Technical Paper

MATHEMATICAL MODEL TO PREDICT THE CAPACITY OF FRESH PRODUCE MARKET

- A Case Study on *Kramat Jati* Central Wholesale Market -

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ABSTRACT

Deregulation policies for the supply chain of agricultural products brought not only a rapid increase in fresh produce that were transacted in most of wholesale markets in Indonesia, but also the difficulty in striking an appropriate balance between the expansion of the profit from these transactions and the control of environmental damages in the market as well as surrounding areas. In this study, engineering fieldwork was carried out for totally nine months since 2000, and then a market capacity model has been proposed to predict maximum acceptable amount of incoming products per unit area in the market. The model calculation was based on the standardized unit area in the market. The model was applied to the average amount of daily incoming products to estimate minimal floor space for each product in the market, and then the results indicated that the market capacity should be 15% larger than that in 2003 to solve the overstocks of the products in all the passages of the market. However, it would be difficult to provide sufficient floor space of fresh produce in the market if the number of wholesalers reaches almost the double, as planned by the market authority, after the completion of the reconstruction project. Therefore, the supply chains should be radically improved to attain the rationalized market in Jakarta, including the abolishment of the regulation related to the status of the market as the only central wholesale market.

Keywords: *Engineering fieldwork, mathematical model, maximum acceptable amount,minimal floor space, supply chain*

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INTRODUCTION

Indonesian national and regional policies on deregulating the supply chain of agricultural products among provinces after the economic crisis in 1997-98, brought a rapid increase in total amounts of fruit and vegetables that were transacted in most of wholesale markets, especially the *Kramat Jati* fresh produce market, the Jakarta's only central wholesale market established in 1974. Accordingly, relevant stakeholders found it difficult to manage the central market, striking an appropriate balance between the expansion of the profit from these transactions and the control of environmental damages in the market as well as surrounding areas.

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The authority of the *Kramat Jati* market has implemented the market facility reconstruction project since 2002, and then the market would become remarkably convenient for wholesalers after the completion of the project; however, no radical programs were implemented to solve the issue of solid waste disposal due to financial and institutional limitations.

Although several literatures can be found on the supply chain of the specified fresh produce such as mangoes in Indonesia (Herlambang et al., 2005), banana supply chain in Indonesia and Australia (Singgih and Woods, 2003; 2004), maize in East Java (Yonekura, 1995) and vegetables in West Java (Morooka, 1997) as well as (Itagaki et al., 1999), institutional analyses on the fresh produce market in Indonesia is still limited except the following studies: Price-quality relationships in the fresh produce industry (Batt and Parining, 2000), the bazaar economy in Indonesia (Geertz, 1978) and its institutional analysis (Asami, 1996) as well as Kramat Jati central wholesale market (Evilisna et al., 1998). Furthermore, until now no predictive models are available for the market capacity on the basis of engineering fieldwork in the market. That means the market authority would continue to struggle against a steep increase in incoming products, while available floor space of the market is limited.

The objectives of this work is to predict the market capacity of the *Kramat Jati* central wholesale market with a mathematical model proposed on the basis of engineering fieldwork in the market.

SUBJECTS AND METHODS

Engineering fieldwork was carried out at the *Kramat Jati* central wholesale market in the East Ward of metropolitan Jakarta, Indonesia for totally nine months since 2000 (October 2000 to April 2001; July 2001 to August 2001; November 2003; August 2004).

The central market deals the largest transactions among 157 traditional markets in Jakarta. It reaches 2,200 m^3/day on the average for totally 30 fruit and 37 vegetables transacted in the 24-hour-open market, through which approximately 20,000 people and 700 trucks come and go every day—including 500 street vendors and 2,000 or more daily workers. Most of the products are transacted at 3 a.m., 5 a.m., and 5 p.m.

Until the reconstruction of the market starting in 2002, the total area of the market was 148,000 m^2, including 21,933 m^2 for 3,573 outlets—usually called kiosks—, 16,005 m^2 for all other buildings, and 36,000 m^2 of free floor space. According to the market authority, the layout of the marketplace is going to be changed through the implementation of the reconstruction project as follows: 51,409 m^2 for 5,225 kiosks—36,109 m^2 for wholesalers and 15,300 m^2 for intermediate wholesalers—, 8,159 m^2 for the management office buildings, 21,096 m^2 for miscellaneous shop buildings, 2,203 m^2 for the mosque, and 600 m^2 for the authorized service center.

Market Capacity Model

Figure 1 shows a modeling layout of an outlet in the market, usually called a kiosk. Rectangular packaging units in the same size of *a* (m) in the long side and *b* (m) in the short side are placed in a kiosk of *d* (m) and *e* (m) in two sides. *M* is maximum number of packaging units in a kiosk in the direction along with the long side, and *N* is the one along with the short side. Given that the minimum width of passages in a kiosk is assumed to be 0.5 (m), maximum numbers of these packaging units in a kiosk are given by the equation (1).

$$\left.\begin{array}{l} d-Nb \geq 0.5 \\ e-Ma \geq 0.5 \end{array}\right\} \quad (1)$$

In the case of cylindrical packaging units, these parameters can be expressed as follows:

$$\left.\begin{array}{l} d-2Nr \geq 0.5 \\ e-2Mr \geq 0.5 \end{array}\right\} \quad (2)$$

Maximum area for loading products in a kiosk, S_{kp} (m^2), can be expressed as:

$$S_{kp} = MNS_p \quad (3)$$

where S_p (m^2) is the base area of the packaging unit. Maximum weight of the products loaded per unit area, C_q (kg/m^2), can be written as follows:

$$C_q = \frac{W \times J}{S_p} \quad (4)$$

where W (kg) is the weight of the products per packaging unit, and J is number of tiered packaging units. Effective maximum weight of products per unit area in a kiosk, C_{kq} (kg/m^2), can be calculated in the following equation:

$$C_{kq} = C_q \times \frac{S_{kp}}{S_k} \quad (5)$$

where S_k (m^2) is the area of the kiosk.

Substitution of equation (3) and (4) into equation (5) gives

$$C_{kq} = \frac{JMNW}{S_k} \quad (6)$$

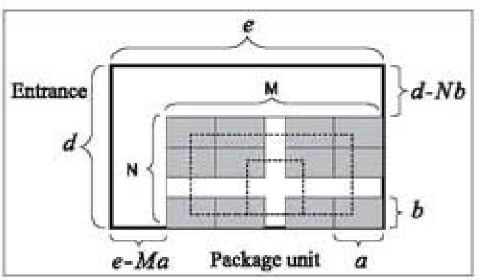

Figure 1 Modeling layout of an outlet in the market

On the other hand, minimum floor space for each product in the market, A (m^2), is approximated by:

$$A = Max\left[A_1, A_2\right] \quad (7)$$

where,

$$A_1 = \frac{C}{C_{kq}} \times \frac{t_1}{t_2} \quad (8)$$

$$A_2 = \frac{C}{C_{kq}} \times \left(1 + \sum_{0}^{F} PI^{j}\right) \quad (9)$$

where C : the weight ton of the incoming product; t_1 (hr) : the average period on sale; t_2 (hr) : opening hours in the market; and PI : the daily ratio of the amount of the products remained unsold to the total.

Since the amounts of daily incoming products were recorded using the volume ton, volume of trucks, these values were converted into weight ton by the following equation:

$$C = \frac{14 \times C_t \times h}{4} \quad (10)$$

where C_t is daily volume tons of incoming products, h is the weight density of products in packaging unit calculated from volume and weight of each packaging unit.

Maximum days on sale F can be related to the ratio of the final amount of products remained unsold to the total Q as follows:

$$Q = PI^F \quad (11)$$

By using this model, effective maximum weight of products per unit area in the kiosk can be calculated from area of a kiosk, weight of the product with the packaging unit, and the number of tiered packaging units. Based on the results obtained through our fieldwork, the ratio of the final amount of products remained unsold to the total products was assumed to be 10% (Q=0.1). In the case of F=1, A_1 in Eq.(8) was regarded

Table 1 Observed packaging units in the *Kramat Jati* central wholesale market

Form of packaging	Shape of packaging	Size (cm)				Products (weight per packaging unit; kg)
		a	b	h	r	
wooden box	rectangular	35	50	45		Tomato (30)
		40	60	40		Mango (50)
		35	50	40		Avocado (20)
		40	60	35		Papaya (40)
		25	45	10		Grape (5)
bamboo basket	cylindrical			50	60	Orange (60), Broccoli (50)
cardboard box	rectangular	30	50	70		Markisa (50)
plastic sack	rectangular	50	85	30		Cabbage (50)
						Carrot (60)
						Kidney bean (30)
						Jack fruits (50)
						Cabbage (40)
						Corn (50)
plastic net	rectangular	50	80	30		Potato (60)
		50	85	30		Shallot (50) Hot pepper (40)
plastic tie	rectangular	60	80	60		Leek (50) Celery (50)

as the minimal floor space. In addition, it was assumed that products were sold with equal amount during all period on sale, and then the average period on sale t_1 (hr) can be expressed as

$$t_1 = \frac{24 \times F}{2} = 12F \tag{12}$$

RESULTS AND DISCUSSION

Table 1 shows a list of observed packaging units in the market—wooden box, bamboo basket, cardboard box, plastic sack, plastic net, plastic tie and unpackaged. Weights of each item per packaging unit were determined with reference to the results of the interviews with several wholesalers in the market.

Table 2 shows daily and annual weights for each incoming product in 2003. The weight density of 22 products (14 vegetables and 9 fruits) in the packaging units was calculated based on the survey results, and then the total weight of these commodities reached over 90% of gross weight of all incoming products. In particular, the largest nine commodities shown in Table 2 reached 70%.

Table 3 shows the number and area of kiosks for wholesalers and others. Among 19 types of kiosks, the largest in the number and area of kiosks is 8 m^2—55% in number and 56 in area. Therefore, the uniformly-8 m^2-sized kiosks placed in the reconstructed market were assumed to apply the market capacity model to calculate the overall floor space for the sale of each product.

Table 2 Daily and annual weight tons for each incoming product in the market (2003)

Products	annual weight tons	daily weight tons	Ratio (%)
Tomato	52,519	144	6.4
Mango	108,733	298	13.2
Orange	188,484	516	22.9
Potato	63,754	175	7.7
Shallot	44,952	123	5.5
Hot pepper	82,999	227	10.1
Cabbage	50,174	138	6.1
Melon	29,863	82	3.6
Watermelon	32,434	89	3.9
Others	169,790	465	20.6
Selected	823,702	2,257	100

Table 3 Number and area of kiosks

Area of kiosk (m^2)	Size of kiosk		For wholesale		Total	
	c (m)	d (m)	Number of kiosk	Area (m^2)	Number of kiosk	Area (m^2)
3	2	1.5	68	204	822	2,466
4	2	2	324	1,296	530	2,120
4.5	1.5	3	25	113	169	761
5	2	2.5	0	0	2	10
6(2*3)	2	3	150	900	339	2,034
6(3*2)	3	2				
7	2	3.5	16	112	17	119
7.5	2.5	3	57	428	68	510
8	2	4	1,093	8,744	1,097	8,776
9.5	1.9	5	7	67	7	67
10	2	5	147	1,470	147	1,470
10.5	3.5	3	13	137	18	189
12	6	2	0	0	1	12
14	3.5	4	3	42	3	42
15	3	5	2	30	2	30
16	4	4	1	16	1	16
19.25	2.75	7	2	39	2	39
20	4	5	20	400	20	400
22.5	7.5	3	69	1,553	69	1,553
total	-	-	1,997	15,548	3,314	20,612

Table 4 Parameters calculated by market capacity model

Product	F	C_q (kg/m²)	C_{kq} (kg/m²)	S_{kp} / S_k	PI	J
Tomato	2	685.7	410	0.61	0.32	4
Mango	7	833.3	387.5	0.45	n. a.	4
Orange	10	636.9	232.5	0.35	n. a.	3
Potato	7	600	360	0.6	n. a.	4
Shallot	1	352.9	187.5	0.64	0	3
Hot pepper	1	282.4	150	0.64	0	3
Cabbage	2	352.9	187.5	0.64	0.32	3
Melon	10	n. a.	308	n. a.	n. a.	n.a.
Watermelon	10	n. a.	308	n. a.	n. a.	n.a.

Various parameters calculated by the market capacity model were shown in Table 4. Maximum weight of all products loaded per unit area, C_q (kg/m^2), was ranging from 300 to 500 except for pepper. The values of tomato and mango were larger than other products due to the number of tiered wooden boxes.

Table 5 shows minimal floor space of each product, A (m^2). Since most of the products were usually overstocked in the pathways, 1 meter wide in average, the ratio of area for loading products in 10m^2-sized-kiosk was applied to the model and areas for overstocked products, A' (m^2) were considered to estimate minimal floor space of the products.

Actual floor spaces of the products were 15,548 m^2, among which all the vegetables were 7,799 m^2, all the fruit 7,749 m^2, pineapple 466 m^2, banana 424 m^2, melon and watermelon 1,736 m^2, pepaya 324 m^2, hot pepper 1,680 m^2, potato 839 m^2, and so on. The results indicated that the 20% shortage of minimal floor space for main products corresponded to the areas for overstocked products in the pathways of the market.

The number of kiosk is going to reach 150% of the previous one, from 3,573 to 5,225 after the completion of the reconstruction project. If the average area of kiosks is still constant before and after the reconstrution project, the minimal floor space in the renewed market will be 30,142 m^2(= 20,612 m^2 x 5,225 kiosks / 3,573 kiosks).

Table 6 shows maximum limits of incoming products after the reconstruction project. Annual limits can be calculated as product of 1.14 (= 30,142 m^2/ 26,556 m^2) and weight of incoming products shown in Table 3, if several parameters such as the incoming ration of the products, average period on sale in the Eq. (12) and effective maximum weight, remain constant after the completion of the reconstruction project.

The model calculation results demonstrated that the reconstructing project would be able to extend market's capacity to 115% without overstocked products in the passways, and 150% with overstocked, as shown in Table 6. However, it would be difficult to provide sufficient floor space of fresh produce in the market if the number of wholesalers reaches almost the double, as planned by the market authority, after the completion of the reconstruction project. Therefore, the supply chains should be radically improved to attain the rationalized market in Jakarta, including the abolishment of the regulation related to the status of the market as the only central wholesale market (Local government law of DKI Jakarta, No.D.V.a.18/1/17/1973).

Table 5 Minimal floor space required in the market

Products	A (m^2)	A' (m^2)
Tomato	483	267
Mango	2,781	1,986
Orange	11,476	8,190
Potato	1,804	1,444
Shallot	274	219
Hot pepper	632	505
Cabbage	862	488
Melon	1,328	1,063
Watermelon	1,443	1,154
Main products	21,082	15,315
Total	26,556	19,291

Table 6 Maximum limits of incoming products after the reconstruction project

Products	Annual limit (ton/year)	Daily limit (ton/year)
Orange	213,940	586
Melon	33,896	93
Watermelon	36,814	101
Mango	123,419	338
Hot pepper	94,208	258
Shallot	51,023	140
Tomato	59,612	163
Potato	72,365	198
Cabbage	56,950	156
Others	192,721	528
Total	934,948	2,562
(Overstocked) Total	1,287,031	3,526

CONCLUSIONS

1) A market capacity model has been proposed to predict maximum limits of the amount of incoming products per unit area in *Kramat Jati* Central Wholesale Market.
2) The model calculation results indicated that the minimum area of the market should be 20% larger than the one in 2003 to solve the overstocks of the products in the market's passages.
3) The model calculation also demonstrated that the market capacity could be 15% larger than that in 2003, and could be 50% larger if incoming products were overstocked in all the passages of the market.
4) It would be difficult for the market to provide sufficient areas for commodity sales if the number of wholesalers in the market becomes almost the double after the completion of the project, as planned by the market's authority.

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