Business service production responsive to the spatially dispersed stochastic demands
-- Optimal Stock Location Model Approach --

Makoto Okumura * and Makoto Tsukai **

* Professor, Center for Northeast Asian Studies, Tohoku University (41 Kawauchi, Aoba-ku, Sendai, 980-8576, Japan) mokmr@cneas.tohoku.ac.jp
** Associate Professor, Department of Civil and Environmental Engineering, Hiroshima University (1-4-1 Kagamiyama, Higashi-Hiroshima, 739-8527, Japan) mtukai @hiroshima-u.ac.jp

Abstract
Business service sector has become a focal point of urban industrial agglomeration, because now, it occupies largest proportion of urban jobs and it's existence is critical for additional industry locations of most other sectors. That sector includes knowledge-based special service as law, tax, and other kinds of special consultancies, who does not use much of space or heavy transportation, then it seems be benefited from ICT development and be very much foot-loose. However, empirical studies on the location pattern of business service sector up to now often relies on the historical regression on population distributions or on the description of famous but not be proved as typical case; we cannot get enough insights about how its location will be changed under the further ICT development or other kind of Environmental changes from these empirical approach.
This paper focuses on the point that most business service is very labor intensive, but it cannot autonomously decide the labor usage schedule independent from the uncertain demands. In order to respond to the spatially dispersed stochastic demands, the business service company must prepare several stocks of employments larger than the expected average demands. Because larger stocks can more effectively covers the stock-out risk, increasing return appears for stock location decision, that is suggested as the strong agglomeration power for the business service sector.
This paper applies an optimal stock location model to analyze the employment allocation pattern of a representative business service firm. It may consider the risk of delayed response to the requests from the customers. The model can tell how the business environment changes such as ICT developments and transportation service improvements affect on the business service sector locations, based on case study in Japanese system of cities.

Keywords: business service, knowledge-based production, industry location, stochastic demand, optimal stock location.

Acknowledgements: We thank for the statistical and calculation work done by Mr. Naoki Takada, a graduate student of Tohoku University. This work is one of the outputs of the joint research projects of CNEAS, Tohoku University, supported by the grant-in-aid for scientific research (b) by the JSPS.

1.**Introduction**

Business service as a focal industry

In many developed countries in the world, growth of labor share of the tertiary industry are observed, reflecting the trend of industriazation of service or soft works. Corresponding to this industriazation trend, many firms have considering the out-sourcing of the soft or service works, because out-sourcing is now rational strategy because of the following two points: *specialty* and *scale economy*. The first point, *specialty* means that the outsourced workers can be more concentrated on the specialized work than in-house workers who must engage several types of the work in his/her career in the firm. They can get deeper experience and more specialized knowledge than in-house generalists. The second point, *scale economy*, comes out in the shorter time range; the out-sourced workers can get more number of work from also the outside of the firm. Development of ICT made it easy for firms and governmental agencies, to exchange information or knowledge with the out-sourced workers, and resulted in the remarkable development of information-related business service firms.

Business service industry is sometimes very labor intensive. A firm must prepare enough number of specialists in order to provide a good quality service to the customers, but such labor cannot be maintained in small city with scarce demand. Therefore, the size of city seems an essential condition of location of the business service industry. Moreover, large size city with larger number of business service firms can afford more suitable service for customer firms, then gathers new locations. Positive feedback loop through business service industry is there for the customer firm's location, and then mutually related firms are easy to be concentrated to small number of large cities. Recent empirical studies concerning on the location decision of manufacturing firms show the importance of business service industries near-by, then business service sector has become a focal point of urban industrial agglomeration.

Comparing to the dense history of empirical works concerning on the business service firms and other industries, theoretical considerations on location mechanism of the business service industries are not enough, in order to prospect the future location of the sector in the era of fast ICT developments.

Simultaneity of production and consumption is one of the most unique characteristics of service industry. In machine repair business, for example, the repair service cannot be prepared before the point of service order from the customer who meets the malfunction or brake down of the machine. They cannot reserve the repair service as same as the stock of manufactured products. It is also difficult to change the number of the repair engineers adjusted to the changed number of orders. Alternately, they must prepare the larger numbers of the engineers than the average demand.

The business service firm must locate their staff providing the service to respond to the stochastic orders (demand) from the spatially dispersed customers. In order to suppress the location and employment cost, the firm wants to reduce the number of workers, but shortage of workforce results excessive hour works to execute the ordered works and additional cost of operation.

We consider that the firm's location problem is similar to the products stock location problem of a merchandize firm. This paper applies an optimal stock location model to analyze the employment allocation pattern of a representative business service firm. It may consider the risk of delayed response to the requests from the customers. The model can tell how the business environment changes such as ICT developments and transportation service improvements affect on the business service sector locations, based on case study in Japanese system of cities.

Related studies

In many developed countries, out-sourcing in manufacturing sector became popular in late 1980's (Coffey and Bailly 1992) and business service industry began to gather attentions of the student of regional economics. Saxenian (1994) proved the importance of business service supporting firms for the location of computer manufacturers and electronic communication devices, based on the questionnaire surveys to the firms in the Silicon Valley or the Route 128 area around Boston. The effect of business service existence on the successive location of other sectors was statistically proved, and therefore, business service industry became the focal point of urban industrial agglomeration. Esparza and Kramence (1996) conducted a survey to the business service firms around Chicago and proved that the amount of works exponentially decreases along the increase of distance from the customer firms. Both O'hUallacain and Reid (1991), and Bennett and Graham (1998) statistically proved that the location of business service industry is strongly affected by city population size, due to the strong effects of accessibility to the customer firms.

Comparing to the macro-scopic empirical analyses like above, micro-scope researches focusing on individual business service firm are not many up to now. Phillips et al.(1998) analyzed the optimal size of a firm and number of customers, considering that works of the firm are stochastically ordered by the customer firms, but they excluded spatial dimension from the considerations.

As logistical applications of Operations Research theory, several number of studies are there investigating the distribution center locations (Hansen et al. 1987, Daskin1995). Japanese distribution systems were also studies by Kawabata (1995), Ishiguro et al.(1998), and so on, but most of them exclude the decision of stock size from considerations. Nozick and Turnquist (1998) connected the optimal stock size decision (as Phillips et al. 1998) with the standard fixed-cost un-capacitated facility location model (Erlenkotter 1978). Following to Masters (1993) and Diks et al.(1996), Nozick and Turnquist (2001) modeled the multi-strata distribution system where each stratum have stocks. The present authors improved the model of Nozick and Turnquist (2001) by introducing the spatially different location cost, and applied it to Japanese distribution center locations (Okumura and Tsukai 2003). That model showed the coexistence of the distribution centers without safety stocks covering expensive large cities having dense demand and the centers with safety stocks at less expensive cities; such coexistence were not observed by the former model (Tsukai and Okumura 2001).

2. Model formulation

Assumptions

We consider a representative firm in business service industry, where simultaneity of demand and supply, or production and consumption are required. Hereto after, we explain the assumptions of the model using the case of typical industry of this category:

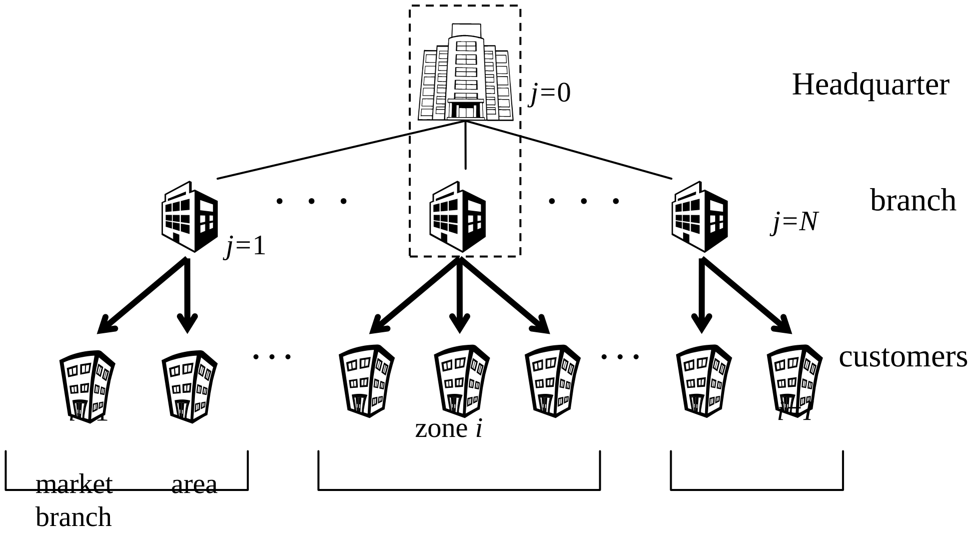

Figure 1 Two echelon structure of a representative firm

machine repair service.

(1) This firm provides repair service to the all customers spatially distributed over the country as figure 1..
(2) This firm is composed by two strata; one headquarter office, and N branch offices. All geographical areas in the country ($i = 1, \cdots, I$) is divided into N market areas, corresponding the locations of the branch offices.
(3) Once a customer make an order of machine repair service in each market area, the respective branch office dispatches one engineer to the customer place for a given days. The orders occurs randomly and independently. Any repair works at one market area can be exclusively executed by the engineers employed at the respective branch office.
(4) The firm dispatch the headquarter staff to each branch office for the purpose of internal education, training and so on. Number of such trips is relative to the number of engineers employed at each branch office.
(5) Location and cost of headquarter office is exogenously given. We consider the given setup cost for one branch office irrespective for the location, and spatially different employment cost at branch office relative to the numbers of engineers.

In reality, orders from the customers near the headquarter office are sometimes covered directly by the headquarter workers, violating the assumption (3). In this model, such customer section in the headquarter office is considered as a branch office whose location is happen to be same as the headquarter, and satisfies the assumption.

In the following formulation, $j = 1, \cdots, N$ denotes one branch office and responsive market area. The demand rate of the branch, described as the average number of orders Λ_j is given by the summation of the zonal demand rate λ_i, weighted with the share variable Y_{ij} .

$$\Lambda_j = \sum_{i=1}^{I} Y_{ij} \lambda_i \qquad (1)$$

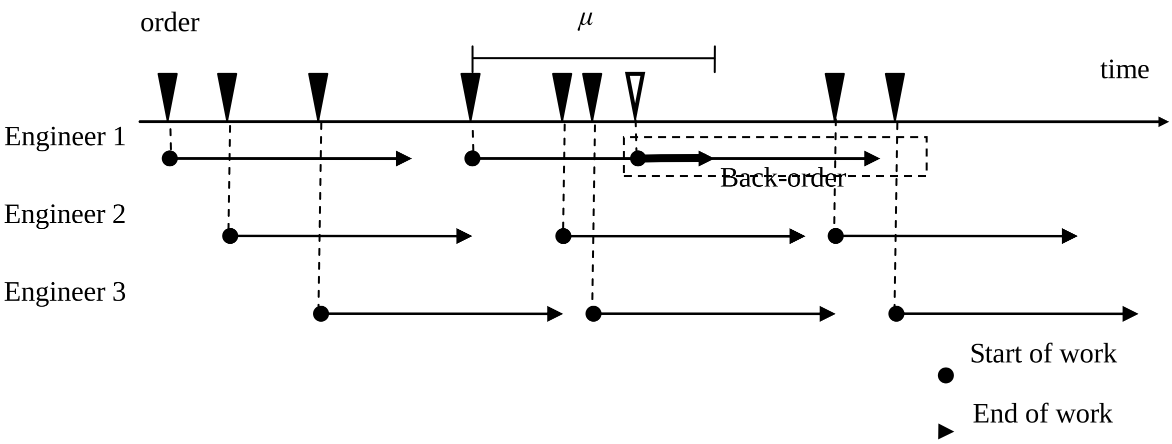

Figure 2　Timing of the work under stochastic orders

Responding to the assumption (3), all orders at each market area must be resolved. This condition is formulated with the following restriction.

$$\sum_{j=1}^{N} Y_{ij} = 1 \qquad \forall i \qquad (2)$$

Stochastic demand and a back-order

If all orders were happen deterministically, allocation of the exact number of engineers same as the average number of orders in each branch office would become the optimal solution, minimizing the employment cost. However, we must consider the stochastic happenings of orders, as noted in assumption (3), where, there are concentrated orders in short time range and those orders exceed the capacity of the average number engineers. Because the employment of workers are not flexible, the firm must hire the larger number of engineers in the stochastic case than that in the deterministic case.

As shown in figure 2, one order requires a work of given day of one engineer. Each engineer cannot respond to the orders more than two. The required work days is described by μ. Within the duration of μ, if orders arrives more than the number of the engineers of the branch s_j, the branch cannot dispatch an engineers to the order. We call this situation as back-order. In case of back-order, the firm promises to finish the latest order in the given duration μ after the timing of the order, although no engineer can begin the work. In order to finish the work in time, extended hour work is required and resulted in additional payment for it. In other words, a back-order gives additional cost α, which is called as penalty cost, hereafter.

The probability of back-order happening is calculated as the probability that no less than s_j orders are additionally arrived at the branch j, during the duration μ. According to the independent random arrival of orders in assumption (3), the numbers of arrived order within a given time follows a stationary Poisson distribution. The back-ordering probability $r_j(s_j)$ can be written as equation (3).

$$r_j(s_j) = \sum_{m_j=s_j}^{\infty} \frac{\exp(-\Lambda_j \mu) \cdot (\Lambda_j \mu)^{m_j}}{m_j!} \qquad (3)$$

When the market area becomes large, average travel time from the branch office to the customer becomes longer, they cannot begin the following work also during the round trip time t_{ij}. Then in our model, we use the occupied duration μ'_j instead of the fixed duration μ in equation (3).

$$\mu'_j = \mu + t_j \qquad (4)$$

where, t_j is the average round trip time within the market area as follows.

$$t_j = \frac{\sum_{i=1}^{I} Y_{ij} t_{ij}}{\sum_{i=1}^{I} Y_{ij}} \qquad (5)$$

If the number of engineers s_j is smaller than the required work force for the average orders $\Lambda_j \mu'_j$, the back order is easily accumulated and bankruptcy occurs with large probability. No bankruptcy condition is given as following.

$$s_j \geq \Lambda_j \mu'_j \qquad \forall j \qquad (6)$$

Employment decision sub-problem

We consider a problem to decide the number of engineers in each branch office, after the locations of branch offices and respective market areas were given. The expected penalty of back-orders is given as the multiplication of the penalty cost α, average demand rate Λ_j, and back-order probability $r_j(s_j)$, which is a decreasing function of the number of engineers there, s_j.

On the other hand, both employment cost and floor space cost are expected to be an increasing function of the employment. For the simplicity, we formulate them as a linear function using unit salary h_j and unit floor rent p_j. As a result, we can formalize the cost minimization problem as equation (7), with the constraint of inequality (6).

$$\min_{s_j} C_S = \alpha \sum_{j=1}^{N} \Lambda_j r_j(s_j) + \sum_{j=1}^{N} (h_j + p_j) s_j \qquad (7)$$

This objective function seems smooth for s_j, we can expect to get an unique solution.

Branch office location sub-problem

Next, we consider the problem to find the inexpensive location of branch office and respective market area division. Total cost is composed by the three parts; location cost, branch office engineers trip cost, and headquarter staff's trip cost. The first location cost C_1 is summation of fixed set-up cost f and employment and floor cost relative to the branch office size, as follows.

$$C_1 = f + (h_j + p_j) s_j \qquad (8)$$

Secondly, we estimate the travel cost of the branch office engineers to the customer place

C_2, based on that estimated number of trips between branch office j and customer area i in unit duration, say one day becomes $\lambda_i Y_{ij}$. We multiply it with d_{ij}, the unit travel cost of one round trip between i and j.

$$C_2 = \sum_{i=1}^{I} \sum_{j=1}^{N} \lambda_i Y_{ij} d_{ij} \qquad (9)$$

Thirdly, we consider the cost of trips between the headquarter and each branch office as assumed by the assumption (4). Normalized frequency of head-branch trips per one branch office worker is given as a constant ℓ and a 0-1 dummy variable indicates the existence of branch office at location j is given as X_j, the headquarter-branch trip cost is given as equation (10).

$$C_3 = \ell \sum_{j=1}^{N} d_{j0} s_j X_j \qquad (10)$$

Now, we can formulate an incapacitated facility location problem having the constraint of the consistency, that is, when share $Y_{ij} > 0$, branch office must be surely located at city j, described as $X_j = 1$. That condition can be alternately described with the constraints in the following formula (11).

$$\min_{X_j, Y_{ij}} C_L = C_1 + C_2 + C_3 = \sum_{j=1}^{N} \{ f + (h_j + p_j) s_j \} X_j + \sum_{j=1}^{N} \sum_{i=1}^{I} \lambda_i d_{ij} Y_{ij} + \ell \sum_{j=1}^{N} d_{jo} s_j X_j \qquad (11)$$

$$\textit{subject to} \quad X_j \in \{0,1\} \quad \forall i, \quad \sum_{j=1}^{N} Y_{ij} = 1 \quad \forall j, \quad 0 \le Y_{ij} \le X_j \quad \forall i, j.$$

Under the given number of engineers of branch office, this problem become an mixed integer linear programming problem concerning X_j, Y_{ij}. Its solution is easily obtained by the algorithm of Erlenkotter (1978).

Linkage between the two sub-problems

These two sub-problems are complementary each other; in the employment decision problem, share of the branches Y_{ij} and related demand rate Λ_j through equation (1) are given from the solution of the second sub-problem. On the other hand, the latter facility location sub-problem needs the size of employment s_j at each branch office, given as a solution of the first sub-problem. Iterative calculation of the two sub-problems with communicating the common variables shown as figure 3 gives totally cost minimizing solution. When we solve the facility location problem as formula (11), we must set the expected employment size of branch offices, where no branch office was located in the previous iteration. In that case, we give the same size as the actually allocated branch office, which have positive value of share for the customers in the respective zone.

Application to other type of business service industry

We have been explained the model based on the case of machine repair industry, where the service work begins with traveling to the customer place and execute repairing work there, followed by the returning trip. Total occupied time μ'_j is the summation of actual repair work and the average time for round trip travel, as equation (4).

If total occupied time is similarly given, we do not mind the timing of the trips. For example, in many research or consultancy works, the service worker first meet with a

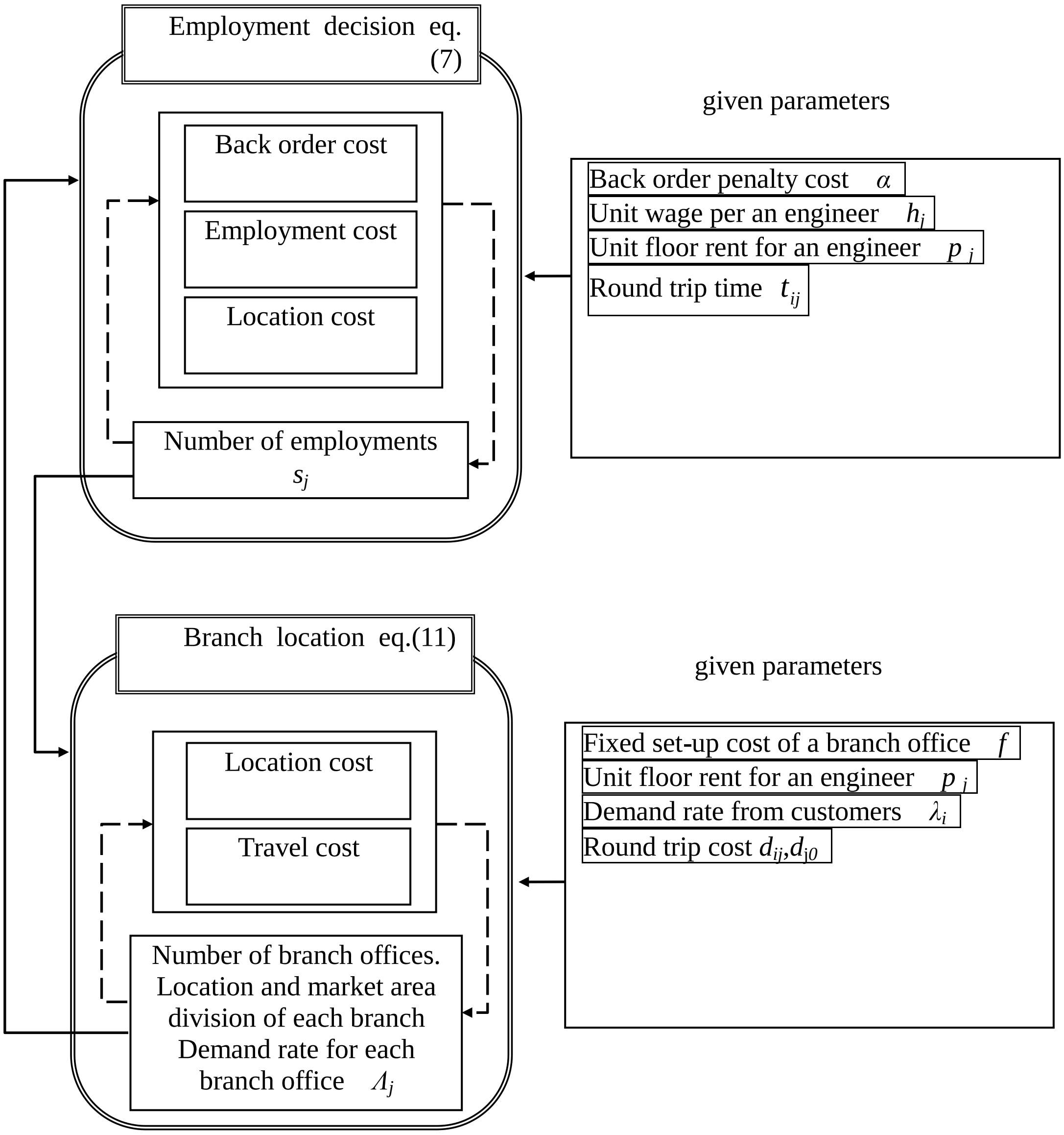

Figure 3 Iterative calculation process of the model

client, understand the client's need, and basic information. They usually execute research work at their own office, not at the client's place. After completing the research work and making the reporting documentations, they travel again to the client and make the final presentation, there. As a result, total occupied time for one work includes actual research time and time for the two round trips. In that case, we consider t_{ij} and d_{ij} as the time and cost for two round trips and apply the same model.

3. Application to Japanese business service industry

Setting of a representative firm and parameters

We consider a representative firm having demand of service for 1,000 engineers during the duration μ, from all over the country of Japan. If these orders would arrive deterministic timing, this firm had required as many as 1,000 engineers in total,

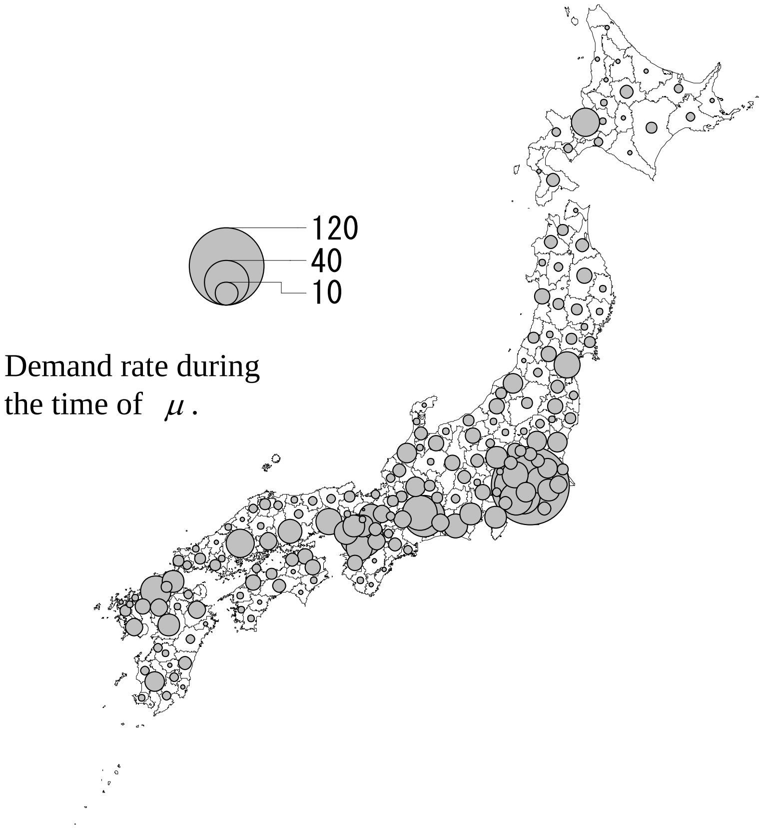

Figure 4 Demand rate in 194 zones during the time length μ

neglecting the travel time. Occurrence of demand (order) from each zone is relative to general size of economic activities, which is described by the total number of employment for all industries in each of 194 zones in year of 2004, as shown as figure 4. Location of the headquarter office is fixed at downtown Tokyo （Tokyo 23 Wards area）. The unit frequency of the trips between the headquarter and branch offices, normalized by the number of branch office engineers is set as $\ell = 0.01$, which means that one round trip of headquarter worker is required for maintaining work of 100 business days by one branch engineer. are set by unit frequency. The back-order penalty is set as $60{,}000\,yen$ in the model.

Each branch office worker use 15.2m^2 of floor space, irrespective to the geographical locations. Land rent is set by the empirical land-rent data at the city, which has largest amount of employments within each zone, as shown in figure 5. With contrast to land rent, we neglect the spatial difference of worker's wage rates, and set the value as 4,578,000 yen/year, irrespective to location. Inter-zonal transportation cost was given from the comparison of generalized cost including time of the railway shortest time route and that of the rail-air shortest time route. Time value of one hour is considered as 3,000 yen.

Empirical employment data

We use the Service Industry Census of Japanese Government in year of 2004, including the number of employments of 10 industrial categories, such as media contents production, advertisement, machine repair, medical service, academic service, waste management, and so on, in each of 47 Prefectures. Combined it with another census data

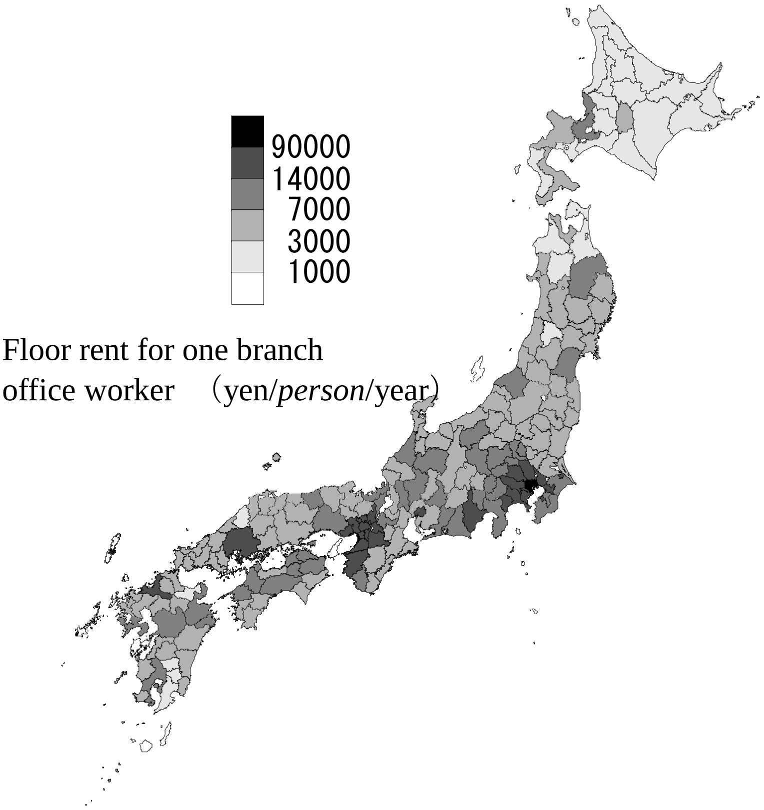

Figure 5 Floor rent for one branch office worker in 194 zones

of Industrial Firms and Settlements in year of 2004 with rough industrial categories but by more detail spatial divisions, we estimated the number of branch office employments of each of the ten service industries in 194 zones of Japan, excluding remote island zones. Through a factor analysis, we can make an order of concentration for those ten industries; media contents production service is the most remarkably concentrated to less number of larger cities like Tokyo, and waste management service distribute most evenly, while machine repair service is in between them. Black bars in figure 6 through figure 8 show the distribution of observed branch office workers of these typical three industries.

Reproduction of employment distribution by the model

Some of the parameters, actually, required time of one work after an order μ, fixed location cost for a branch office f, and travel frequency between the headquarter and a branch office worker ℓ are carefully adjusted, so that the resulted employment pattern reproduce the spatial distribution of branch employments, one of the upper three typical industries.

Strongly concentrated location pattern of the media contents production service is well reproduced as the hollow bars in figure 6, compared with the observed pattern as the black bars, when we set $\mu = 0.5$, $f = 100{,}000$, $\ell = 0.35$. On the other hand, spatially dispersed pattern of waste management service is reproduced when we set longer duration of work: $\mu = 1.5$, cheaper fixed location cost: $f = 2{,}000$, and less frequent interaction between headquarter and branch offices: $\ell = 0.004$, as

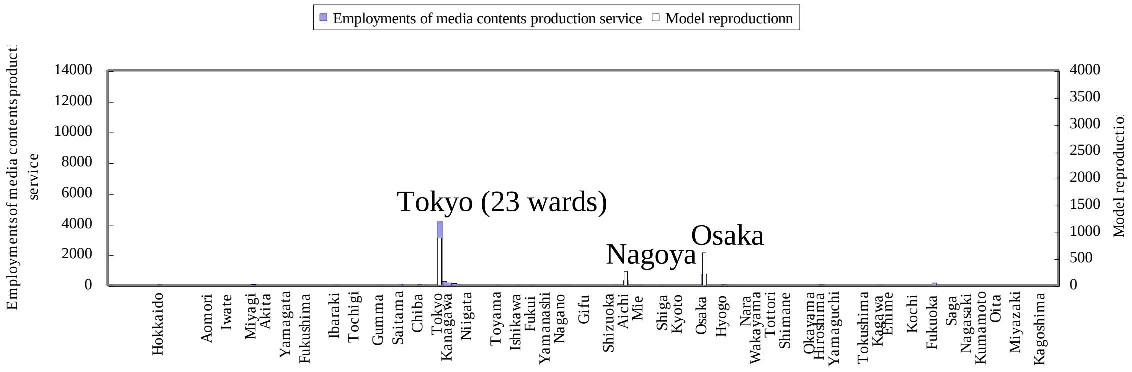

Figure 6　Reproduction of branch office employments of strongly concentrating industry

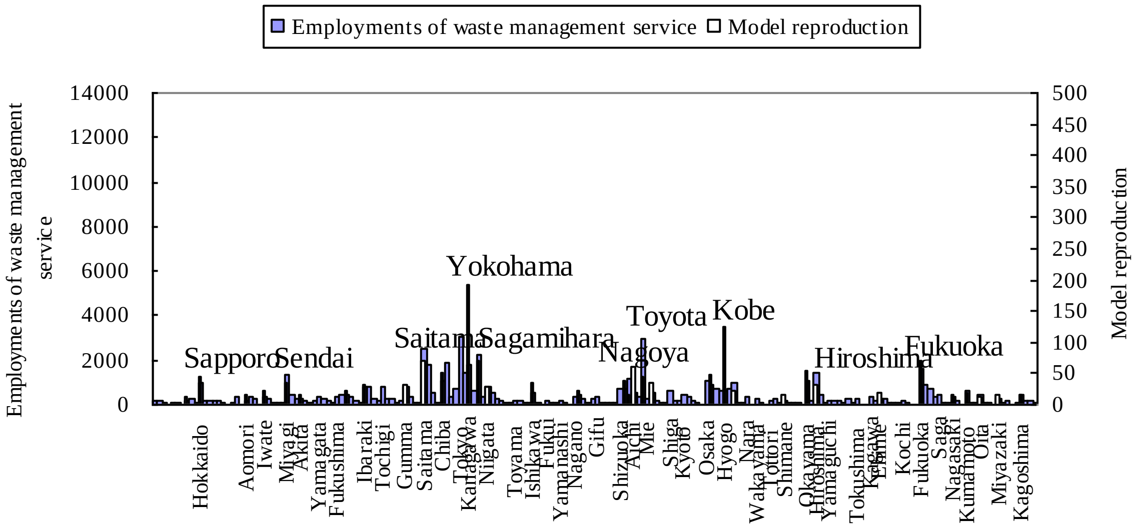

Figure 7　Reproduction of branch office employments of dispersed industry

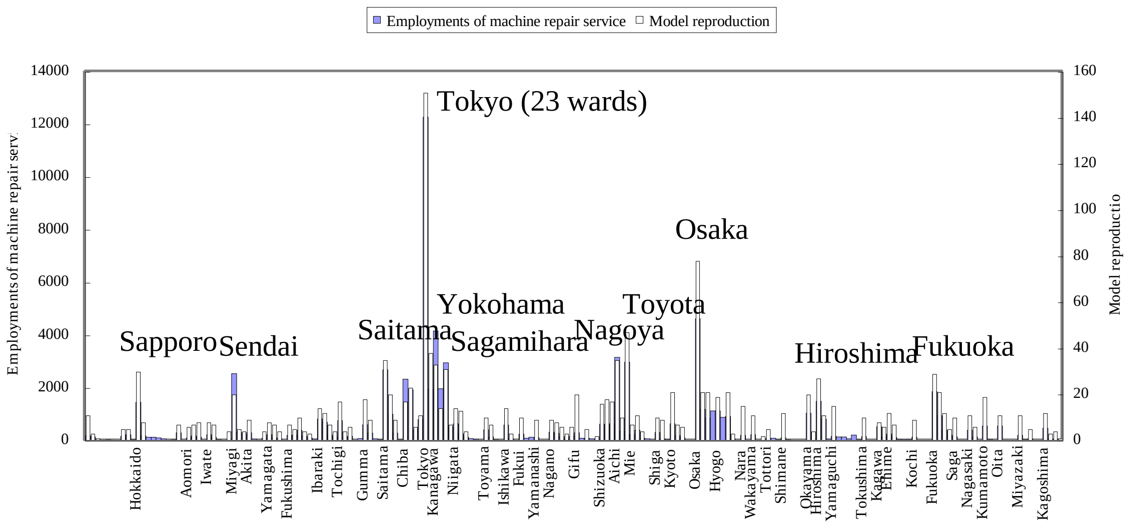

Figure 8　Reproduction of branch office employments of moderately concentrating industry

shown by the hollow bars in figure 7. In that case, several zones around the metropolitan core cities, such as Yokohama, Sagamihara, Toyota and Kobe and other large cities in local area have remarkable employments. The model also reproduces the pattern of medium concentration of machine repair service industry as shown in figure 8, when we set the medium value of the parameters; $\mu = 1.0,\ f = 400,\ \ell = 0.001$.

As shown here, the proposed model can reproduce the overall distribution patterns of different type of service industries by setting different set of parameter values.

4. Simulation to expect the changes in location

Simulation settings

Business service industry is facing the rapid change of business environment, related to the rapid development of ICT technology. In this section, we set shifted values for a parameter corresponding to the expected change due to ICT development.

Case 0 means the benchmark case correspond to the reproduction of the modestly concentrated industry case shown in figure 8; $\mu = 1.0,\ f = 400,\ \ell = 0.001$ and unit floor space per one employment is 15.2m^2.

Case 1 simulate the situation when telecommunication substitutes business contacts between customers and branch office engineers. That change is described in the model through increase of the value of parameter μ, because branch office workers can continuously execute their job without be annoyed from the need of trips to the customer's place. Such situation will be happen especially for the information-based consultancy business, rather than industry such as machine repair. Four different values of parameter were set other than the benchmark case; two of them correspond to the future situation (indexed by "FL" and "FH"), while other two are retrospective (indexed by "OL" and "OH"). Actual values of each setting is shown in table 1.

Table 1 Parameter values for simulations

Settings	Changed Parameter	Old High	Old Low	case0	Future Low	Future High
Case 1 (less need of trips to customers)	Working Duration μ(days)	0.50	0.75	1.00	1.50	2.00
Case 2 (less need of headquarter trips)	Head-Branch Trip Ratio ℓ (times/day/person)	0.020	0.015	0.010	0.0075	0.005
Case 3 (less floor need by tele-working)	Floor space per worker(m^2)	30.4	22.8	15.2	11.4	7.6

Second simulation consider the ICT substitution for trips between headquarter and branch offices. We set two lower values of parameter ℓ in the future, while two larger values in retrospective situations. Actual settings are also shown in table 1.

Third situation affected by ICT is promotion of tele-working, described by the decrease of floor space need in branch office. Settings are shown in table 1.

Output of the simulations

It is not effective for understanding the effects to show the geographical distribution in each simulation. Rather, we show the number of located branch offices and total employments in these offices in table 2, and the rank-size figures concerning on the branch office employment size.

Table 2　Number of located branch offices and total employments

Settings	Old High	Old Low	case0	Future Low	Future High
Case 1 (less need of trips to customers)	155 1734	135 1626	117 1544	79 1400	59 1318
Case 2 (less need of headquarter trips)	106 1535	108 1537	117 1544	119 1544	119 1544
Case 3 (less floor need by tele-working)	95 1494	104 1515	117 1544	118 1551	118 1556

Upper: number of branch offices

Lower: total number of employments in branches

Figure 9 shows the result of case 1 simulations, concerning on the less need of trips to the customer place. Comparing to the previous situation, having milder slope of the rank-size line, decrease the needs of trips to the customers makes the large cities larger and small cities smaller.　The number of branch offices decreases as strong as one third, parallel to the decrease of total employments, as shown in table 2.　If we check the locations of

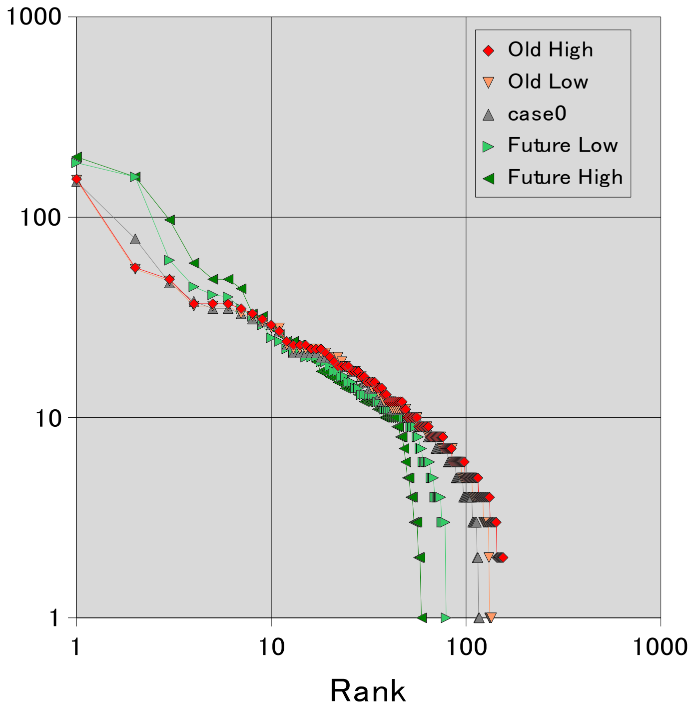

Figure 9 Rank-size relationships of branch office employments in case 1

branch offices in the future, required size of each branch office becomes smaller owing to the less safety margin workers over the average demand, then concentrated location in large metropolitan areas becomes affordable. As a result, the larger city gathers more employments and the small cities lost the branch offices.

Secondly, figure 10 shows the effect of decrease in headquarter-branch office trips. Both Table 2 and figure 10 show that no remarkable changes will occur in branch office locations, either in the size of employment.

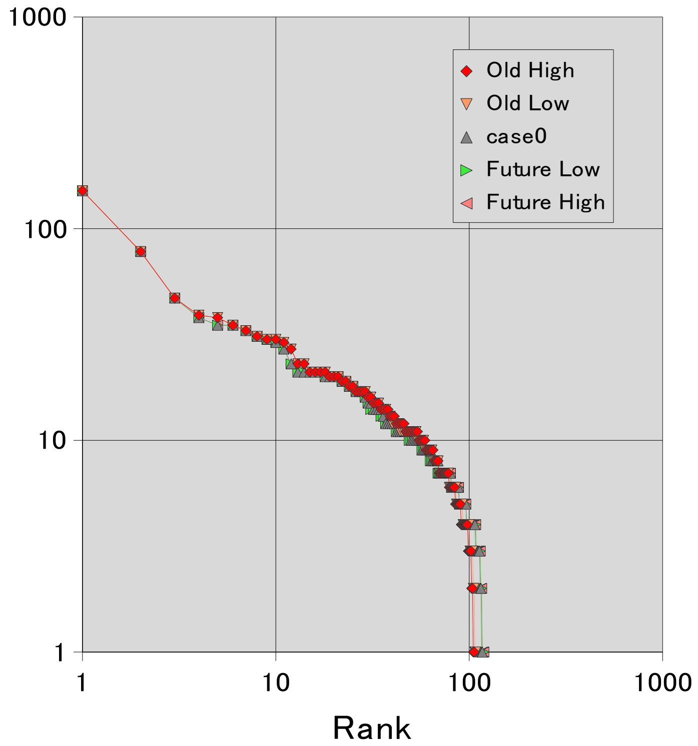

Figure 10 Rank-size relationships of branch office employments in case 2

Thirdly, the effect of tele-working through less need of floor space in branch office is assessed through figure 12. Such decrease of unit floor space enables to locate branch offices in center of metropolis with high floor rent, and cut the travel cost between branch office and customers, highly concentrated in metropolis. That effect does not give the possibility of large size branch office there; rather, it resulted in division of metropolitan offices. As a result, both number of branch offices and total employments will increase, as shown in table 2, but that effect would be not so strong as the effect from telecommunication substitution of trips to customers shown as case 1.

From these results, we can say that in near futre of more convenient and inexpensive ICT services, the number of branch office becomes more strongly concentrated into smaller number of larger cities, comparing to the present situation.

5. Conclusion

This paper focuses on the point that most business service is very labor intensive, but it cannot autonomously decide the labor usage schedule independent from the uncertain demands. In order to respond to the spatially dispersed stochastic demands, the business service company must prepare several stocks of employments larger than the expected average demands. Because larger stocks can more effectively covers the stock-out risk, increasing return appears for stock location decision, that is suggested as the strong agglomeration power for the business service sector.

This paper applies an optimal stock location model to analyze the employment allocation pattern of a representative business service firm. It may consider the risk of delayed response to the requests from the customers as back-ordering. By using different set of parameter values, the proposed model can reproduce several spatial location pattern of different type of service sectors in Japan. The simulation analysis of this model in Japanese system of cities, showed that the ICT developments in near future may result in the stronger concentration of branch office locations as well as that of employments.

The proposed model is based on micro specific consideration on the representative firm, but the applicability of the model was only proved through macro specific goodness of fit, and not in micro basement. One required work in further study is gather individual firm's branch office locations and check the microscopic goodness of fit. The second problem of this model is that only two strata structure of headquarter and branch offices can be modeled. We do not want to build a multi-layer model, that cannot be analyzed without Monte Carlo Simulations. Instead, we want to replace the customers and headquarter office in this model by branch office workers and relating agents, respectively, and the location of headquarter office(s) will be analyzed with the present model. Lastly, more variety of simulation analyses should be done to capture the effect of realistic transport development projects, such as new Shinkansen railway lines, improvement of local airports, and so on.

REFERENCES

Books:

Daskin, M. (1995) Network and discrete location: Models, algorithms, and applications, Wiley, New York.

Hansen, P., Labee, M. and Peeters, D. (1987) Systems of Cities and Facility Location, Harwood.

Saxenian,A. (1994) Regional Advantage: Culture and Competition in Silicon Valley and Route 128, Harvard University Press.

Journal article:

Bennett R.J. and Graham, D.J.(1998) Explaining Size Differentiation of Business Service Centres, Urban Studies, 35, 9,1457-1480.

Coffey,W.J. and Bailly, A. (1992) Producer services and systems of flexible production, Urban Studies, 29, 857-868.

Diks, E.B.B., de Kok, A. G. and Lagodimos, A. G. (1996) Multi-echelon systems: a service measure perspective, European Journal of Operations Research, 95,241-263.

Erlenkotter, D. (1978) A Dual Based Procedure for Uncapacitated Facility Location, Operations Research,26, 6, 992-1009.

Esparza,A. and Kramence A.J. (1996) The spatial extent of producer service markets:

hierarchical models of interaction revisited, Papers in Regional Science, 75, 375-396.

Ishiguro, K., Inamura, H., Tokunaga, Y. (1998) An analysis of warehouses' activity and heir historical trend in Japan, Journal of Infrastructure Planning and Management, 4-45, 632, 13-22 (in Japanese).

Kawabata, M. (1995) Progress in information network system and location changes in consumer product wholesalers, Geographical Review of Japan, 68, 5, 303-321 (in Japanese)

Masters, J. M. (1993) Determination of near optimal stock levels for multi-echelon distribution inventories, Journal of Business Logistics, 14, 165-195.

Nozick, L. K. and Turnquist, M. A. (1998) Integrating inventory impacts into a fixed-charge model for locating distribution centers, Transportation Research E, 34, 173-186.

Nozick, L. K. and Turnquist, M. A. (2001) A two-echelon inventory allocation and distribution center location analysis, Transportation Research E, 37, 425-441.

O' hUallachain, B. and Reid, N. (1991) The Location and Growth of Business and Professional Services in American Metropolitan Areas, 1976-1986, Annals of the Association of American Geographers, 81,2, 254-270.

Okumura M. and Tsukai M.(2003) Distribution Network Configuration Considering Inventory Cost, The43rd Congress of the European Regional Science Association, University of Jyvaskyla, Finland, Reviewed-Session, CD-ROM,343.

Phillips,D., MacPherson, A. D. and Lentnek、B. (1998) The optimum size of a producer service firm facing uncertain demand, Environment and Planning A, 30, 129-142.

Tsukai, M. and Okumura, M. (2001) Highway network and geographical advantage as freight center locations, Proceedings of Eastern Asia Society for Transportation Studies, 4, 527-541.