A Framework for Unused Capacity: Theory and Empirical Analysis

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Abstract

Firms build excess capacities in fixed cost resources for two purposes - to accommodate uncertainty and to plan for potential growth. Fluctuating demand and internal processing times result in uncertainty, while lead times in building fixed resources result in excess capacities being built to meet future growth in demand. These give rise to unused capacity costs. Our objective, in this paper, is to develop a framework that disaggregates unused capacity cost into categories of unused capacities, and thus provide decision-relevant information for management to plan and manage excess capacity. In addition, this paper uses the data from an international semiconductor company to investigate the usefulness of the proposed theoretical framework and test its implementation.

Keywords

Unused Capacity
Excess Capacity
Excess Capacity Drivers
Bottlenecks
Resource Allocation
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Introduction

We develop a framework for reporting unused capacity of resources, and then illustrate how the framework can be used for decisions using field data from an international semiconductor company. Cost is an important factor that affects profits and is largely influenced by the company's structure and operational efficiency. Separating costs into variable costs and fixed/committed costs, we develop the framework for further disaggregating fixed costs so as to facilitate operational and strategic decisions.[1]

Fixed costs exhibit unique characteristics, and in general, are incurred to build capacity for production. Excess capacity in any form, be it factory or human resource indicates costs spent for possible future benefit in terms of facilitating growth and meeting additional market share. The extent of unused capacities in the firm's resources depends on their goals, strategies and any under usage or wastage due to inefficient operation. Some of the excess capacities are planned strategically and their costs are not subjected to continuous cost reduction efforts.

In an Activity Based Costing framework, all costs are applied to the product or cost object (a product, for example, may be a manufactured item, an organizational unit or a service) for building effective pricing strategies. The cost drivers for fixed activity resources are determined based on perceived relationships of cost driver to activity resource consumption. The appropriate base level to be used is a matter of concern and this paper deals with this issue. The choice of base level should result in product costing accuracy, facilitate strategic decision making and appropriate

[1] For variable cost the wasteful usage beyond efficient consumption is under the control of the company. In order to determine the non-value added portion of the variable cost one need to find the efficient consumption level for the output achieved through bench marking or engineering studies. The non-value added cost is then necessarily reduced through continuous improvement efforts.

responsibility assignment for the provision and consumption of these fixed activity resources.

The framework relies on two characteristics of businesses, in general, and the deployment of capacity resources that drive fixed costs, in particular. The two characteristics are the *uncertainty* with respect to demand and service time, and the *stickiness* (non-instantaneous adjustment) of resources. The effect of these characteristics on resource capacity provides the backbone for the framework. Specifically, planned excess capacity can be disaggregated into the uncertainty effect and the adjustment cost effect.

We provide a numerical example to show how the developed framework provides decision-facilitating information for managers. Specifically, the information on the uncertainty effect can direct attention of the top management towards instituting changes in business processes and procedures that mitigate uncertainty (decrease the variance) of processing times. The information on adjustment cost effect provides a veracity check on the long-term and medium-term expectations of demand (sales growth), and also helps the top management hone their strategies with respect to using excess capacity for delivering higher quality of service. Overall, these components of planned excess capacity provide information for the top management to manage capacity decisions.

The unplanned excess capacity, which is the deviation of the actual from the planned capacity utilization, provides decision-facilitating information for operational improvements either at the production centre or the marketing centre. As such, our framework for disaggregating the variance of fixed costs provides relevant information for appropriate responsibility centres to take action, if necessary.

We use data obtained from an international semiconductor company to demonstrate how the framework can be applied and used for decision-making. We find that with time the adjustment effect and unplanned effect (the difference between budgeted and actual utilization of capacity) dampen and stabilize. This will allow for continuous improvement strategies.

By implication, our framework can also assist management with identifying impaired assets as required by FAS 144. Using the numerical example we also illustrate how the proposed framework could be used to provide aggregate supplemental information on excess capacities for external reporting. Information on excess capacity could help alleviate meltdown of firms similar to the ones recently in the telecom industry, which was spawned to a large extent by excess capacities that were built in the late 1990s.

We proceed by developing the basic forces that create a need for excess capacity.

Fundamental Drivers of Excess Capacity

Resources defined broadly encompass all inputs that help the enterprise generate its output.[2] Investments in resource capacity are made based on the expected demand because instantaneous adjustment of capacity is impossible and/or extremely costly. This notion of non-instantaneous capacity adjustment has been recognized in the inter-temporal, choice-theoretic framework of explaining Tobin's *q*. The idea is that investments, positive or negative, do not translate into immediate capacity adjustments. The costs associated with such non-instantaneous capacity adjustments, i.e., the costs of stickiness are referred to as adjustment costs.[3] In effect, an investment made today does not immediately translate into available capacity, and hence, capacity needs to be planned so as to meet future demands. For instance, it takes time to build a manufacturing facility, or employees have to be trained after recruitment so that they

[2] This broad definition is implicit in the framework for measuring opportunity costs developed by Balakrishnan et al. (2001).

[3] See Hayashi (1982) who in turn uses Uzawa's (1968, 1969) Penrose function to justify the adjustment cost.

can be "put to use". The presence of adjustment costs creates an imbalance between available capacity and utilized capacity.

Certain "bottlenecks" in resource capacities contribute to unused resources in others. This is related to the notion of lumpiness of resources, which creates an imbalance across the capacity of various resources. This is referred to as activity slack in line balancing in the operations management literature. For instance, if the lead-time for building office space is greater than that for training employees, then investment in office space could be much higher than that in employees in the short-run. Consequently, in the short-run the employee resource would appear to be a "bottleneck" resource that dictates the maximum potential utilization of the office space.

Uncertainty with respect to the demand and the production time, i.e., the time to fulfil the demand, together also contribute towards an imbalance between available capacity and utilized capacity. This notion of carrying excess capacity to buffer uncertainty has been recognized in the operations management and queuing theory literature. This idea is illustrated with a simple example where the demand can be 10 or 20 units per day with equal probability. First, consider a scenario where demands can be backlogged at no cost -- then investing in resource capacity that can produce 15 units per day ensures that all demands can be fulfilled and capacity utilization is hundred percent. However, some customers – the ones whose orders are backlogged -- will have to wait for a longer time. Second, consider a scenario where backlogging demand is costly – then, investing in resource capacity that can produce 15 units per day and utilizing the capacity to its fullest to stock excess production in inventory balances the expected demand. In these scenarios, inventory and backlogging demands are buffer capacities that are created to mitigate the effect of demand uncertainty. To balance the excess cost of backlogging, one may increase the capacity above 15 and maintain a buffer capacity.

To see the intuition behind the excess capacity notion, consider a *service setting*. The distinguishing feature in a service setting is that demands cannot be inventoried or backlogged. This notion is all too common for us – we wait in our cars in traffic jams or at toll booths, we wait on hold for an operator to pick up the phone, we wait in line at supermarkets – primarily because our demand cannot be backlogged or we cannot be serviced through an inventory. Hence, wait appears to arise because demand is greater than the capacity of service resource. However, quite the opposite is true. Consider a scenario in which a checkout clerk can service one customer every five minutes, and there are two checkout clerks (the capacity) who can serve two customers in five minutes. There can be one, two, three, or four customers who can potentially demand service in each five-minute block with equal probability. Thus, on average there are two customers in each five-minute block. There will be five-minute blocks when only one customer demands service, at least 25% of the time (in the long-run); at that time one of the checkout clerks will be idle – and this idle time cannot be utilized later. On the other hand, 50% of the time there will be 3 or 4 customers demanding to check out, which will make the customers wait. If this continues the waits will become infinitely longer. This is because in equilibrium the number of customers coming to checkout (the input flow) is set equal to the number of customers leaving the checkout counter (the output flow). Because of periods of idle capacity, the capacity needs to be larger than the expected demand to keep the balance of input and output flows. This creates a demand for excess capacity that arises due to uncertainty of demand. The uncertainty in production (service) time works in a similar fashion.[4]

Overall, lumpiness of resources and uncertainty lead to excess capacity.

[4] The equilibrium wait times is given by the Pollaczek-Khintchine formula, which incorporates the notion that in equilibrium the capacity has to be higher than the expected demand (see Grossman and Harris, 1999). Radhakrishnan and Balachandran (1995, 2001) have used this to study cost allocation problems.

Capacity in general is defined as all resources that are generated as part of the strategy to mitigate the effects of uncertainty.[5] These effects together imply that on average capacity utilization will be less than hundred percent.

We next develop a framework that integrates the uncertainty and adjustment cost effects.

Development of the Framework

We define capacity in terms of output units – time available for use. For instance, for equipment it could represent the equipment hours, for employees the staff or labour hours, etc. The available time measure makes it simpler to deal with multiple products/services being produced by the same resources and provides a good numeraire for being a common measurement unit. We classify resource capacity into five categories: theoretical capacity, maximum capacity, efficient capacity, bottleneck (practical/normal) capacity and budgeted capacity.

Theoretical capacity: Theoretical capacity is the theoretical maximum output that is possible if the resource is utilized to its fullest possible extent. With time as the common measurement unit, for equipment, this implies 24 hours a day for 365 days a year, while for employees it would be 8 hours a day for 365 days a year.

Maximum capacity**:** Maximum capacity is maximum output that is possible with the current technology and environment. In essence, this allows for normal maintenance and breaks. For instance, in an 8-hour day employees might be able to work effectively for only 6 hours, because of fatigue factors; an equipment might need to undergo regular maintenance, etc. Essentially, the difference between the theoretical and maximum capacity, provides a measure of a potential increase in output with innovation in business processes and/or technology. However, it is essential to note that with the present technology the theoretical capacity is a mere "unattainable" benchmark. Maximum capacity can be viewed as the best utilization by the most efficient firm that experiences no or minimal uncertainty.

Efficient capacity: Efficient capacity is the optimal utilization of capacity allowing for randomness in demand and production process. As discussed earlier, uncertainties preclude utilization of capacity to its fullest possible extent. Efficient capacity is thus the maximum expected capacity utilization that can be attained given the current uncertainties in demand and production/service technologies. The difference between maximum capacity and efficient capacity is entirely due to random factors, and provides a measure of a potential increase in output by reducing randomness in demand by adopting innovative pricing strategies, etc., and reducing randomness in processing times by reducing uncertain breakdowns in process, lower quality parts entering the process, etc.

Bottleneck capacity**:** Bottleneck capacity is the efficient capacity that can be employed in the short-run, due to imbalance across resources. This is directly related to the concept of practical/normal capacity that is discussed in management accounting textbooks. In general, this is the capacity that would normally get utilized in the present environment, given the technology, uncertainty and adjustment costs. The difference between this and the efficient capacity provides a measure of the potential future growth that the management expects, and should, in general, be planned. Note that for at least one of the resources the difference between the efficient and bottleneck capacities will be zero. If the difference between efficient and bottleneck capacities is not zero, and the management did not plan for it, then the management can take actions to sublet/lease or look for alternative output markets to utilize the capacity.

Budgeted capacity**:** Budgeted capacity reflects the short-term plan and the difference between bottleneck and budgeted

[5] Balakrishnan and Sprinkle (2002) incorporate the effects of inventory changes in the "traditional" profit variance analysis.

capacity reflects the management's expectation of future growth potential.

The actual capacity utilization shows the extent of under utilization below the budget that may be due to inefficiencies. These have the importance of signifying inefficiencies in the process that may need corrective action. The actual capacity utilization may exceed the budgeted capacity. However, it cannot exceed the maximum capacity.

The overall unused capacity is the difference between the maximum utilization capacity and the actual capacity utilized. This is non-value added cost. The six capacity definitions enable desegregation of unused capacity cost into various categories that provide relevant information for appropriate managers. Given the above capacity definitions, several unused capacity costs or effects can be derived[6]. The rate per unit is computed as the Fixed cost divided by the maximum capacity.

We next provide a numerical example of the framework and discuss the implications for decision making by managers and investors.

[6] Definitions are as follows:

a. The *Uncertainty Effect* is the rate per unit times the difference between maximum and efficient capacities.
b. The *Bottleneck Effect* (or lumpiness effect) is the rate per unit times the difference between efficient and bottleneck capacities.
c. The *Practical Effect* is the rate per unit times the difference between bottleneck and practical capacities (provided they differ).
d. The *Budget Effect* (or stickiness effect) is the rate per unit times the difference between practical and budget capacities.
e. The *Adjustment Cost Effect* is the total of the Bottleneck Effect, Practical Effect and the Budget Effect.
f. The *Planned Unused Capacity* is the total of the Uncertainty Effect and the Adjustment Cost Effect.
g. *Unplanned Unused Capacity* is rate per unit times the difference between budget and the actual utilization capacities.
h. *Total Unused Capacity* is the sum of Planned and Unplanned Unused Capacities.

Numerical Example and Discussion

To illustrate the framework with an example, our focus is on creating a "summary report" of an income statement that will provide information for managers and investors.

Consider a chemical testing lab facility with three resources: testing staff, equipment and lab facility. The lab conducts a large variety of tests. An engineering study was employed to convert all the tests into one numeraire test (which is referred to as the test). Thus, the output is measured in terms of the number of tests.[7] The theoretical, maximum and the budgeted capacities should be obtained from management reports, a study of best competitor practices and engineering estimates. To get information on efficient capacity the expected fluctuations in demand and growth need to be obtained. Questions such as: what is the maximum demand in a given period that cannot be backlogged, what is the uncertainty with respect to labour force and production facility failures etc. need to be addressed.

In addition, using the mean demand and production rates, some queuing formulas and heuristics may be employed to arrive at the efficient utilization capacity. The bottleneck (practical/normal) capacity is derived directly by identifying the bottleneck resource. The resulting annual capacities are provided in Panel A of Table One.

[7] The engineering study essentially started with time as the measure and then converted the different tests into the typical high volume tests. In effect, we could have constructed the example with the time measure as the measure of output. In actual application, proper cost drivers should be chosen to represent the consumption of each resource as required by cause-effect allocation frameworks such as ABC. Thus each resource can have a different cost driver such as time spent on testing for staff resource, machine hours or time occupied for equipment resource and square feet occupied by staff and equipment for facility resource (using a two stage allocation). For this illustration, we avoid this unnecessary complication and use number of tests as the sole cost driver.

Table One: Numerical Example, Excess Capacity Characteristics

Panel A: Resource Capacity[a]

	Staff Resource	Equipment Resource	Facility Resource
Theoretical Capacity	30,000	40,000	60,000
Maximum Capacity	18,000	30,000	40,000
Efficient Capacity	15,000	20,000	30,000
Bottleneck Capacity	15,000	15,000	15,000
Budgeted Capacity	12,000	12,000	12,000

Panel B: Resource Cost

	Staff Resource	Equipment Resource	Facility Resource
Annual Cost	$360,000	$60,000	$180,000
Rate Per Test[b]	$20.00	$2.00	$4.50

Panel C: Financial Impact of Excess Capacity

	Staff Resource	Equipment Resource	Facility Resource
Uncertainty Effect[c]	$60,000	$20,000	$45,000
Lumpiness (Bottleneck) Effect[d]	$0	$10,000	$67,500
Stickiness (budget)Effect[e]	$60,000	$6,000	$13,500
Adjustment Cost Effect[f]	$60,000	$16,000	$81,000
Planned Excess Capacity[g]	$120,000	$36,000	$126,000

Notes to Table One

a. The capacity is in terms of output units, the number of tests.
b. The rate per test is the annual cost divided by the maximum capacity.
c. The uncertainty effect is the rate per test times the difference between maximum and efficient capacity.
d. The lumpiness (bottleneck) effect is the rate per test times the difference between efficient and bottleneck capacity.
e. The stickiness (budget) effect is the rate per test times the difference between bottleneck and budgeted capacity.
f. The adjustment cost effect is the total of the bottleneck lumpiness effect and the budget stickiness effect.
g. The planned excess capacity is the total of the uncertainty effect and the adjustment cost effect.

Panel B of Table One, provides the annual cost of each resource and the rate per test that are computed based upon the maximum capacity. From this we can determine the amounts and costs of excess unused capacity. The differential between maximum and efficient capacity are 3,000 [=18,000 – 15,000], 10,000 [=30,000 – 20,000], and 10,000 [=40,000 – 30,000] tests, for the staff, equipment and lab facility resources, respectively. This indicates the “buffer” effect due to uncertainty. Specifically, the uncertainty with respect to processing times is higher for the equipment, since the demand uncertainty is common to all resources. The lab facility resource shows a buffer primarily due to safety and environmental regulations and future expansion strategies. The differential between the efficient and bottleneck capacities are 0, 5,000 and 15,000 tests for the staff, equipment and facility resources; respectively and between bottleneck and budget it is 3,000 for all the resources. This is indicative of the adjustment costs associated with lumpiness and stickiness of the resources respectively. The staff resource is the least lumpy and can potentially be adjusted more easily to suit the demand conditions, than the equipment or the facility resource.

Panel C of Table One provides the financial consequences of uncertainty and adjustment costs. The cost of uncertainty is obtained by multiplying the cost per test for each resource and the differential between the maximum and the efficient capacity. Thus, for the staff resource the cost of uncertainty is $60,000 [=(18,000 – 15,000) 20]. Similarly, the cost of uncertainty is $20,000 and $45,000 for equipment and facilities respectively. The cost of bottleneck lumpiness (a portion of the adjustment cost) is obtained by multiplying the cost per test for each resource and the differential between the efficient and bottleneck capacities. The costs of bottleneck lumpiness are $0 [=(15,000 – 15,000) 20], $10,000 [=(20,000 – 15,000) 2], and $67,500 [=(30,000 – 15,000) 4.50] for the staff, equipment and facility resources, respectively. The adjustment cost effect of bottleneck lumpiness is much higher for the facility than the equipment, indicating that it is much easier to adjust the equipment capacity than the facility capacity. The cost of budget stickiness (the other portion of the adjustment cost) is obtained by multiplying the cost per test for each resource and the differential between the bottleneck and budgeted capacities. The cost effects of budget stickiness are $60,000 [=(15,000 – 12,000) 20], $6,000 [=(15,000 – 12,000) 2], and $13,500 [=(15,000 – 12,000) 4.50] for the staff, equipment and facility resources, respectively. The cost of budget stickiness reflects the unit cost of the resource, since the excess capacity is the same for all resources. As discussed earlier the cost of budget stickiness reflects the ramping-up of capacity in expectation of near range future sales.

In general, the practical or normal capacity could be lower than the bottleneck capacity if there are adjustment costs (budget stickiness or bottleneck lumpiness) associated with the bottleneck resource. In this example, if there are some employees who cannot be utilized to the fullest possible extent, because of attrition and training of new employees, the practical capacity of the staff resource can be lower than the efficient capacity of 15,000 tests. However, the staff resource will continue to be the bottleneck resource.

Table Two: Numerical Example, Income Statement – Internal Reports

Panel A: Data for the Year			
Number of Tests			10,000
Revenue per Test			$100
Materials and Other Variable Costs per Test			$25
Rate per Test Based on Budgeted Capacity (Fixed Costs)[a]			
Staff Resource		$30	
Equipment Resource		$5	
Facility Resource		$15	
Total Fixed Cost Per Test			$50
Rate per Test Based on Maximum Capacity (Fixed Costs)[b]			
Staff Resource		$20	
Equipment Resource		$2	
Facility Resource		$4.50	
Total Fixed Cost Per Test			$26.50
Panel B: Income Statement (Traditional) [c]			
Revenue	$100 x 10,000	$1,000,000	
Variable Cost	$25 x 10,000	($250,000)	
Fixed Cost	$50 x 10,000	($500,000)	
Normal Profit		$250,000	
Volume Variance	$50 x (10,000 – 12,000)	($100,000)	
Profit		$150,000	
Panel C: Income Statement (Excess Capacity Framework)[d]			
Revenue	$100 x 10,000	$1,000,000	
Variable Cost	$25 x 10,000	($250,000)	
Fixed Cost	$26.50 x 10,000	($265,000)	
Normal Profit		$485,000	
Volume Variance			
Planned Excess		($282,000)	
Unplanned Excess	$26.50 x (10,000 – 12,000)	($53,000)	
Profit		$150,000	

Table Two: Numerical Example, Income Statement – Internal Reports (cont'd)

Panel D: Volume Variance -- Excess Capacity Framework[e]

	Staff Resource	Equipment Resource	Facility Resource	Total
Uncertainty Effect	$60,000	$20,000	$45,000	$125,000
Lumpiness (bottleneck) Effect	$0	$10,000	$67,500	$77,500
Stickiness (budget) Effect	$60,000	$6,000	$13,500	$79,500
Adjustment Cost Effect	$60,000	$16,000	$81,000	$157,000
Planned Excess Capacity	$120,000	$36,000	$126,000	$282,000
Unplanned Excess Capacity	$40,000	$4,000	$9,000	$53,000

Notes to Table Two

a. The rate per test based on budgeted capacity is computed as the cost of the resource divided by the budgeted number of tests for the year.
b. The rate per test based on maximum capacity is computed as the cost of resource divided by the maximum capacity of that resource.
c. Income Statement (Traditional) is prepared using the rate per test based on the budgeted capacity.
d. Income Statement (Excess Capacity Framework) is prepared using the rate per test based on the maximum capacity.
e. The uncertainty, bottleneck lumpiness, budget stickiness and adjustment cost effects and planned excess capacities are defined in Table 1.
f. The unplanned excess capacity is the difference between the budgeted and the actual number of tests times the rate per test based on the maximum capacity.

Internal Reports

Table Two, Panel A provides the data for the given period. The actual number of tests during the period is 10,000, the price per test is $100, and the supplies and variable costs are $25 per test. The rate per test based on budgeted capacity, which is the traditional method of applying costs to the product is $30 [=$360,000/12,000], $5 [=$60,000/12,000], and $15 [=180,000/12,000], for the staff, equipment and facility resources, respectively. This gives a total fixed cost rate based on budgeted capacity of $50 [=$30 + $5 + $15] per test. The rate per test based on maximum capacity, which is based on our framework of applying costs to the product is $20 [=$360,000/18,000], $2 [=$60,000/30,000], and $4.50 [=180,000/40,000], for the staff, equipment and facility resources, respectively. This gives a total fixed cost rate of $26.50 [=$20 + $2 + $4.50] per test. The use of maximum capacity as the rate basis for applying fixed costs is consistent with McNair (2000), Klammer (1996), and Cooper and Kaplan (1992). The main difference is that the maximum capacity of each resource need not be the same, reflecting the adjustment costs and uncertainty effects that are attributable to each resource.

Panel B of Table Two provides the income statement under the traditional capacity measure, i.e., the fixed cost rate per test based upon the budgeted (practical/normal) capacity. The normal profit is $250,000 and there is an adverse volume variance of $100,000, due to the fact the planned activity level of 12,000 tests exceeded the actual number of tests of 10,000. This helps to identify the responsibility of the operating manager. For example, the $100,000 adverse volume variance could be beyond the operating manager's control.

Panels C and D of Table Two provide the income statement under our method of excess capacity reporting. The normal profit under our framework is much higher than the normal profit under the traditional method. The higher normal profits indicate the long-run margins, when the all the sales growth and capacities are balanced (as per long run management expectations). The volume variance under our framework leads to an adverse $282,000 planned and an adverse $53,000 unplanned. The unplanned volume variance is due to the volume variance under the traditional method, i.e., the difference between the budgeted and the actual number of tests. The planned excess capacity is explained in the excess capacity report in Panel D of Table 2.

The framework incorporates Deming's principles that either variability is a fact of life or only the top management can attend to it. Making the operating managers responsible for this could lead to gaming of performance measures and consequent adverse results. In essence, the planned excess capacity is the responsibility of the top management to attend to. An important point here is that the top management should not ask the operating managers to show a full utilization. This is because both uncertainty and adjustment costs require carrying some excess capacity. The report shows that the uncertainty related excess capacity associated with the facility and staff resources are quite high. Note that the excess capacity due to uncertainty arises due to stochastic processing times and demand fluctuations. The top management should consider aspects such as training the staff and improving business processes and procedures (reengineering efforts) to decrease the variability in processing times and consequently decrease the excess capacity due to uncertainty. Working with customers can help reduce the cost due to demand fluctuations.

The cost of budget lumpiness is highest for the facility resource followed by the equipment resource. This is in accord with intuition. The top management should review the capacity of the facility with the long-range plans to ensure that the excess capacity is in line with long-range plans. If not, the management can choose alternative lines of business and/or disinvestments if possible.

The budget effect reflects the cost of excess capacity to fulfil medium range demands. Similar to the bottleneck effect, the top management should review the capacity with medium range plans. The high cost of excess capacity of the staff resource to mitigate non-instantaneous adjustment of capacity (the stickiness effect), suggests that streamlining business procedures, automating training, decreasing attrition and accelerating the deployment of staff resources would help in decreasing the excess capacity of the staff resource. The unplanned excess capacity is the traditional volume variance.

The top-management can use this framework as an input to manage for impairment of assets. The Statement of Financial Accounting Standard (FAS) 144 requires that firms conduct an impairment of assets test at the business unit level and write-down and plan the disposition of the asset on a periodic basis. While FAS 144 requires that future cash flows be anticipated to perform the impairment test, our framework will provide critical information with respect to these tests. For instance, if the adjustment costs are high, and hence, firms carry a high level of excess capacity, the efficient utilization of capacity (the concept of allowing for randomness of demand and processing times) should provide the upper-bound for the future (long-term) cash inflows.

The planned excess capacity report would also provide information to the top-management to pursue strategic actions with excess capacity.[8] Specifically, the top-management can evaluate avenues for using excess capacity such as customer development, bundling, pledging, employee endowment, exchanging, entry deterrence and differentiation.[9] Overall, the income statement report would provide attention-directing cues that only the top-management can attend to.

From a product costing perspective, including unused capacity costs in the unit cost of tests results in over-costing. The best competitor with no or optimal unused capacity will include only $26.50 in the product cost whereas including the unused capacity costs for the illustrated company results in including a fixed cost of $50 into the unit test cost. It is advisable, from a management control perspective, to cost the test properly (comparable to the most efficient operation) and report the unused capacity cost separately. Management can then understand the market dynamics of the competitors better and strategize their operations accordingly.

External Reports

Financial reports of some industries contain information on capacity utilization. For instance, financial reports of airline companies provide the load factor (a capacity utilization measure). More recently, telecom companies sell, buy and swap excess capacity among them as part of managing capacity. Austen (2001) states, "... by some estimates, 80% of the world's fibre optic communications capacity now sits unused." Global Crossing, which filed for Chapter 11 bankruptcy protection in the USA, in early 2002 is under SEC scrutiny for alleged dealings in excess capacity, which were accounted for inappropriately (see Solomon, 2002, Berman, 2002). Similarly, the capacity of the semi-conductor industry largely remains unutilized with a capacity utilization of 66% (see Scovel, 2002). All of these point to the fact that capacity management and information on excess capacity are important information. As discussed earlier, excess capacity due to adjustment costs provide information on the management's expectations of future sales, and efficient capacity provides an idea about the level of uncertainty. However, the concept of efficient, bottleneck and budgeted capacities can be manipulated. Hence, providing an aggregate measure of excess capacity in terms of percentages would provide information on management's future expectations of sales and also, any strategic use of excess capacity. At least, in this way management will be forced to discuss the strategic use of excess capacity and the reasons for excess capacity – as opposed to pure empire building.

In our illustration, the total excess capacity (planned and unplanned) of $335,000 [=282,000 + 53,000] is divided by the total resource cost of $600,000 [=360,000 + 60,000 + 180,000] to get an excess capacity of 56%. While it would be useful to provide a break-up between the adjustment costs, planned and unplanned capacity – these measures might not be neutral, which is an important concept for verifiability.

We proceed with illustrating the framework with field data.

Empirical Analysis

We obtained data from an international semiconductor company based in Taiwan to investigate an application of the unused capacity framework. We chose a semiconductor company for the study as capacity utilization criteria is extremely important for such firms. Our conversations with the managers of semiconductor firms revealed that they pay particular attention to

[8] Note that here we are assuming that the opportunity cost of excess capacity is zero, because the capacity is in excess of the efficient level. To the extent that consumption can be stored the opportunity cost may not be zero (see Balakrishnan, et al., 2001).

[9] Ng, Wirtz and Lee (1999) conduct a survey and provide a framework for taking strategic advantage of capacity. The strategic uses of excess capacities are described in the study in detail.

building capacity, which commits a firm to a long-term costly investment and increases the necessity to strategically plan for optimal capacity utilization. In general, financial analysts following the semiconductor companies also monitor the capacity information closely, and may use it in their buy/sell recommendations.

We obtained 35 months data, spanning the period January 2002 to November 2004, from the studied company. We discussed the unused capacity framework with the company management and the company provided data for the following definitions of capacity: maximum capacity, budget capacity, and actual used capacity, along with the monthly revenues, variable costs, fixed costs and the actual number of order units. The company did not make a distinction between budgeted capacity and practical capacity. Also, the company could not provide us with data on the bottleneck capacity, because the production process is extremely complex and the company does not maintain records for each individual resource separately. In general, the resource constraints are used in their optimization programs to determine optimal production. The Industrial Engineering department estimates the maximum capacity based on certain assumptions primarily based on industry best standards. By checking the 35 months data we find that in a few cases the actual used capacity, in term of output unit, is higher than the maximum capacity. As per definitions, the actual used capacity cannot be more than the maximum capacity. Therefore, we replace the maximum capacity with the highest actual output unit among 35 months, which is 42,500, instead of using the number given by the firm.

The company does not have the data for efficient capacity. According to our definition, efficient capacity is the optimal utilization of capacity allowing for randomness in demand and production process. We estimate the efficient capacity by using the 35 months demand (actual order units) data in the following way:

*[1 – Standard Deviation of Demand Average Demand]*Maximum Capacity*

We use heuristic reasoning here rather than a queuing formula, as it is not possible to get all the parameter data that are required for the determination using the queuing formula. If the standard deviation is large in relation to average demand, the uncertainty due to demand is high and consequently the efficient capacity is smaller than the maximum. We do not incorporate uncertainty in the production process as the management felt it is not likely to be appreciable.

Descriptive Statistics

Table Three, Panel A summarizes the 35 months means and standard deviations of the variables for which we obtained data from the company. The Actual Order Booked has a mean of 34,087 units and a standard deviation of 11,030 with a coefficient of variation of 32%, exhibiting a high degree of variation; it ranges from a minimum of 15, 854 in September 2002 to a maximum of 49,635 in July 2004. The high variation arises because the semiconductor industry goes through significant fluctuating business cycles. The Sales Revenue has a mean of NT$ 1,797 million (Taiwan currency) and a standard deviation of 436 with a coefficient of variation of 24%, exhibiting lesser variation than the Actual Orders Booked or the Actual Capacity Used. The variable and fixed costs have means (standard deviations, coefficient of variations) of NT$ 247 million (45, 18%) and NT$ 645 million (94, 15%), respectively: they range from a minimum of NT$ 133 million and NT$ 481 million to a maximum of NT$ 322 million and NT$ 805 million, respectively. As such, costs exhibit a lower variance than the Orders Booked indicating that costs are controllable by the company, validating our belief.

Table Three: Semiconductor Company Analysis

Panel A: Descriptive Statistics of the Raw Data		
Variable	**Mean**	**Standard Deviation**
Actual Order Booked (Units)	34,087	11,030
Actual Sale (Unit)	33,361	10,998
Sale Revenues (NT$ Millions)	1,797	435
Variable Costs (NT$ Millions)	247	45
Fixed Costs (NT$ Millions)	645	94
Margin (NT$ Millions)	905	455
Panel B: Capacity Definitions		
Variable	**Mean**	**Standard Deviation**
Max Capacity (Units)	50,005	0
Efficient Capacity (Units)	34,003	0
Budgeted Capacity (Units)	35,949	3,390
Actual Capacity Used (Units)	34,314	11,295
Panel C: Unused Capacity Decomposition		
Variable	**Mean**	**Standard Deviation**
Uncertainty Effect (Units)	−16,002	0
Adjustment Effect (Units)	1,946	3,390
Unplanned Effect (Units)	-1,635	9,183

Notes: *The Company could not provide us with capacities for each individual resource. They did not keep such data. If we were to collect data over a period of time, we would collect for various resources. Given this, we have no information on bottleneck capacity. We calculated the uncertainty effect = difference between maximum and efficient capacities for each month; adjustment effect = difference between efficient and budgeted capacities for each month and unplanned effect = difference between budgeted and actual capacities for each and then calculated the mean and standard deviations of these numbers. The results are tabulated in Panel C.*

Table Three, Panel B provides the mean and standard deviations for several capacity definitions we have used in the decomposition of unused capacity. The maximum and efficient capacities are 50,005 units and 34,003 units (determined using our heuristic formula), respectively for all the 35 months with no deviation. There were no major capital enhancements during the sample period, and thus the maximum capacity can be assumed not to vary during the 35 months. The efficient capacity is the level of buffer capacity required to tide the sales variability. As discussed earlier, the semiconductor industry is subjected to sales volatility due to business cycles and consequently exhibits a high degree of variance in demand. A buffer capacity is maintained to accommodate this variation and is used in the determination of efficient capacity. The Actual Capacity Used has a mean of 34,314 units and a standard deviation of 11,295 with a coefficient of variation 33%, i.e., a high variation; it ranges from a minimum of 15,869 in month February of 2002 to a maximum of 50,005 in month November of 2003. The total unused capacity is 15,691 units on average, computed as the difference between maximum capacity and actual used capacity. Table Three, Panel C shows the uncertainty effect on average is an unfavourable 16,002 units, the adjusting effect of 1,946 units favourable, and the unplanned effect of 1,635 units unfavourable. The favourable effect in the adjustment effect is due to the fact that the firm budgets and operates at a higher level than the efficient capacity as calculated by our formula. In summary, the planned effect accounts for 89.6% of the unused capacity, and the unplanned effect for 10.4%. Among the planned effect, all the unfavourable effect is from uncertainty effect, which can be viewed as the strategic choice of the firm. The unplanned effect can, typically arise, due to inefficient plant management. However, this firm shows very low unplanned effects.

Capacity Changes and the Explained Effects over Times

In this section, we discuss the time series trend of the capacity definitions and the effects. In Figure One, the actual capacity used is very volatile, and the budgeted capacity is adjusted to the level of efficient capacity. It shows that the firm needs to improve the demand forecast or smooth the actual monthly capacity used through back ordering or inventory management.

Figure One: Capacity Changes over Time

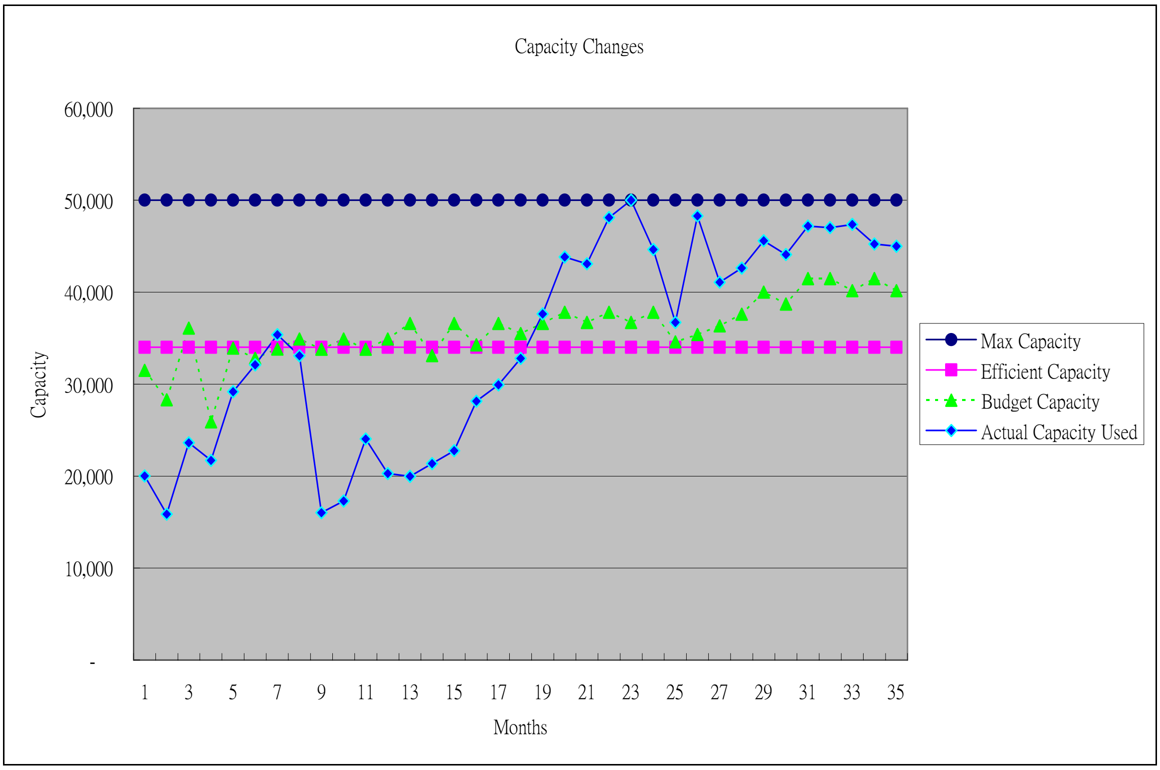
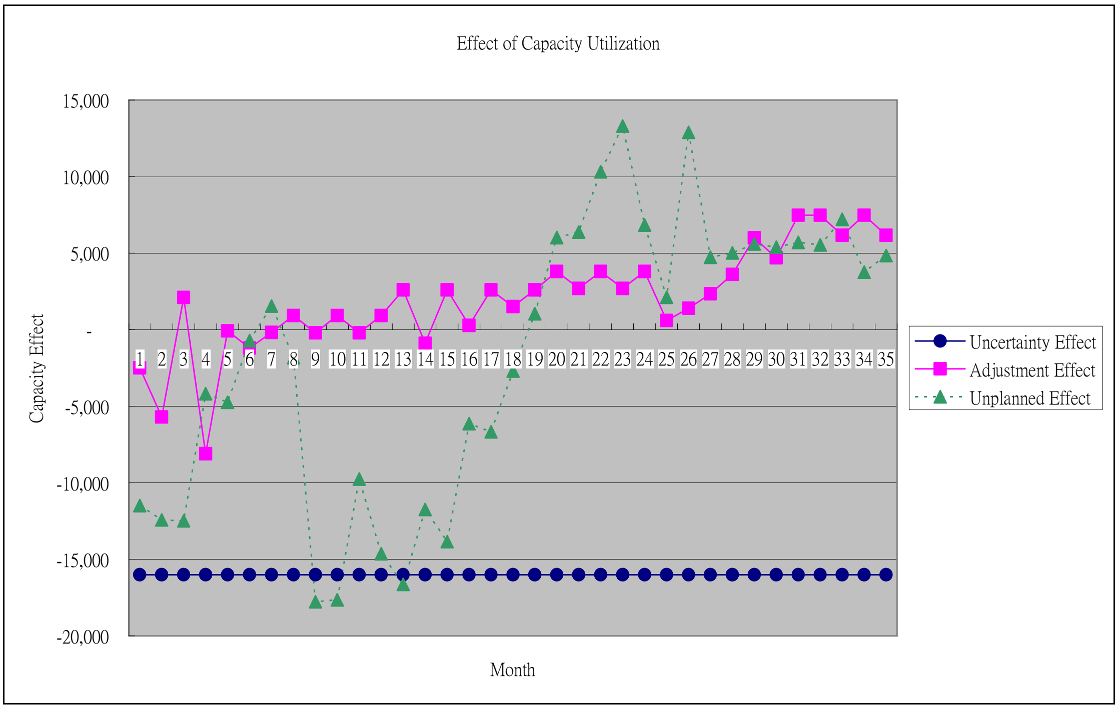


Figure Two: Effect of Capacity Utilization over Time



In Figure Two, the uncertainty effect is near negative 16,000. This means the current capacity of the firm is much larger than the actual demand required. This is likely to be due to strategic long run planning management decisions. The firm shows very low adjustment effects over time, and most of the months exhibit favourable adjustment effects. This low and favourable effect reflects excellent manufacturing management. The unplanned effect is volatile, reflecting again the volatility in demand and production.

Figure Three shows the planned effect reducing over time though the unplanned has high volatility

The Impact of Unused Capacity on Measurement of Product Costs and Pricing

The six capacity definitions are choices for calculating a predetermined resource cost application rate. However, not all are equally desirable candidates to be used as the base for calculating the rate. The product cost using the theoretical capacity as the base level will result in severe underestimation and is not usable for pricing purposes. No competitor can achieve this level of utilization. The efficient capacity level will over cost the product in comparison with a competitor who has better control of uncertainties. Passing on this excess product cost to the customer in terms of excess price will reduce market share in the face of competition. Practical/normal capacity and bottleneck capacity numbers as base levels will result in excess over costing of products in the presence of planned excess capacities in resources. This, again, will undermine competitive pricing. Using budgeted capacity will, in addition to over costing, result in excess fluctuation in product costs among periods of production. The actual capacity utilization, of course cannot be utilized for predetermining rates. The best choice is the maximum capacity for each resource. For every resource, its maximum capacity output should be used to obtain the predetermined rates. This will result in accuracy in product costs as it compares with the cost obtained by a competitor who has no or optimal excess capacity in resources. The product cost so obtained can be strategically used for competitive product pricing. The excess capacity costs calculated will help plan for alternate uses of excess resources and assignment of responsibilities for their existence.

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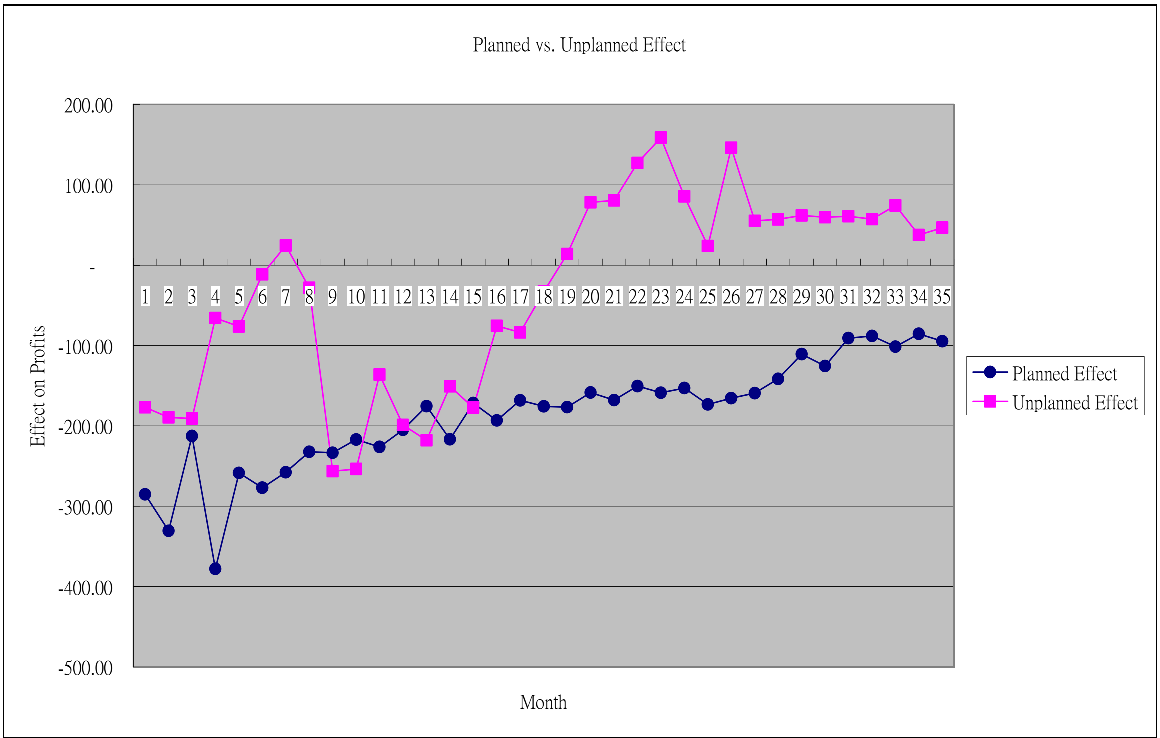
Figure Three: Unplanned Effects over Time



Concluding Remarks

We develop a framework for measuring and reporting unused capacity based upon the prime forces that lead to excess capacity – the uncertainty effect and the adjustment cost effect. The adjustment effect is further divided into bottleneck, practical and budget effects. The product cost obtained under our framework is smaller than the one obtained under the usual approach where the fixed unit cost is obtained by using a smaller base level of practical capacity. Unused capacity framework will clearly identify the costs of unused capacity and not bury it under the product cost.

We also demonstrate on how to implement this proposed theoretical framework to an international semiconductor company. It is inevitable some modifications and simplifications are required. However, these simplifications and modifications do not lessen the usefulness of our theoretical framework. We use the monthly capacity data to evaluate the capacity management and provide some evaluation of the field firm's capacity management strengths and weaknesses.

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