

Aqua Farming: Inventory Issues at the Mattsaka Fish Farm

**Roger J. Gagnon, North Carolina A&T State University
Marco Lam, York College of Pennsylvania**

ABSTRACT

It has been reported that aquaculture or aqua farming would supply one half of the fish and shellfish that is directly consumed by humans. The aquaculture market reached \$86 billion in 2009. Thus, this increasingly important industry provides the backdrop for a case highlighting differential customer service levels. The case involves a family-run koi and goldfish farm that sells its fish on a first come-first serve basis. This proves troublesome when insufficient inventory remain to complete an order for its best customer, for in this industry additional output cannot be produced, it must be grown. This situation provides fodder for pondering the cost of lost sales, the possibility of creating differential customer service levels, and development of a new sales/profit strategy. This case can be used after the students have been exposed to basic inventory concepts and the instructor wishes to introduce the concepts of the cost of lost sales, customer priorities in service levels, alternate sales policies for profit maximization, and business ethics; all this while students are absorbing an understanding of a growth industry and its operations.

INTRODUCTION

Kioshi Mattsaka arrived in Valdosta, Georgia from Osaka, Japan in June 2003. Kioshi's family had raised and marketed Japanese Koi and other exotic fish in Japan for three generations. He wished to begin a Koi and exotic fish farm in the United States for he believed the U.S. was a potentially significant market for the sale of such fish for indoor aquariums, outdoor ponds, and even the restaurant trade. Restaurants would use such fish in aquarium or fish pond displays, dinner entrees, and for the increasingly popular sushi offerings.

To begin his dream Kioshi obtained a mortgage and purchased a 27-acre farm 17 miles west of Valdosta, Georgia. Kioshi believed that this location provided a similar, warm climate to southern Japan (favorable to the Koi and tropical fish), had clay soil needed to establish pond bottoms, provided a good water source, and had land reasonably priced. While the farm had a man-made pond to capture rainwater for farming, Kioshi had twenty-five more shallow ponds constructed. Each standard pond is approximately one-third acre and is two to three feet deep. The five breeding ponds are smaller – only six by twelve feet. This number of ponds would allow Kioshi the flexibility to stock each with different fish and occasionally drain and clean them individually; one pond could be emptied, drained, cleaned, and restocked, while the others would be maintained on a rotating basis. Five ponds would each be reserved for growing imported Japanese Koi, domestic Koi, goldfish, exotic fish, and a restaurant stock or bait fish.

THE HISTORY AND ECONOMICS OF KOI AND GOLDFISH AQUA FARMING

Aquaculture or aqua farming¹ began in China circa 2,500 BC. In 1859 Stephen Ainsworth from West Bloomfield, New York, began experiments with brook trout. By 1864 Seth Green had established a commercial fish hatching operation at Caledonia Springs, near Rochester, NY. By 1866 artificial fish hatching operations were under way in both Canada and the United States. Thus, while aquaculture has been in existence for 4,500 years, its introduction in the United States began as recently as the mid 1800's. However, aquaculture has progressed rapidly in North America. When the Dildo Island fish hatchery opened in Newfoundland Canada in 1889, it was the largest and most advanced in the world.^{2,3}

In 2004 China, the largest reported aquaculture producer in the world, reported producing 30.61 million tonnes of fish. The US, ranked 10th in world aqua farming production, reported .61 million tonnes.

According to the 2005 US Census of Agriculture total sales of aquaculture products were \$1,092,386,000^{4,5} in 2002. The average sales per aquaculture farm was \$253,513. Total sales of ornamental fish (including Koi and goldfish) were \$51,297,000. Sales of Koi totaled \$6,561,000 and for goldfish \$9,762,000⁶. The US Census of Agriculture reports 92 domestic goldfish farms and 193 Koi farms.⁷

FISH POND SET-UP, OPERATION, AND DELIVERY⁸

Kioshi arranged the ponds such that water would run downhill from the upper ponds to the lower. The ponds are two to three feet deep to provide sufficient depth to discourage four-legged and winged predators, such as blue herons, easy standing room for fish consumption. Drainpipes in each pond keep the water level and least six inches from the top of the one-and-one half to two foot banks. This helps to prevent overflow in heavy rains and helps deter land-based predators easy access to the pond banks. One quarter-inch rat wire covered with plastic fastened over the drain pipe inlets prevents the fish from slipping through. The ponds are very close together allowing only enough space between for walking/working between them.

In addition to the man-made water reservoir Kioshi had a 120 foot well drilled with six inch casing. With an attached pump this provides ample clean water for cleaning ponds and maintaining water levels.

The ponds are cleaned once annually on a rotating basis. All vegetation is cleaned out and they are allowed to remain dry for at least several weeks in order to eradicate harmful insects and injurious marine life.

The fish spawn all summer, but the first spawning around the end of May is usually the best. Before this time the breeders (usually in a ratio of two males to each female) are placed in the smaller ponds. These ponds must be free of all vegetation, otherwise the females will lay eggs among the vegetation. Another "holding" pond, without fish, is readied for the eggs. Since the breeding pond is without vegetation the females lay their eggs onto the only vegetation available - trays covered with Spanish moss. The males fertilize the eggs almost immediately. A complete spawning from a healthy, mature female produces from 15,000 to 20,000 eggs. The removal of the egg laden moss from the breeding pond to a larger holding pond is ongoing and may take several weeks. The eggs and baby fish must be removed to a separate pond, as other larger fish, even their parents, may devour them.

About three weeks before the breeding season Kioshi places a bushel of rotted cow manure in each corner of the holding ponds which are to receive the eggs. This process creates microscopic marine life on which the baby fish feed for the first month. Thereafter, they are fed four times weekly a mixture of cottonseed meal and number one grade middling.

On average about seventy percent of goldfish and Koi turn gold. The other thirty percent retain their original dark olive color; they are sold as Baltimore minnows to sporting goods stores or bait shops.

Goldfish and Koi can be ready for market in as little as three months after hatching. To grade the fish for size and color Kioshi uses an oil-covered table similar to a pool table with a hole in each corner. The fish are dumped upon the wet table surface – sized and judged for color – and then pushed through the proper holes into water-filled containers. This does not harm the fish since they can survive for a short period out of water as long as their gills are wet.

Depending on the size of the order the fish are delivered to local dealers by tank truck, which can hold eight large tanks for larger orders, or by trucks holding large tins for small orders. For small orders the fish are poured from the tin into a net and then to a water-filled can at the store. Water from the store aquarium is added to the can to acclimate the fish to the water in which they will be displayed and live. For larger orders the fish can be pumped from one or more tanks on the truck.

Kioshi is also contemplating raising aquatic plants along with the fish for additional profit. Anacharis, cabomba, water lilies, and water hyacinths are in the greatest demand. Kioshi has even heard that some water plants, which mature rapidly in such fertilized water, can be sold as feed to hog farms, which are very prevalent throughout the Southeast U.S.

The purchase, construction, stocking, and marketing of Kioshi's new business required two years, but in 2006 the Matsuka Koi and Exotic Fish Farm Company was ready to begin commercial operations. In total Kioshi anticipated raising 300,000 fish annually. The company would be operated as a wholesale fish supplier selling fish from current stocks and importing unique varieties from Japan, Vietnam, and Thailand, when requested. Thus, the company operated as both a raise-to-stock and custom import order shop.

COMPANY ORGANIZATION

Most aquacultural companies such as Matsuka are small, often family run, and employ very few employees. Kioshi's wife and two teenage children assisted with the business bookkeeping and operations. In addition a year earlier Kioshi added two fulltime workers to assist with the daily tending of fish feeding, fish and pond water quality and disease control, breeding operations, collecting fish for distribution, and shipping. However, with sales growing Kioshi brought in several relatives and friends from Japan to assist with the business. He hired a cousin, Aiko Oshima, as sales and advertising manager, Toshi Masuko, as the new company accountant and purchasing manager, Saburo Yoshida, a nephew with experience in inventory planning and distribution management, and Equchi Ishimura, a friend and experienced zoologist to manage the fish and pond quality and disease control program. This program included ascertaining the quality of: current fish stocks, ongoing breeding operations (fish species could not be mixed or contaminated in the breeding operation), purchased (incoming) fish stock, fish feed, and pond quality - including water and soil surfaces, and predator control.

PRODUCTS AND CUSTOMERS

There are many varieties of Koi, goldfish, and exotic fish. Some varieties of Japanese Koi are listed in Table 1.

Table 1

Varieties of Japanese Koi¹

Doritsu	Bekko	Asasgi	GinRin Kohaku	Kawarimona
Kikari	Goshiki	Kahaku	Komonryu	Kuyaku
Goromo	Gin Matsuba	Sanke	Orenji Ogon	Platinum Ogon
Ochiba	Tancho	Tancho Sanke	Showa	Shusui
Utsuri	Yamabuki Ogon			

¹Source: Forever-Mango.com

Kioshi prices his Koi by type, size, and appearance, but other fish such as goldfish are priced by size and type. Tables 2 and 3 in the Appendix show Kioshi's prospective price list for goldfish and Koi species. As indicated in Table 3 high quality, "show quality" Koi are priced individually.

Most fish are sold to pet shops and large box stores, but some are purchased by restaurants and sushi bars both for aquarium or pond displays. In total Mattsaka had 37 reliable customers with over 100 different shipping locations. One of Kioshi's largest customers was the Fish and Reptile Pet Store Company, which was a nationally franchised pet store company. This firm had 53 franchised store locations throughout the United States and Canada. Most were located in medium and large cities. Kioshi could arrange for deliveries from his fish farm to any eastern or midwestern U.S. or eastern Canadian location or directly from foreign sources, such as Japan, when necessary. However, only 3% of Kioshi's orders required a shipment directly from a foreign source to his company or to the customer. These orders were for extremely rare or premium-sized Koi or exotic tropical fish.

To fulfill customer orders fish are netted from the appropriate pond(s). The openings of the pond-wide net determines the size of the fish to be caught. For large orders entire ponds can be emptied by netting the fish or draining the water to a sufficiently low level where the fish could be caught by hand nets. For large orders the fish are transported in trucks or trailers equipped with fish tanks augmented with water recirculation equipment, temperature controls, and oxygenation equipment. Self contained, battery -powered fish tanks can also be loaded on aircraft for air delivery.

The lead time for land shipments by the Mattsaka Company usually require 1 to 3 days. Air freight can be used to expedite orders and were received in 1 to 2 days, depending on order size and destination.

NEW PROBLEMS, OLD CUSTOMERS

Aiko, the sales and advertising manager, beamed with pride as she entered the warehouse, which served as administrative quarters, testing laboratory, and tool, chemical, and feed storage. “Well, I just sold a truck load of 6” domestic Koi to the Fish and Fowl Pet Store chain”, she remarked with pride. “Good, but how much 6”- 8” butterfly Koi does that leave us with?” questioned Kioshi. “That is a very popular size for that variety”, he added. “I do not know, but there are still some of that size and smaller ones left in the #2 pond”, Aiko said. In recent months the company has had difficulty in forecasting demand for the medium size and larger Koi and exotic fish. And with the warmer months approaching demand was certain to increase as more pet stores would increase their stocks and restaurants would replenish their outdoor ponds and indoor aquariums for customer interest. Watching the meandering fish in aquariums and ponds amused the customers and lessened their perception of waiting for table seating or order preparation.

At that point Saburo, the inventory and distribution manager, stepped inside to record that pond #2 was down to 20% of fish capacity or about 200 6” to 8” koi. No sooner had Saburo reached his desk than a computer order from the Fish and Reptile Company (FRC) (Mattsaka’s largest customer) filled his computer screen. They were ordering five hundred 6” to 8” domestic Koi; a large tank truck would be sent for pick-up in 2 days. Saburo knew that they did not have 500 domestic koi remaining in the size FRC wanted. The other tanks were filled with smaller Koi, breeding fish, other fish types, or empty for cleaning in preparation for the “busy season”. It would require another year for the smaller butterfly Koi to grow to the 6” to 8” size. What could they do?

Kioshi, Aiko, and Saburo gathered in the main office to think this through. They were fairly certain they could produce about 200 of the needed 500 koi. But the other 300? They did not want to lose such a valued customer. Kioshi decided to call Ron Thompson at FRC to explore some options and negotiate an agreement. After a 20 minute discussion FRC would accept several options: (1) accept the 200 full size fish and 300 smaller 4” Koi at a considerable discount or (2) accept the 200 full size fish and 300 other 6” Koi. Mattsaka would have to subcontract from a competitor fish farm. After some calculations and discussion Kioshi agreed to the first option.

After closing his cell phone Kioshi turned to Aiko and Saburo and exclaimed, “We handled this crisis, but I do not like *how* we settled this problem. This was expensive in both dollars and our reputation for outstanding customer service. Saburo, what is our policy on stocking or breeding our Koi to supply our customers?” Saburo hesitated, then remarked, “We dedicate five ponds to constantly breed the fish varieties. Two ponds are dedicated to butterfly Koi and other varieties of Koi – one pond for the smaller sizes 4” or less and another for the largest sizes. Four ponds are dedicated to each of the other fish varieties. It is not uncommon for one or more ponds to be empty occasionally for cleaning.

We try to replenish our stock from our breeding programs. If we cannot, we order from other domestic or overseas fish farms the type and number of fish we need to replenish a variety. It takes about two months before we can move fish from the breeding pond to another pond. Replenishing a variety from another fish farm can take from 3 days to one month. When we receive an order, regardless of the customer, we check our inventory supply; if we have the fish in stock we prepare the fish for delivery and adjust the inventory record for that fish stock. If we do not have an adequate supply of fish, we try to negotiate some agreement, but this does not

happen very often. However, it does seem to be occurring more often as our reputation grows and sales expand. I am not certain how much money or future business we lose by not being able to satisfy customer orders – especially with our largest customer. We try to “turnover (sell) as many ponds of fish as possible” in a year, regardless of which customers may be short on some orders. It is sort of “max sales revenue by first come-first sold” strategy. It is expensive to just keep feeding these fish! We have considered digging more ponds to give us more flexibility, but have never reached a final decision as to how we would allocate the fish to them.”

FUTURE PLANS

In planning for future operations Kioshi was considering establishing another fish farm on the west coast, probably in southern California, to handle demand in the western U.S. and Canada. He thought this might greatly expand their market potential and provide some economies of scale. He wondered if this would make the problem of forecasting and satisfying customer orders any easier? Or would the company just incur the same forecasting, inventory, and sales problems they now have?

ENDNOTES

¹ Includes the farming of freshwater and saltwater organisms such as fish, mollusks, crustaceans and aquatic plants.

²“History of Aquaculture”, Food and Agriculture Organization, United Nations, 1988.

³“Milner, James W., “The Progress of Fish-culture in the United States”, United States Commission of Fish and Fisheries Report of the Commissioner for 1872 and 1873, (1874), 535-544. http://penbay.org/cof/cof_1872_1873.html.

⁴“Summary by Value of Aquaculture Products Sold, United States: 2005 and 1998”, Table 3, pg. 10, 2002 Census of Agriculture, USDA, National Agricultural Statistics Service.

⁵ This includes food fish, sport fish, baitfish, ornamental fish, crustaceans, mollusks, and miscellaneous aquaculture.

⁶“Summary by Value of Aquaculture Products Sold, United States: 2005 and 1998” , Table 3, pg. 7, 2002 Census of Agriculture, USDA, National Agricultural Statistics Service.

⁷ “Summary by Value of Aquaculture Products Sold, United States: 2005 and 1998” , Table 3, pg. 7, 2002 Census of Agriculture, USDA, National Agricultural Statistics Service.

⁸ Much Information for this section was obtained from, “A Goldfish Farm in Virginia”, <http://www.profitfrom.com/profitable-hobbies-articles/raising-goldfish.htm>.

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“A Goldfish Farm in Virginia”, <http://www.profitfrog.com/profitable-hobbies-articles/raising-goldfish.htm>., Pages 1-5.

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QUESTIONS:

1. Saburo remarked that the company's sales policy was to, "turnover (sell) as many ponds of fish as possible in a year, regardless of which customers may be short on some orders." Does this sales policy affect other decisions such as inventory policy and customer service policy? Comment on the pros and cons of this current sales and economic policy or objective. Suggest an alternative company sales/customer policy that could possibly aid with the current dilemma.
2. What inventory cost should Mattsaka consider in developing inventory policies?
3. Does Mattsaka inherently consider customer fill rates? Should they?
4. What inventory policy is Mattsaka inherently using?
5. What alternative inventory policies could Mattsaka use?
6. How could they allocate additional fish to ponds to help with their inventory stockout problems?
7. What changes to Mattsaka's inventory allocation policies would you suggest?
8. Would adding a west coast operation eliminate, improve, or worsen the inventory problems Kioshi is currently facing?
9. Mattsaka Koi and Exotic Fish Farm Company is a small, family-run business. Could the same inventory problem that befell Kioshi occur at a large fish producer?

APPENDIX

Table 2

Delivered Prices of Goldfish by Size¹

<u>Type of Goldfish</u>	<u>Size</u>	<u>Price per Hundred</u>
Comets	1.5 to 2 inches	\$3.20
	2 to 2.5 inches	\$4.00
	2.5 to 3 inches	\$5.00
	3 to 4 inches	\$8.00
	4 to 5 inches	\$12.00
	5 to 6 inches	\$32.00
Moors	1.5 to 2 inches	\$12.50
	2 to 2.5 inches	\$20.00
	2.5 to 3 inches	\$30.00
Shuburkins	1.5 to 2 inches	\$8.00
	2 to 2.5 inches	\$12.00
	2.5 to 3 inches	\$18.00
	3 to 4 inches	\$25.00
Fantails	1.5 to 2 inches	\$8.00
	2 to 2.5 inches	\$12.00
	2.5 to 3 inches	\$18.00
	3 to 4 inches	\$25.00
Baitfish	1.5 to 2 inches	\$15.00 per 500
	2 to 3 inches	\$20.00 per 500
	3 to 4 inches	\$25.00 per 500

¹ "A Goldfish Farm in Virginia", <http://www.profitfrog.com/profitable-hobbies-articles/raising-goldfish.htm>.

Table 3

Price List for Koi and Butterfly Koi¹

Decorative Grade²			Select Grade³		
<u>Size</u>	<u>Price</u>		<u>Size</u>	<u>Price</u>	
4" – 6"	\$20	3 for \$50	3" – 4"	\$22	3 for \$55
6" – 8"	\$35	3 for \$90	4" – 6"	\$34	3 for \$85
8" – 10"	\$45	3 for \$115	6" – 8"	\$44	3 for \$110
10" – 12"	\$85	3 for \$215	8" – 10"	\$60	3 for \$150
12" – 14"	\$99	3 for \$250	10" – 12"	\$125	3 for \$325
14" – 16"	\$150	3 for \$375	12" – 14"	\$175	3 for \$450
16" – 18"	\$175	3 for \$440	14" – 16"	\$225	3 for \$575

Import Quality Grade⁴		
<u>Size</u>	<u>Price</u>	
4" – 6"	\$59	3 for \$150
6" – 8"	\$79	3 for \$200
8" – 10"	\$150	3 for \$375
10" – 12"	\$199	3 for \$500
12" – 14"	\$300	3 for \$750

Individually Priced High Quality Koi

These individually priced fish are even higher quality than the Import Quality and represent the best Koi that Matsuka Fish Farm has to offer. Many will have show qualities, and be considered Tategoi (with potential) and have all the makings of a possible winner. These fish are priced individually on a per fish basis; this is determined by market value, uniqueness, and overall quality.

¹Price and grade list from Hanover Koi Farms. <http://www/jnfkoifarms.com/Frame-904640-koipricelistpage904640.html>.

²Decorative grade represents the least expensive Koi and come in a wide variety of colors and patterns. This grade is designed for those that just want some colored fish for their ornamental or farm ponds.

³Select grade is the most popular seller and overall the best overall fish for the money. The average person would find these fish to be extremely attractive, and colorful.

⁴Domestic bred and raised in the U.S., but represent pure varieties that equal or surpass the average fish imported from Japan when comparing overall quality.

TEACHING NOTES

Suggested Answers to Matsaka Koi and Exotic Fish Farm Company Case Study:

- 1. Saburo remarked that the company's sales policy was to, "turnover (sell) as many ponds of fish as possible in a year, regardless of which customers may be short on some orders." Does this sales policy affect other decisions such as inventory policy and customer service policy? Comment on the pros and cons of this current sales and economic policy or objective. Suggest an alternative company sales/customer policy that could possibly aid with the current dilemma.**

The current company sales policy definitely does affect the inventory policies and customer service policies – especially those customers whose orders are not fulfilled. While the current sales policy may maximize the number of fish or the number of ponds of fish sold (in the short term), it may not maximize long run profits. This may be due to hefty stockout costs particularly for Matsaka's largest customers. Additionally, this lack of customer service may drive customers to look for new Koi and goldfish suppliers. This is a particular concern for Matsaka's largest customers.

- 2. What inventory costs should Matsaka consider in developing an inventory policies?**

It is expensive to: (1) keep the fish while they are maturing, (2) order additional fish needed to replenish certain stocks and the supplies needed to sustain them, and (3) the costs incurred in ordering additional fish (at a higher cost) from another supplier in order to complete customer orders, which Matsaka cannot fulfill. Therefore, holding, ordering, and shortage or backordering costs should be considered in establishing new inventory policies.

- 3. Does Matsaka inherently consider customer fill rates? Should they?**

It appears that Matsaka is *not* considering customer fill rates explicitly. (They are maximizing the number or ponds of fish sold.) When choosing reorder points and order up to levels Matsaka should consider the trade-off between having too much inventory when demand is lower than expected and having too little inventory when demand is higher than anticipated.

- 4. What inventory policy is Matsaka inherently using?**

At this time, the company uses an order-point, s , and order-up-to quantity, S . This is known as an (s, S) policy. This system is frequently encountered in practice (Silver *et al.* 1998, p. 239). Silver *et al.* note that values for s and S are usually set arbitrarily. An inventory management class could address how to obtain reasonable values for s and S .

- 5. What alternative inventory policies could Matsaka use?**

Here, the instructor can introduce a variety of policies; (s, Q) , (s, S) , (R, S) , and

(R, s, S). These policies are defined by order-point, s; order-up-to quantity, S; order quantity, Q; and review period length, R. Discussions can address continuous versus periodic review and fixed order sizes versus order-up-to quantities.

6. **How could they allocate additional fish to ponds to help with their inventory stockout problems?**

As mentioned Matsaka currently maximizes “ponds of fish sold”. This does not necessarily maximize profits or customer service levels. And indeed Matsaka has different customer classes – different size customers that account for different levels of its business. Stockouts occurring for the largest customers may incur lost sales, high backorder costs, etc. and significantly affect future sales and profits. Thus, Matsaka may wish to establish multiple demand or customer classes with differing service levels.

Multiple demand classes has received some attention in the literature (e.g., Nahmias and Demmy 1981, Ha 1997) but the topic is typically not included in operations management and inventory textbooks (Kleijn and Dekker 1998). To balance supply with demand, companies are increasingly utilizing customers’ varying service requirements by rationing inventory among these different demand (customer) classes (Deshpande *et al.* 2003). Sparked by adoption of inventory rationing in practice and the interest that revenue management has received in the airline industry, multiple demand classes, customer differentiation, and inventory rationing is being revisited by scholars.

In practice, some companies physically separate their inventory, while others have created different SKUs for the various demand classes. (One note of caution should be mentioned for rationing a product for multiple customer demand classes. One should check the appropriate federal and state laws for the legality of rationing a free market product.) A drawback of these approaches is that the company does not take advantage of inventory pooling (Deshpande et al. 2003). In Matsaka’s case the company could reserve certain ponds of stock for their largest customers or when fish inventory is at or below a critical level, reject demand from less valuable customer classes. They could backorder the demand for these customers and still satisfy demand for high level customers. Hence, they could *ration* their inventory. Interestingly, for certain fish species Matsaka could have inventory on-hand and be backordering at the same time.

For a further discussion on multiple demand classes see HA (1997) and Arslan et al. (2007).

7. **What changes to Matsaka’s inventory allocation policies would you suggest?**

Experiencing several stock-outs might not justify changing the company’s inventory policy. However, if analyses indicate a systematic problem, changing the reorder point or safety stock levels would be appropriate. Deshpande et al. (2003) discuss how not utilizing the differences in service requirements among customers is costly. Matsaka could differentiate service requirements by allocating certain fish ponds or stocks to their largest customers.

8. **Would adding a west coast operation eliminate, improve, or worsen the inventory problems Kioshi is currently facing?**

Whether adding a new operation would add to the problem or reduce the problem depends on whether demand for Koi in the two geographic areas is correlated. See formula. The variance for the combined demand is a function of the individual variances and the correlation between the two demands

$$(\sigma_{a+b})^2 = \sqrt{(\sigma_a^2 + \sigma_b^2 + 2\rho\sigma_a\sigma_b)} \quad \sigma_{a+b} = \sqrt{\sigma_a^2 + \sigma_b^2 + 2\rho\sigma_a\sigma_b}$$

Where ρ is the correlation coefficient and σ_i is the standard deviation of demand for operation i .

Note that if the demand is negatively correlated, an average in one operation could be offset by a shortage in the other operation. However, if the demand is positively correlated, adding a new operation would only add to the problem.

9. **Mattsaka Koi and Exotic Fish Farm Company is a small, family run business. Could the same inventory problem that befell Kioshi occur at a large fish producer?**

Yes, if the company has the same inventory policies. We note, however, that the larger company would have a larger variety of customers spread out over the United States or even globally. Therefore the correlations among the various demands are more likely closer to 0. As a result the variation in the total demand over all correlations is therefore likely smaller than the variation observed by the small firm.

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