8	18	12	330
	Total	200	100	300	280	880

Distribution pattern is as follows:

Location	Demand: Boston	Philadelphia	Galveston	Raleigh	Supply Capacity
Albany	10 200	15 50	22	20	~~250~~ ~~50~~
Little Rock	19	15	10 300	9	~~300~~
Pittsburgh	17	8 50	18	12 280	~~330~~ ~~50~~
Total	200	100	300	280	880

$$\text{Total Cost} = (200\times 10) + (50\times 15) + (50\times 8) + (300\times 10) + (280\times 12)$$
$$= \$9510$$

Because the Atlanta location minimizes the cost, the decision is to construct the new plant in Atlanta.

2.4.3. Hybrid Analysis

A disadvantage of the Qualitative method discussed earlier is that location decision is made based entirely on a subjective evaluation. Although Quantitative method overcomes this disadvantage, it does not allow us to incorporate unquantifiable factors that have a major impact on the location decision.

Example:

The Quantitative techniques can easily consider:

- transportation cost, and
- operational costs,

but intangible factors such as;

- the attitude of a community toward businesses,
- potential labor unrest,
- reliability of auxiliary service providers

are difficult to capture though these are important in choosing a location decision.

Therefore, we need a method that incorporates subjective as well as quantifiable cost and other factors.

Hybrid Analysis

A multiattribute, single-facility location model based on the ones presented by Brown and Gibson (1972) and Buffa and Sarin (1987).

This model classifies the objective and subjective factors important to the specific location problem being addressed as:

- critical,
- objective, and
- subjective.

The meaning of objective and subjective factors is obvious. The meaning of critical factors needs some discussion.

Critical Factors:

In every location decision, usually at least one factor determines whether or not a location will be considered for further evaluation.

For instance, if water is used extensively in a manufacturing process (e.g. a brewery), then a site that does not have an adequate water supply now or in the future is automatically removed from consideration. This is an example of a critical factor.

After the factors are classified, they are assigned numeric values:

$$CF_{ij}\begin{cases} 1 & \text{if location } i \text{ satisfies critical factor } j \\ 0 & \text{otherwise} \end{cases}$$

OF_{ij} : cost of objective factor j at location i

SF_{ij} : numeric value assigned (on a scale of 0–1) to subjective factor j for location i

w_j : weight assigned to subjective factor j ($0 \leq w_j \leq 1$)

Assume that we have m candidate locations and p critical, q objective and r subjective factors. We can determine overall critical factor measure (CFM_i), objective factor measure (OFM_i), and Subjective Factor Measure (SFM_i) for each location i with these equations.

CFM_i : overall critical factor measure for location i,

OFM_i : objective factor measure for location i,

SFM_i : subjective factor measure for location i,

LM_i : location measure for location i.

$$CFM_i = CF_{i1}, CF_{i2}, \ldots, CF_{ip} = \prod_{j=1}^{p} CF_{ij} \qquad i = 1, 2, \ldots, \mathrm{m}$$

$$OFM_i = \frac{\max_i \left[\sum_{j=1}^{q} OF_{ij}\right] - \sum_{i=1}^{q} OF_{ij}}{\max_i \left[\sum_{j=1}^{q} OF_{ij}\right] - \min_i \left[\sum_{j=1}^{q} OF_{ij}\right]} \qquad i = 1, 2, \ldots, \mathrm{m}$$

$$SFM_i = \sum_{j=1}^{r} w_j SF_{ij}$$

The location measure, LM_i for each location is then calculated as:

$$LM_i = CFM_i \left\lfloor \alpha\left(1 - OFM_j\right) + \left(1-\alpha\right)SFM_i \right\rfloor$$

where α is the weight assigned to the objective factor measure.

After LM_i is determined for each candidate location, the next step is to select the one with the greatest LM_i value.

Example:

Mole-Sun Brewing Company is evaluating six candidate location; Montreal, Plattsburgh, Ottawa, Albany, Rochester, and Kingston for a new brewery. The two critical, three objective and four subjective factors that management wishes to incorporate in its decision making are summarized in the table below. The weights of the subjective factors are also provided in the table.

Determine the best location if the subjective factors are to be weighted 50% more than the objective factors.

	CRITICAL FACTORS		OBJECTIVE FACTORS			SUBJECTIVE FACTORS			
Location	Water Supply	Tax Incentives	Revenue	Labor Cost	Energy Cost	Community Attitude (0.3)	Ease of Transportation (0.4)	Labor Unionization (0.25)	Support Services (0.05)
Albany	0	1	185	80	10	0.5	0.9	0.6	0.7
Kingston	1	1	150	100	15	0.6	0.7	0.7	0.75
Montreal	1	1	170	90	13	0.4	0.8	0.2	0.8
Ottowa	1	0	200	100	15	0.5	0.4	0.4	0.8
Plattsburgh	1	1	140	75	8	0.9	0.9	0.9	0.55
Rochester	1	1	150	75	11	0.7	0.65	0.4	0.8

Solution:

$\alpha = 0.4$ so that the weight of the subjective factors ($1-\alpha = 0.6$) is 50%more than that of the objective factors.

Calculate:
Sum of objective factors = Revenue – Costs

	CRITICAL FACTORS		OBJECTIVE FACTORS				SUBJECTIVE FACTORS			
Location	Water Supply	Tax Incentives	Revenue	Labor Cost	Energy Cost	Sum of Objective Factors	Community Attitude (0.3)	Ease of Transportation (0.4)	Labor Unionization (0.25)	Support Services (0.05)
Albany	0	1	185	-80	-10	95	0.5	0.9	0.6	0.7
Kingston	1	1	150	-100	-15	35	0.6	0.7	0.7	0.75
Montreal	1	1	170	-90	-13	67	0.4	0.8	0.2	0.8
Ottawa	1	0	200	-100	-15	85	0.5	0.4	0.4	0.8
Plattsburgh	1	1	140	-75	-8	57	0.9	0.9	0.9	0.55
Rochester	1	1	150	-75	-11	64	0.7	0.65	0.4	0.8
					Max=	95				
					Min=	35				

$$CFM_i = CF_{i1}, CF_{i2}, \ldots, CF_{ip} = \prod_{j=1}^{p} CF_{ij} \qquad i = 1, 2, \ldots, m$$

$$CFM_{Albany} = 0 \times 1 = 0$$

$$CFM_{Kingston} = 1 \times 1 = 1$$

$CFM_{Montreal} = 1 \times 1 = 1$

$CFM_{Ottawa} = 1 \times 0 = 0$

$CFM_{Plattsburgh} = 1 \times 1 = 1$

$CFM_{Rochester} = 1 \times 1 = 1$

$$OFM_i = \frac{\max_i \left[\sum_{j=1}^{q} OF_{ij} \right] - \sum_{i=1}^{q} OF_{ij}}{\max_i \left[\sum_{j=1}^{q} OF_{ij} \right] - \min_i \left[\sum_{j=1}^{q} OF_{ij} \right]} \qquad i = 1, 2, \ldots, m$$

$$OFM_{Albany} = \frac{95-95}{95-35} = 0$$

$$OFM_{Kingstony} = \frac{95-35}{95-35} = 1$$

$$OFM_{Moptreal} = \frac{95-67}{95-35} = 0.467$$

$$OFM_{Ottawa} = \frac{95-85}{95-35} = 0.167$$

$$OFM_{Plattsburgh} = \frac{95-57}{95-35} = 0.633$$

$$OFM_{Rochester} = \frac{95-64}{95-35} = 0.517$$

$$SFM_i = \sum_{j=1}^{r} w_j SF_{ij}$$

$SFM_{Albany} = (0.3 \times 0.5) + (0.4 \times 0.9) + (0.25 \times 0.6) + (0.05 \times 0.7) = 0.695$

$SFM_{Kingstony} = (0.3 \times 0.6) + (0.4 \times 0.7) + (0.25 \times 0.7) + (0.05 \times 0.75) = 0.6725$

$SFM_{Moptreal} = (0.3 \times 0.4) + (0.4 \times 0.8) + (0.25 \times 0.2) + (0.05 \times 0.8) = 0.53$

$SFM_{Ottawa} = (0.3 \times 0.5) + (0.4 \times 0.4) + (0.25 \times 0.4) + (0.05 \times 0.8) = 0.45$

$SFM_{Plattsburgh} = (0.3 \times 0.9) + (0.4 \times 0.9) + (0.25 \times 0.9) + (0.05 \times 0.55) = 0.8825$

$SFM_{Rochester} = (0.3 \times 0.7) + (0.4 \times 0.65) + (0.25 \times 0.4) + (0.05 \times 0.8) = 0.61$

$$LM_i = CFM_i\left[\alpha\left(1 - OFM_j\right) + \left(1-\alpha\right)SFM_i\right]$$

$$LM_{Albany} = CFM_{Alb}\left[\alpha\left(1 - OFM_{Alb}\right) + \left(1-\alpha\right)SFM_{Alb}\right]$$
$$= 0\left[0.4\left(1-0\right) + \left(1-0.4\right)0.695\right] = 0$$

$$LM_{Kingston} = CFM_{King}\left[\alpha\left(1 - OFM_{King}\right) + \left(1-\alpha\right)SFM_{King}\right]$$
$$= 1\left[0.4\left(1-1\right) + \left(1-0.4\right)0.6725\right] = 0.4035$$

$$LM_{Montreal} = CFM_{Mont}\left[\alpha\left(1 - OFM_{Mont}\right) + \left(1-\alpha\right)SFM_{Mont}\right]$$
$$= 1\left[0.4\left(1-0.467\right) + \left(1-0.4\right)0.53\right] = 0.5312$$

$$LM_{Otatwa} = CFM_{Ottw}\left[\alpha\left(1 - OFM_{Ottw}\right) + \left(1-\alpha\right)SFM_{Ottw}\right]$$
$$= 0\left[0.4\left(1-0.167\right) + \left(1-0.4\right)0.45\right] = 0$$

$$LM_{Plattsburgh} = CFM_{pla}\left[\alpha\left(1 - OFM_{Pla}\right) + \left(1-\alpha\right)SFM_{Pla}\right]$$
$$= 1\left[0.4\left(1-0.633\right) + \left(1-0.4\right)0.8825\right] = 0.6763$$

$$LM_{Rochester} = CFM_{Roc}\left[\alpha\left(1 - OFM_{Roc}\right) + \left(1-\alpha\right)SFM_{Roc}\right]$$
$$= 1\left[0.4\left(1-0.517\right) + \left(1-0.4\right)0.61\right] = 0.5592$$

LM_{Albany} = 0
$LM_{Kingston}$ = 0.4035
$LM_{Montrela}$ = 0.5312
LM_{Ottawa} = 0
$LM_{Plattsburgh}$ = 0.6763 ← Highest!!!
$LM_{Rochester}$ = 0.5592

Therefore; based on an α value of 0.4, the Plattsburgh location seems favorable. However, as the weight of the objective factors, α, increases more than 0.6, the Montreal location becomes attractive.

Assignment: Show how Montreal location will be attractive with (α = 0.7).

2.5. Techniques for Continuous Space Location Problems

Continuous space location models determine the optimal location of one or more facilities on a two-dimensional plane. The obvious disadvantage is that the optimal location suggested by the model may not be a feasible one—for example, it may be in the middle of a water body, a river, lake, or sea. Or the optimal location may be in a community that prohibits such a facility. Despite this drawback, these models are very useful because they lend themselves to easy solution. Furthermore, if the optimal location is infeasible, techniques that find the nearest feasible and optimal locations are available.

The most important and widely used distance metrics:

- **Euclidean distance** is the "ordinary" distance between two points that one would measure with a ruler, and is given by the Pythagorean formula.

  The *Euclidean distance* between points **p** and **q** is the length of the line segment $\overline{\mathbf{pq}}$. In Cartesian coordinates, if $\mathbf{p} = (p_1, p_2, p_n)$ and $\mathbf{q} = (q_1, q_2 ... q_n)$ are two points in Euclidean n-space, then the distance from **p** to **q** is given by:

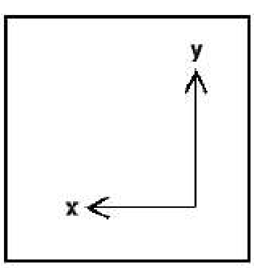
$$\mathrm{d}(\mathbf{p},\mathbf{q}) = \sqrt{(p_1-q_1)^2 + (p_2-q_2)^2 + \cdots + (p_n-q_n)^2} = \sqrt{\sum_{i=1}^{n}(p_i-q_i)^2}.$$

- **Squared Euclidean distance** uses the same equation as the Euclidean distance metric, but does not take the square root. As a result, clustering with the Euclidean Squared distance metric is faster than clustering with the regular Euclidean distance.

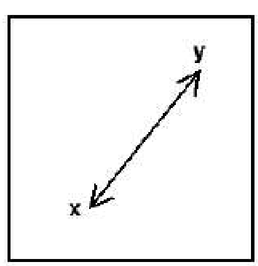
- **Rectilinear distance** is known as city block distance or Manhattan distance as well. The distance, d_1, between two vectors $\mathbf{p}, \mathbf{q}$ in an n-dimensional real vector space with fixed Cartesian coordinate system, is the sum of the lengths of the projections of the line segment between the points onto the coordinate axes. More formally,

$$d_1(\mathbf{p},\mathbf{q}) = \|\mathbf{p}-\mathbf{q}\|_1 = \sum_{i=1}^{n}|p_i-q_i|,$$

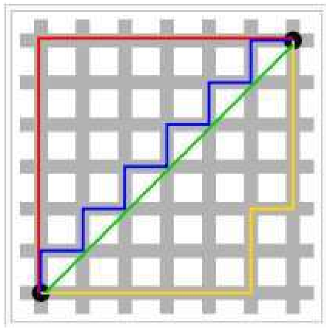
  where $\mathbf{p} = (p_1, p_2, \ldots, p_n)$ and $\mathbf{q} = (q_1, q_2, \ldots, q_n)$ are vectors.



Manhattan



Euclidean



Taxicab geometry versus Euclidean distance: The red, blue, and yellow lines have the same length (12) in Manhattan geometry for the same route. In Euclidean geometry, the green line has length $6\times\sqrt{2} \approx 8.48$, and is the unique shortest path.

Single-facility location models, each incorporating a different distance metric, along with the solution methods or algorithms for these models will be introduced in this section. Because the optimal solution for a continuous space model may be infeasible, where available, we also discuss techniques that enable us to find feasible and optimal locations.

Techniques for Continuous Space Location Problem:

4. Median Method
5. Contour Line Method
6. Gravity Method
7. Weiszfeld Method

2.5.1. Median Method

As the name implies, the median method finds the median location and assigns the new facility to it. This method is used for single-facility location problems with rectilinear distance. Consider m facilities in a distribution network. Due to market-place reasons (e.g., increased customer demand), it is desired to add another facility to this network. The interaction between the new facility and existing ones is known. The problem is to locate the new facility to minimize the total interaction cost between each existing facility and the new one.

At the macro level, this problem arises, for example, when deciding where to locate a warehouse that is to receive goods from several plants with known locations. At the micro level, this problem arises when we have to add a new machine to an existing network of machines on the factory floor. Because the routing and volume of parts processed on the shop floor are known, the interaction (in number of trips) between the new machine and existing ones can beeasily calculated. Other non-manufacturing applications of this model are given in Francis, McGinnis, and White (1992).

Consider this notation:

- **c_i** cost of transportation between existing facility i and new facility, per unit
- **f_i** traffic flow between existing facility i and new facility
- **$x_i y_i$** coordinates of existing facility i

The median location model is then to:

$$\text{Minimize } TC = \sum_{i=1}^{m} c_i f_i \left[\left| x_i - \bar{x} \right| + \left| y_i - \bar{y} \right| \right] \qquad (1)$$