6. Economies of Scale in Information Technology

Software industry has high development cost or fixed cost but low distribution cost or marginal cost. This include enterprise software, personal software, games. Consider Microsoft, Oracle, SAP, Manhattan Associate, Nintendo, Sony. Social media industry share something similar and in addition, enjoy the strong network effect, consider Facebook. In such industry, the winner take all becomes reality.

7. Diseconomies of scale

If the marginal cost increases to pass the average cost, there is diseconomies of scale. In supply chain, in what situation the marginal cost can grow that fast? Remember the average cost already considered the shared investment cost and other fixed cost. Here are some possibilities:

1. When the volume exceeds the capacity and the marginal cost is very high such as double pay if most of the cost is labor, or outsource when the cost is high, or requires additional investment without good long term prospect, etc.
2. The market for the added quantity are at different locations, such as in a different country. The transportation cost is high.
3. In market where the economies of scale is low: low investment cost, high variable cost, variable cost does not go down as the volume goes up, such as service centers, travel agent.
4. Organizational issues that cost extra cost with large scale. This can be in communications, organizations, motivation, lack of synergy, moral hazard, etc.
5. External factors such as shared raw materials, public goods such as crowding of roads that marginal cost increases a lot with volume.

8. Economies of scale at the macro level

If we view the supply chain as a loop or the entire product life cycle, what are the impact of the economies of scale? Amazon, UPS, Ford, Apple, Coke, Anheuser-Busch InBev are big, however, it is still trying to grow bigger through, merger and acquisition, etc. Economies of scale is one of the motivations to grow. We will discuss some other factors that cause later in this course. That means, their supply chain cost at least do not grow with the volume. What are the impact?

8.1 The benefits from the economies of scale

The cost reduction leads to lower prices. Lower prices leads to more consumption, meaning more people can enjoy the project. Consider fashion, appliances, electronics, food, bandage, etc. When

there is scarcity in the supply of such goods, many people cannot acquire sufficient goods to satisfy their basic human needs.

The sufficient and affordable goods for basic human needs allows the people in the lower economic conditions to enjoy similar benefits as those at the higher economic conditions such as nutrition, clean water, shelter, vaccination.

The consolidation with new technology may leads to higher quality, lower emissions, lower waste, and lower environmental footprint.

The lower production cost allows the firms to invest to improve worker's work environment to improve their health.

8.2 The drawbacks from the economies of scale

The dramatic cost reduction measured by amount of time it would take to do something leads to over supply of certain goods, such as fashion, food, electronics. Consider how many human-hours needed to make a pair of pants over the years. Due to the division of labor, mechanization, computerization, the total time required is much less than an hour for mass produced pants. To compete, the suppliers find various ways to entice the consumer to buy more. They even pre-damage the product to sell as fashion. Such products are less functional, less durable but fashionable.

The low cost by the existing large suppliers make it difficult for the smaller players to enter the market, even with innovative ideas. Take food for example, we know true grass fed beef, free range chicken, organic vegetables are better but the lack of scale put them in disadvantage. Some on-line retailers may have exact type of product you need with good service. However, the free shipping from Amazon may lure you away.

9. SUMMARY OF ECONOMIES OF SCALE

Economies of scale is a very strong economic force. A larger production quantity almost always incur lower cost per unit when the production capacity is sufficient. Even when the capacity is insufficient, and the marginal cost starts to trend up, the average cost may still be lower than that in a smaller scale counterpart. As a supplier of product or services, one should always take advantages of economies of scale.

Batching is also kind of scale effect. In many situations, batching is an important mean for cost reduction. However, larger batches can also come with slower speed, longer cycle times, delays, and excess inventories. etc.

In economics, the economies of scale are often explained as a concept with illustrations. In supply chain, many important factors of the scale effect can be quantified explicitly with sufficient accuracy for decision-making. This section included some of these factors.

Take beer supply as an example. It has been many years that the fastest growing sector in the beer industry are microbreweries (up to 15,000 barrels) and craft beers or microbreweries (up to 6 mil US gal, or nearly 10 times). The cost at these smaller facilities are higher. However, consumers

Exercises

1. What are the main forces of economies of scale?
2. Many industries consolidate from cottage to fragmented to loose oligopoly and to tight oligopoly. What are the driving forces behind the consolidation?
3. In a simple production system involving a large investment and fixed incremental cost with production capacity of *C*, how do you quantify the economies of scale?
4. What are the benefits of large batch sizes and small batch sizes?
5. What is the biggest hurdle in batch size reduction?
6. If everything else equal and you managed to increase demand, what will happen to the monthly inventory cost? How about average inventory cost per item?
7. What are the reasons for quantity discount?
8. In anticipation of wide adoption of 3-D printers, a firm is considering major investment to make 3-D printers. It narrows down the options to two types of production systems: A and B.

System	Annual Equivalent Investment $/year	Production cost per printer $/printer	Change over cost $/changeover	Product types	Demand per type Units/week
A	3,000,000	1,000	400	2	600
B	5,000,000	1,000	10	4	500

1.1. Please quantify the economies of scale considering only the investment, production cost and production quantity perspective.

$$\sum D_A = 2 * 600 = 1200/week = 62400/year$$

$$\sum D_B = 4 * 500 = 2000/week = 104000/year$$

$$AC_A = \frac{3{,}000{,}000}{62400} + 1000 = 1048.1/year$$

$$AC_B = \frac{5{,}000{,}000}{104000} + 1000 = 1048.1/year$$

1.2. (relevant to later sections) Assuming adjusted holding cost *h'* = $0.1 per unit per week for all product types, what should be the common manufacturing cycle times and

3. ECONOMIES OF UNIFORMITY

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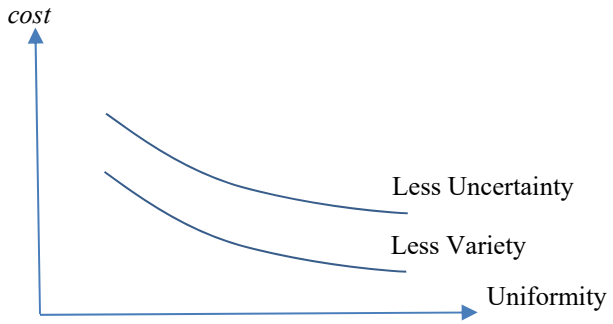
The uniform operations are the easiest to run. Uniform demand would have no seasonality, no uncertainty. Uniform product would only have one type. Uniform facilities have identical buildings and machines with same personnel, etc. However, the demand is never uniform, customers want different products, which requires different machines and personnel. When these vary, there is additional cost, challenge as well as opportunities to succeed among competitions.

Variability can be deterministic, such as different product lines, planned activities, customer orders on hand, seasonality in a day, a week, a month or a year. Imagine if you run a business with clear seasonality in a week, you have to adjust the work force and facilities to meet the varying demand, often at a higher cost than a uniform demand. You can use deterministic optimization tools or MRP to find the best plan with minimum cost. Even at the optimum, there is still extra costs.

The variability can also be uncertain or probabilistic. Such as customer demand, the interruptions in the business caused by nature, sickness, departure, material shortage, etc. These are related to complex human behavior, markets, weather, political changes, natural disasters, or other unpredictable or uncontrollable factors. Organizations use various means to hedge against such uncertainties or plan for the lost. Such use of resources is the cost of uncertainty to the organization. For example, in order to cope with uncertain demand, safety stock are stored to balance between excess and shortage, which leads to high expected long term expected cost., or the cost of uncertainty. Another example is to build a new factory against uncertain future demand. Too much capacity lead to low utilization while too little capacity leads to overtime, unmet demand, etc. This can also be the case in planning for work force, buying for equipment, plan for number of sections of a class, etc.



What is good about variability? It offers challenges and provides opportunities for those who can manage variability better than others. Uncertainty offers opportunity for the business of finance and insurance. It offers “spice” in professional and daily life. Without variability or uncertainty, the world can be less colorful if you have an active mind. In this section, we will discuss the quantification of cost of variability and ways to cope with variability.

Variability exists in many situations. Supply chain is a “flow” system in which goods, (people), information and funds flow through the system. Supply chain engineering or management is to understand and control of the flow to reach maximum flow efficiency. The variation can occur in

the arrival to the system such as materials, people and demand. Variation can also occur within the system, such as weather delays, wait in the queue, wait for matching conditions. Variation can also occur in the system that support the flow, interruptions, stoppage, running out of supply, etc. One can model the inflow with demand variations, model system variability with stochastic process, and model interruptions with process breakdowns. For each types of variation, the objectives of modeling is to understand the system and reduce the impact of variations.

1. THE COST OF DETERMINISTIC VARIATION

The deterministic variation can be in demand type and timing. It can be the equipment and raw materials. It can also be in the personnel. A complete uniform supply chain is in constant and uniform flow of single product or service with no start, no stop, no variety or just one product. It is difficult to find such ideal situation. May be certain segment in the system during some time in a water supply where there is a large water tower to buffer for the differences. You are encouraged to find a continuous and constant supply chain of a single product or service. You will find almost not possible to find one.

In most supply chains, there are starts and stops, even with a single product or service. This can be due to start and end of shifts, reloading of raw materials or removal of finished products. The start and stop cost time in ramping up and shutting down, loss of materials or quality products, procedures to setup and shutdown may need personnel, etc. These can all be deterministic.

1.1 The cost of product variety

In most supply chains, there are multiple products and services going through the same system, the changeover from one to another is inevitable. In change over, one has to shut down the current one and setup for the new one, which may require different equipment, document, computer applications, recipes, etc. The supply rate of each product must be higher than demand rate of the product. Demand can occur while the supply chain is working on other products. Therefore, the product may need to be stored. The supply chain must include buffering space and fund to keep the product or service to satisfy the demand while the system is producing other products.

Sales people love to promise different products. If the volume is the same, and the variety increases from 1 to n, what is the cost implications in the production and supply chain?

1. The raw material cost may go up because for each raw material type, such as a particular color of the paint, the volume decreases. You may no longer enjoy the quantity discount.
2. The tools, such as size of the spray nozzle, may be different and incur additional cost.
3. There will be change over cost in production.
4. The reduced demand for each product requires smaller lot sizes and lead to higher inventory related cost.
5. We will see in later section that the total safety stock levels will go up.

6. The variety increases the complexity in supply chain management and lead to extra cost.
7. …

Example: A firm build a commodity product with single color. The revenue for the product is $1 mil per year. The margin on the product is 10%. It faces challenges from its competitors. The company is investigating if it should add 3 more colors to maintain its market size. The forecasted demand for the original color is half of the original demand, and the 3 new colors share the other half, equally. The cost of the material for the original color was $60,000 per year before, including the logistics cost. It will increase by 2% for the original color per unit. The cost for the 3 other colors will increase 10%. The additional tooling cost will be $3,000 per year. The changeover cost was only the startup and shutdown cost everyday valued at $10,000 per year. The changeover cost due to the changeover between colors will add $8,000 per year, including the inventory related cost due to the smaller lots. The added complexity The added complexity will require software changes, the manager's attention, the worker training. The total is estimated at 10,000 per year. What will be the extra cost due to the addition of the new colors? How would you like to present your case to management.

Assumptions: The problem statement has captured all the major cost items. The annual equivalency costs are sufficiently accurate for the purpose of this analysis.

Solution:

1. The calculation for the extra cost
    a. The extra material cost is $\frac{60000}{2} * (0.02 + 0.10) = 3{,}600$
    b. The extra tooling cost is $+3000$
    c. The added changeover cost 8000
    d. The added management and training cost 10000
    e. The total cost: 24,600/year
2. The added cost is 2.46% of the revenue. The firm can still have profit. However, the added color will reduce the margin by almost 25%, quite significant. If the firm must add colors to remain in the market, it can. However it should also look for synergies to reduce the extra cost. If in position, can also change the pricing structure.

1.2 The cost of seasonality

The actual demand is never constant 24 hours a day seven days a week. The demand for some products and service are strongly seasonal over a year: holiday goods, sky equipment, school supplies, recreational supplies, UPS deliveries, resorts. Some vary in a course of a month such as office supplies, social security services. Some good vary over a week such as food, seats on flights, hotel rooms. Some vary over a day, such as food, medical services, classroom, busses.

When the demand varies, one can plan the capacity based on the peak demand. When off-peak, there will be waste of capacity such as idle facilities and personnel. You can call this buffer with

capacity. One can also plan with level capacity around the average demand, and build up good and services during off peak and store them for the peak season demand, assuming the products and services can be stored. For example, one cannot store a surgery operation. One can also plan the capacity to chase the demand pattern. One can also supplement the capacity by using temporary work force such as in UPS, outsource peak demand, etc.

In any design, there is cost associated with the demand change in the forms of excess capacity, inventory of goods or services if they can be stored. Some goods or services cannot be stored effectively, such as fresh produce, seats on an airplane or surgeries.

Example: Let's consider a very small example. The setup cost is $150 per setup. The monthly demands in next quarter are (20, 30, 40). The holding cost is $10 per month. The production capacity is 30 per month.

The average demand is 30 per month. You can find $EOQ = \sqrt{2 * 150 * 30/10} = 30$ per order. The order cycle is 1 month per order. The cost of this policy is $C(EOQ) = \sqrt{2 * 150 * 30 * 10} = \$300$ per month. The total inventory related cost in the 3 month period is $900.

However, the demand is not constant. The system will be 33% idle in the first month, and 33% over capacity in the last month. Since the total capacity is sufficient, one way to deal with this is to build up excess inventory in the first month, and carry it over to the 3rd month. This will lead to extra inventory cost of 10 units carry over 2 periods, or 10 * $10 * 2 = $200, or over 22% of the total inventory cost. Another way to deal with this is to run overtime in the 3rd period. Typically, firms pay 150% or 200% above the normal pay, which will also lead to significant cost. We have not considered the cost of idle time in the first period, which may be immaterial.

1.3 The cost of facility variety

Southwest airlines, the 3rd largest airlines in US, has about 750 Boeing 737s. The simplicity reduced the cost of maintenance, reduces the complexity in scheduling, training, and support. Delta airlines, on the contrary, operates over 900 planes include Airbus 220s, 319s, 320s, 321s, 330s, 350, and Boeing 717, 737s, 757s, 767s, 777, and MD 88, 90.

1.3.1 Delta

Delta is a full service airline with international routes, domestic routes and regional routes. It runs hub-and-spoke networks. In order to have the right capacity, the right class combinations, the right ranges, it opted to have many different types of planes. Due to mergers and due to the negotiation power, Delta also has equipment from two competitors in a duopoly.

The benefits: of the variety is to have the plane with correct capacity, range, classes for the suitable routes. For example, from hub Atlanta to hub Amsterdam, Boeing 777 or A350 or A330 are best choices. From Atlanta to Salt Lake City, from Atlanta to Charlotte, …

The drawbacks of Delta fleet is that its fleet is highly non-uniform. It needs multiple and different maintenance facilities, holds expensive spare parts inventory for many part types, employ technicians with different trainings for different aircraft types.

1.3.2 Southwest

The benefits of Southwest strategy is from the uniformity of aircraft in Southwest can have similar maintenance facilities with similar tools, smaller set of spare parts inventory, less types of technician, exchangeability of equipment, etc.

The drawbacks is in the types of customer and market it can server.

1.4 Uniformity among certain handling characteristics

In logistics, goods can be handled in the same way. In that way of handling, the goods are considered uniform. For example, UPS has letters, small packages, cases and pallets. Each type is handled the same. All small packages, although different sizes, shapes and firmness, they are handled the same by the operators since the operators are flexible. The concept of unit load is to take advantage of handling uniformity in transportation, stacking, equipment design, etc.

1.5 Summary of economies of deterministic uniformity

There can be differences in other dimensions such as personnel, etc.

2. ECONOMIES OF SCOPE

The economies of scope is the cost savings of producing *n* products or services as a whole minus the total cost of producing them individually. The economy of scope can be expressed as

$$\text{Econoimes of Scope} = TC(q_1,...q_i...q_n) - \sum_n TC(q_i)$$

If this negative, there exist economies of scope.

Let's consider the economies of scope in different types of the deterministic economies of uniformity.

In supply chain, there is some initial investment cost *I*, such as building, equipment, fleet, etc. To build a product or provide a service type *i*, a minor setup K_i is needed such as adding the storage system or setup the tools on the machine, or modifying the trucks for certain services such as temperature control, lift gate, etc. During operations, the change of products or services will incur a changeover cost *K*. Typically, $I >> K_i$. In production or service, there is a variable cost