

Studies on the Optimal Location of Retail Store Considering the Obstacle and the Obstacle-Overcoming Point

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Abstract. Studies on the optimal location of retail store have been made in case of no obstacle (Minagawa *et al.* 1999). This paper deals with the location problem of retail store considering obstacles (e.g. rivers, railways, highways, etc.) and obstacle-overcoming points (e.g. bridges, railway crossings, zebra crossings, overpasses, etc.). We assume that (1) commercial goods dealt here are typically convenience goods, (2) the population is granted as potential demand, (3) the apparent demand is a function of the maximum migration length and the distance from the store to customers, (4) the scale of a store is same in every place and (5) there is no competitor. First, we construct the basic model of customers' behavior considering obstacles and obstacle-overcoming points. Analyzing the two dimensional model, the arbitrary force attracting customers is represented as a height of a cone where the retail store is located on the center. Second, we formulate the total demand of customers and determine the optimal location that maximizes the total demand. Finally, the properties of the optimal location are investigated by simulation.

Keywords: location problem, obstacle, obstacle-overcoming point, optimization, maximum migration length, retail store

1. INTRODUCTION

In this study, we reveal the location problem of retail stores. Many studies of the location problem are based on "Laws on the retail gravitation" which is proposed by Reilly and Converse (1949). This theory is expanded by Huff (1964) and Nakanishi and Cooper (1974). Many application studies which were based on these models were discussed by many researchers (Craig *et al.* 1984, Drezner 1994, Avella *et al.* 1998). But, these studies concern the measurement of the suction force.

We have been studying about basic laws of the optimal location of commerce by constructing a model and calculating (Minagawa *et al.* 1999). This paper deals with the location problem of retail store considering

obstacles and obstacle-overcoming points. Obstacles mean rivers, railways, highways, etc. And obstacle-overcoming points mean bridges, railway crossings, zebra crossings, overpasses, etc.

2. MODELING OUR PROBLEM

In this study, we assume that the only one obstacle exists in the planning area, and the only one obstacle-overcoming point exists. The optimal location, where the total volume of demand is maximized, is determined under the condition that the only one convenience store starts its business in the planning area.

We perform the sensitivity analysis and discuss about properties of the optimal point of location.

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2.1 Prerequisites

Some prerequisites are defined as follows:

- (1) Commercial goods dealt here are typically convenience goods.
- (2) The population is granted as the potential demand.
- (3) The apparent demand is a function of the maximum migration length and the distance from the store to customers.
- (4) The scale of a store is same in every place.
- (5) There is no competitor.

2.2 Symbols

The symbols used in this study are as follows

m, n :the length of planning area ($m \leq n$)

(k, l) :the point of launching the new store

(s, t) :the point of obstacle-overcoming

$P(i, j)$:the population at the point (i, j)

$$P(i, j) = \begin{cases} P & \text{if } 0 \leq i \leq m \text{ and } 0 \leq j \leq n \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

g :the migration length which customer moved from the point (i, j) to the point (k, l) to buy the commercial goods (Euclidean distance)

$$g = \sqrt{(k-i)^2 + (l-j)^2} \quad (2)$$

$f(i, j, k, l, h)$:The suction force of distance at the point (i, j) when located a new store at the point (k, l) in the maximum migration length h .

$$f(i, j, k, l, h) = \begin{cases} 1 - g/h & \text{if } 0 \leq g < h \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

where,

h :maximum migration length of major goods of the store

The maximum migration length means the maximum distance in which the customer moves to buy the goods. We regard the area where the distance to the store is less than maximum migration length h as the trade area.

3. 1 OBSTACLE AND 1 OBSTACLE-OVERCOMING POINT MODEL

In this chapter, we deal with the model of 1 obstacle and 1 obstacle-overcoming point (cf. Figure 1).

We call the separated planning area by an obstacle,

the planning area 1 and the planning area 2.

In this situation, first we formulate the suction force of the distance considering 1 obstacle and 1 obstacle-overcoming point. Second, we formulate the total volume of demand using the suction force. Third, we calculate the optimal location that maximized the total demand by simulation. Finally, we discuss properties of the optimal location.

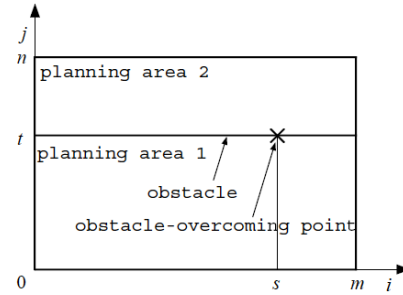


Figure 1. Model of 1 obstacle and 1 obstacle-overcoming point.

3.1 Formulating the suction force of the distance

We assume the new store is launched at the point (k, l) in the planning area 1. Typically, the area that the distance to the store is less than maximum migration length h are inside the circle with a radius of h with the center (k, l) and the trade area of the new store.

This thinking is acceptable in the customers who live in the planning area 1. But, this thinking is unacceptable in the customers who live in the planning area 2. Because, customers in the planning area 2 must pass the obstacle-overcoming point (s, t) to go to the new store. Thus, we can't regard the suction force as a simplified cone.

Then, the suction force of the distance is formulated as follows.

First, the obstacle doesn't influence customers who live in the planning area 1. Therefore, the suction force of the distance is given by the Eq. (3).

Second, the obstacle influences customers who live in the planning area 2. Therefore, the suction force of the distance in the planning area 2 must be considered the obstacle-overcoming point.

Result of consideration, the suction force of the distance is as follows:

$$g_1 = g_{11} + g_{12} \quad (4)$$

where,

$$f(i, j, k, l, s, t, h) = \begin{cases} 1 - g_1/h & \text{if } 0 \leq g_1 < h \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

g_{11} :the distance from the point (s,t) to the point (k,l) (cf. Figure 2)

$$g_{11} = \sqrt{(k-s)^2 + (l-t)^2} \quad (6)$$

g_{12} :the distance from the point (i,j) to the point (s,t)

$$g_{12} = \sqrt{(s-i)^2 + (t-j)^2} \quad (7)$$

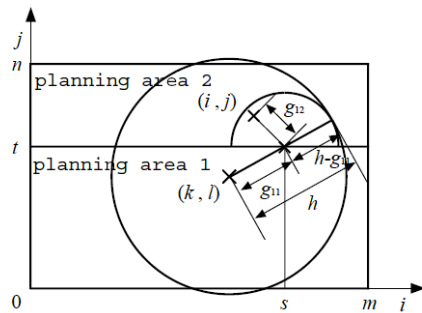


Figure 2. Model of suction force of the distance(1 obstacle and 1 obstacle-overcoming point)

3.2 Formulating the total demand

We formulate the total demand of the new store launching at the point (k,l) . First, the demand D_1 at the point (i,j) in the planning area 1 is given by the product of the population $P(i,j)$ and the suction force $f(i,j,k,l,h)$.

$$D_1 = P(i, j) f(i, j, k, l, h) \quad (8)$$

Second, the demand D_2 at the point (i,j) in the planning area 2 is determined by the product of the population $P(i,j)$ and the suction force $f(i,j,k,l,s,t,h)$.

$$D_2 = P(i, j) f(i, j, k, l, s, t, h) \quad (9)$$

Finally, the total demand D is determined as follows:

$$D = \int_0^i \int_0^m D_1 didj + \int_0^i \int_0^m D_2 didj \quad (10)$$

The optimal location is obtained as the maximum of the total demand D of the new store in Eq. (10).

3.3 The simulation of the optimal location

We perform the simulation of the optimal location by using Eq. (10). To start the simulation, we define some conditions as follows:

- (1) The planning area is 100 times 80 units. Now, 1 unit is shown 10m times 10m.

- (2) The population of the planning area is 1 person/100m².
- (3) The obstacle exists at $j=60$ and $i=0 \sim 100$ units.
- (4) The obstacle-overcoming point exists at the point (60,60) units.
- (5) The maximum migration length is 1,000m.

Under these conditions, we perform simulation by computer. Then, we regard the maximum migration length h and the obstacle-overcoming point (s,t) as variables. The maximum migration length changes from 40 to 180 units and the obstacle-overcoming point changes from 50 to 100 units. The result of simulation is shown in Table 1.

4. DISCUSSION

After the simulation in this case, we have extracted several properties about the optimal location.

Property 1: The optimal location (k^*,l^*) moves to the obstacle-overcoming point (s,t) by increasing the maximum migration length h with a certain obstacle-overcoming point (s,t) . But, the optimal location isn't at the obstacle-overcoming point (s,t) and converges on a certain point.(cf. Figure 3)

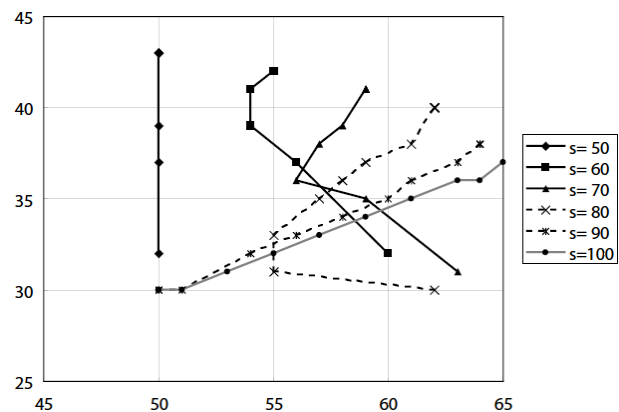


Figure 3. Effect of the maximum migration length h on the optimal location

Property 2: Closing the obstacle-overcoming point (s,t) to the terminal point (m,t) , the optimal location (k^*,l^*) moves to the obstacle-overcoming point (s,t) . More closing the obstacle-overcoming point (s,t) to the terminal point (m,t) , the optimal location (k^*,l^*) moves to the point of center in the planning area 1.(cf. Figure 4)

Property 3: When the maximum migration length h is small and the obstacle-overcoming point (s,t) is close at the terminal point (m,t) , we can get the optimal location (k^*,l^*) at the point of center in the planning area 1.

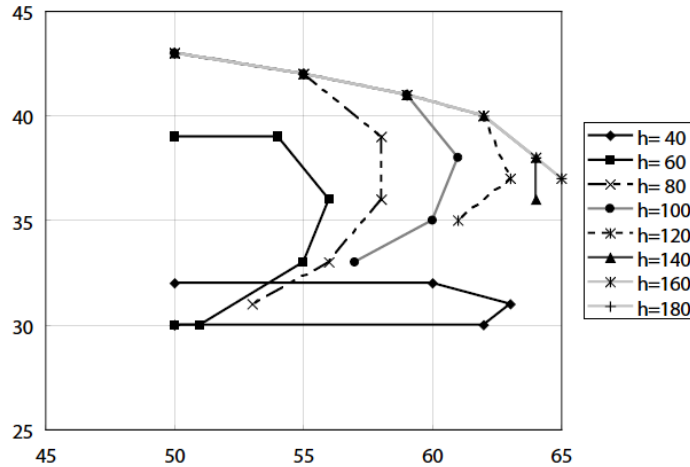


Figure 4. Effect of the obstacle-overcoming point (s,t) on the optimal location

Table 1. The result of simulation

h	s = 50		s = 60		s = 70		s = 80		s = 90		s = 100	
	D	(k*,l*)	D	(k*,l*)	D	(k*,l*)	D	(k*,l*)	D	(k*,l*)	D	(k*,l*)
40	1618.45	(50,32)	1618.45	(60,32)	1604.79	(39,30)	1605.82	(62,30)	1604.79	(39,30)	1604.79	(39,30) ¹
50	2394.57	(50,37)	2380.69	(56,37)	2276.77	(49,29)	2285.15	(55,31)	2276.77	(49,29)	2276.77	(49,29) ²
60	3177.16	(50,39)	3143.22	(54,39)	2897.01	(51,30)	2953.05	(55,33)	2897.01	(51,30)	2887.97	(50,30)
70	3842.00	(50,43)	3791.35	(54,41)	3408.82	(54,32)	3529.72	(57,35)	3408.82	(54,32)	3347.63	(51,30)
80	4371.71	(50,43)	4312.41	(55,42)	3837.20	(56,33)	3996.29	(58,36)	3837.20	(56,33)	3721.40	(53,31)
90	4783.74	(50,43)	4730.92	(55,42)	4198.90	(58,34)	4386.27	(59,37)	4198.90	(58,34)	4046.01	(55,32)
100	5113.37	(50,43)	5065.83	(55,42)	4512.87	(60,35)	4722.40	(61,38)	4512.87	(60,35)	4331.53	(57,33)
110	5383.06	(50,43)	5339.85	(55,42)	4792.14	(61,36)	5019.26	(62,40)	4792.14	(61,36)	4587.71	(59,34)
120	5607.81	(50,43)	5568.19	(55,42)	5044.94	(63,37)	5274.32	(62,40)	5044.94	(63,37)	4821.60	(61,35)
130	5797.98	(50,43)	5761.41	(55,42)	5275.72	(64,38)	5490.14	(62,40)	5275.72	(64,38)	5038.22	(63,36)
140	5960.98	(50,43)	5927.02	(55,42)	5476.03	(64,38)	5675.13	(62,40)	5476.03	(64,38)	5241.21	(64,36)
150	6102.25	(50,43)	6070.55	(55,42)	5649.62	(64,38)	5835.46	(62,40)	5649.62	(64,38)	5429.80	(65,37)
160	6225.86	(50,43)	6196.14	(55,42)	5801.52	(64,38)	5975.74	(62,40)	5801.52	(64,38)	5595.44	(65,37)
170	6334.92	(50,43)	6306.96	(55,42)	5935.55	(64,38)	6099.52	(62,40)	5935.55	(64,38)	5741.59	(65,37)
180	6431.87	(50,43)	6405.46	(55,42)	6054.69	(64,38)	6209.55	(62,40)	6054.69	(64,38)	5871.50	(65,37)

¹In this case, the point of from (39,29) to (61,29) and from (39,30) to (61,30) are the optimal location, too.

²In this case, the point of from (49,29) to (51,29) and from (49,30) to (51,30) are the optimal location, too.

5. CONCLUSION

The results of this study in case of 1 obstacle and 1 obstacle-overcoming point are as follows:

- (1) Apparent demands in the separated areas are given in Eq. (8) and (9).
- (2) Total demand D is given in Eq. (10).
- (3) The point of the optimal location (k^*,l^*) moves according to the change of the maximum migration length h and the obstacle-overcoming point (s,t) , by

the simulation.

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