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CAPACITY ANALYSIS OF A SUGAR PRODUCTION PROCESS BASED ON THE COST OF UNUSED CAPACITY

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Abstract

The most widely used two measures to describe the usage of resources in production processes are capacity utilization and efficiency. This paper recapitulates and analyzes in details the problems linked to their application. Measuring capacity usage with conventional measures raises a number of problems, and frequently results in wrong management decisions. Hence, we have the need to introduce a technical parameters based measure but also with having an economic content. This new measure, the 'cost of unused capacity', is more and more often used to characterize resource usage even in non-technical systems. In order to apply this method including the new feature, we established a mixed integer linear programming model. The corresponding calculations will be demonstrated through an example of a small sample problem taken from sugar production industry.

Keywords: operations management, capacity analysis, managerial accounting.

1. Conventional Measures of Unused Capacity

Capacity is one of the most important measures of resources used in production. Its definition and analysis is therefore one of the key areas of production management. There are two widespread measures that can be used for the analysis of capacity usage. Capacity usage relates the actual output quantity to the quantity produced under ideal conditions (designed capacity), while efficiency compares the actual output with the maximum output possible according to the work schedule (effective capacity) (WATERS, 1991). It can be seen that the difference between the two measures stems solely from the planned and the foreseeable unused capacity. Foreseeable capacity losses are caused by planned batch setups, productivity problems known to the management and thus included in production, and shutdowns according to the work schedule.

It is worth examining what the practical reasons resulting in unused capacity are. The low capacity utilization of a process means that the equipment produces less than what it could. The measure reflects e.g. problems present in orders and material or tools supplies. Efficiency is a measure defined with more imposed conditions than capacity utilization, because it includes also planned shutdowns.

This measure can be improved by re-organizing production, setting up new shifts, re-scheduling breaks, etc.

Capacity usage and efficiency are common practical measures in technical areas. Their appropriateness becomes obvious when the company is hardly, or not at all, capable of satisfying the emerging need. Then, the resources used in production bottlenecks become extremely critical, so these conventional measures are regularly monitored, and efforts are made to improve them. Based on the monitoring results, there can be intervention aiming at the elimination of the unused capacity due to the bottleneck resource as early as during production. Typically, in relatively flexible mass production, where due to the mass nature, every capacity unit is important, and where due to flexibility it is simpler to intervene, capacity usage and efficiency are analyzed monthly, weekly, or even every hour, depending on the nature of the process. In the case of more rigid processes lending themselves less flexibly to changes, the measurement of usage parameters determines production management to a smaller degree, and interventions are less frequent.

Capacity enhancement is another far-reaching production management decision. It can be determined how much one wants to expand the bottleneck capacity, and to what extent the enhancement affects the utilization of auxiliary processes and that of other resources. This is important to note because here you calculate the measure values not for ongoing production, but for capacity planning.

2. Difficulties in Using Conventional Measures

The use of conventional parameters often leads to wrong decisions. Three aspects of the problem merit a detailed study: the absence of economic content, quantity based approach, and the unduly high emphasis laid on technical processes (KOLTAI – SEBESTYÉN, 1998).

The biggest problem is perhaps that, due to their technical nature, conventional measures do not provide a clue as to the value of the equipment under scrutiny. When evaluating equipment, it is apparent that if a cheap resource is left unused, the resulting error is less severe than in the case of an expensive one. During production, downtimes of newly purchased computer controlled manufacturing center cost more than those of a repeatedly upgraded automatic lathe waiting to be sent to scrap.

The quantity orientation of conventional capacity measures reveals that these do not refer to the necessity of capacity matched to need. In other words, in general, it is not known what the damages caused by yield reduction due to unused capacity are, nor can you tell what cost reductions could be achieved by eliminating unused capacities.

The technical nature of the measures derives from several sources. The historical reason is that they appeared when the weight of service processes in production systems was less dominant, and their management significance was accordingly smaller. Then, due to technical development, producers achieved greater and greater degrees of utilization producing more and more, so conventional measures played an important role. It was easy to quantify processes, the data required for calculations were easy to measure, and, finally, the capacities of machines and other equipment were simple to determine. However, the latest management methods like TQM and TPM, and the evolution of logistics results in promoted supplementing the old measures from the economic side, underlined the economic importance of the production-supplying environment. The increasing economic weight of the service sector also required the knowledge of efficiency. However, in this area, the data necessary for the calculation of conventional measures are often difficult to obtain.

If capacity measures could side step the problems discussed above, i.e. if they could include the value of resources, and could refer to the costs of unused capacity, then better decisions could be made in a number of cases. Changes in the nature of production, and the enhanced significance of auxiliary processes made calculations necessary for production and service types where processes are difficult to quantify. The appearance of activity-based costing (ABC) solved precisely these problems, because the main goal of the method is to analyze and differentiate the overhead costs associated with capacity maintenance and operation. When using ABC for the determination of cost data, the results are also appropriate for performing capacity usage calculations (COOPER, 1988; LEWIS, 1993).

3. Economic Description of Unused Capacity

The ABC calculation attempts to approximate an ideal situation where the overhead is only incorporated in the product to the extent it actually exploits its resources. In the past, due to the small ratio of overheads, it was sufficient to use a single cost driver for overhead allocation. The presently observed growth of the ratio of overheads makes it important to accurately allocate them to different products. Different products use resources to a different extent, therefore, several cost drivers are used. The ideal case would of course be to use a separate cost driver for every cost, but this is impossible to realize in practice. Costs must be grouped, and a characteristic cost driver must be assigned to each cost group. The ABC method works on the basis of this principle (COOPER, 1988; KOLTAI, 1994).

In the course of describing capacity through an economic measure, the costs associated with capacity maintenance and operation must be determined. Generally, the costs can be split up into two groups. The relation of *direct costs* with the product or service can be stated unequivocally, and their magnitude varies proportionally to the quantity of the latter. Accordingly, the direct material cost can be determined precisely in every finished item produced. Material costs are influenced by the produced quantity, and by proportion actually incorporated in the finished product. Similarly, the cost of a worker paid on a performance basis can be calculated directly, because it is known precisely how long it takes him/her to produce a product item. The relation of *overheads* with the product is more complicated. A good example is provided by the wages of a maintenance worker. The worker in question performs maintenance operations on several of the machines owned by the company. It is very difficult to trace the cost of the maintenance worker to the individual products. The ABC method is capable of measuring more accurately the usage of these overheads. The essence of the method is to collect the direct costs of products and services, and to project the overheads on products according to some approximation scheme best expressing the actual usage. Overheads are mainly fixed, because increased quantities affect their magnitude only negligibly, or not at all.

To perform a capacity calculation, one has to know the ratio of the costs of the machine, equipment, plant or division depending on, and independent of, the output. These costs are closely related to the resource where they appear. The operated resources can be divided into groups on the basis whether they are provided according to their usage needs or in advance, without the prior knowledge of these needs (COOPER – KAPLAN, 1992).

There is no capacity problem associated with *resources provided on the basis of direct needs*, because these are provided on the basis of known or estimated needs. E.g. there is a known quantity of parts or base materials supplied for the production of an order of a well-defined quantity. There is an estimated workforce to be employed for seasonal works (provided the magnitude of seasonal needs is known). It goes without saying that even in the case of resources allocated on the basis of direct needs, it may happen that the available quantity is not immediately used. The gap between available and used quantities can be bridged by inventory.

Resources provided in advance are those that are made available independent of direct needs. Even though needs are forecasted by different methods to some degree, still there is the constraint of availability prior to the time when the need actually appears. E.g. when equipping a plant with machines, it is the equipment itself that constitutes the resource made available in advance. Precious machines and equipment parts must be purchased subsequent to plant planning, but prior to starting production, and there are no needs to be counted with this time. A typical example is the employment of permanent workforce. In this case, the workforce is available for a given period in the short run, independent of the task to be performed. If the resources in question are not fully exploited, a capacity surplus is created. The difference between the available and the actually used quantities is called unused capacity. Unused capacity and stored stocks are both to be avoided by management. However, the most important difference between them is that inventory remains usable, perhaps at a later date, while unused capacity is lost in production.

There are three typical groups of resources provided in advance. One of them is *investment*. The company invests in machines, equipment, or buildings that present costs to be paid in advance and that are expected to operate for quite a number of years. The need is known in part due to forecasting methods and different profitability calculations, but still, the operating costs must be paid without the actual (prior) knowledge of the need. The periodic costs of resources made available in advance are basically depreciation and maintenance costs. Another cost type is *contract* costs. In this case, the company signs a contract for the future use of a service. A typical example is when an economic unit suffering from capacity shortages rents the free storage or equipment capacity of another company, or pays in advance for the future availability of credits or resources provided by a financial institution. The third and last typical example is that of *workforce*. This includes those employees who are paid a fixed wage (e.g. administrators). These wages must be provided in advance, irrespective of the future magnitude of the actually observed need.

4. The Capacity Balancing Model

The *cost of unused capacity* can be calculated when the specific resource cost, the actual resource usage and the planning capacity are known. The determination of the group of resources allocated in advance, the collection of their fixed costs, and the measurement of the actual capacity usage require the development of the management information system (COOPER – KAPLAN, 1999). The analysis of the cost of unused capacity is based on the following simple formula:

Activity Availability = Activity Usage + Unused Capacity

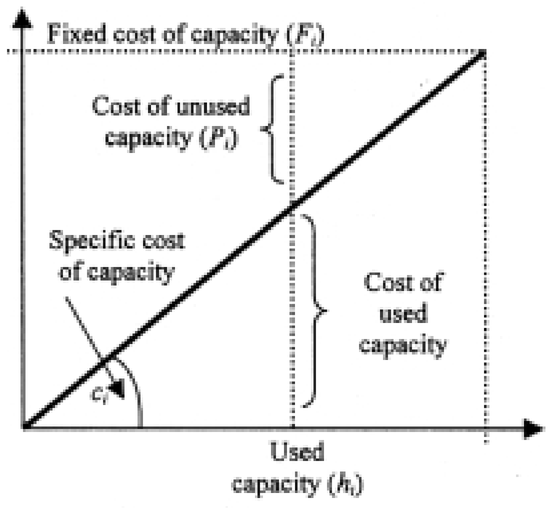

Fig. 1. Interpretation of the cost of unused capacity

The cost of capacity is the entire cost paid beforehand to obtain the resource under consideration. This consists of the costs of capacity rightfully used in operation – also called exploited – and the cost of unnecessarily allocated, that is, unused capacity, as shown in *Fig. 1* (COOPER – KAPLAN, 1992; KOLTAI – SEBESTYÉN, 1998). The separation into two parts of capacity costs can be appropriately done by linear approximation. There also exist theoretical models for the description of

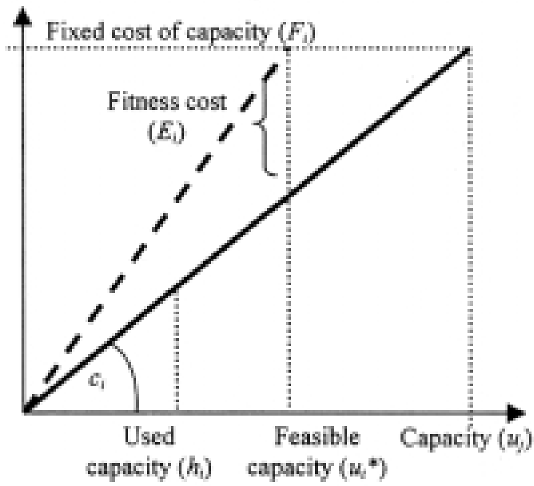

Fig. 2. The fitness cost

capacity utilization costs in terms of a non-linear function, but they are seldom used in practice. Dividing the costs of availability during a given period of the resource by its quantity available during the same period of the resource, you obtain the specific cost of the resource in question, which is just the slope of the linear function shown in *Fig. 1*. Knowing the quantity of used resource and the specific cost it is easy to calculate the *cost of unused capacity*. If u_i is the capacity, h_i is the actual production, and F_i is the total fix cost of the resource, then the unused capacity is given, according to *Fig. 1*, as

$$P_i = f_i \left(1 - \frac{h_i}{u_i}\right). \tag{1}$$

Fig. 2 shows that if the bottleneck resource is only able to produce u_i^*, then you can define the *fitness cost* (KOLTAI, 1995):

$$E_i = f_i \left(1 - \frac{u_i^*}{u_i}\right). \tag{2}$$

The cost of unused capacity has a certain prehistory. In the foreign literature, COOPER and KAPLAN displayed the appearance of the cost of unused capacity in the contribution statement report taking Hewlett-Packard as an example. LADÓ (1981) in his work defined the same quantity through a standard cost calculation but used the name passive costs, and supplemented it with the notion of *intensity difference*, the latter being the cost of bound capacity not justified by technology. Developing the method introduced by LADÓ, KOLTAI separated calculations done for fixed and proportional costs in standard cost calculation (KOLTAI, 1992). Although the method of LADÓ is a general one that can be applied to systems other than technical, it still became known mainly in the machine-producing industry, due to more favourable data collection conditions.

To calculate the cost of unused capacity, you need the capacity, the usage and the overhead of the resource to be considered, which are in turn supplied by the ABC system. Let us take e.g. the monthly fixed cost of machine setup to be \$600, and its capacity to be 300 hours. If in given months the setups required 250 working hours, then according to *Fig. 2* the cost of unused capacity is

$$E_i = f_i \left(1 - \frac{u_i^*}{u_i}\right) = 600 \left(1 - \frac{250}{300}\right) = \$100.$$

The analysis can be done for the actual resource, for a part of the resource, but also in an aggregate way for the set of resources belonging to more than one activity center. It must be stressed that here you have a cost type that does not appear in the accounting report. If it did, that would mean that the same cost is included twice in the report. That is, this cost cannot be interpreted from the accounting point of view, but it is nevertheless an important information for management decisions.

The application possibility of the cost of unused capacity will be demonstrated on the following example. When making capacity enhancement decisions, one often encounters the problem that the bottleneck migrates, and the desired output value can only be achieved after a whole series of enhancements. However, the series of enhancements made in order to realize the output quantity set for target may result in the formation of an entire set of unused capacities, generated around the new bottleneck arising as a consequence of the process, not to mention that the same problem of unused capacities may arise prior to the enhancement, too. The model described below attempts to perform an economic system enhancement for the quantity defined by the market limitation. The mixed integer valued programming model proposed for the analysis of the problem is the following:

$$z = \max\left(Bf - \sum_{i=1}^{N} c_i s_i - \sum_{i=1}^{N} b_i x_i\right) \quad (3)$$

subject to

$$B = \mathrm{MIN}\,[K_i + x_i \Delta K_i], \quad i = 1, \ldots, N, \quad (4)$$

$$s_i = \mathrm{MAX}\,[K_i - B; 0], \quad i = 1, \ldots, N, \quad (5)$$

$$B \leq M, \quad (6)$$

where

N	–	the number of resource groups in the system,
B	–	the capacity of the bottleneck of the system,
K_i	–	the capacity of the ith resource group ($i = 1, \ldots, N$),
ΔK_i	–	the capacity enhancement unit of the ith resource group ($i = 1, \ldots, N$),
s_i	–	the free capacity of the ith resource group ($i = 1, \ldots, N$),
c_i	–	the unused capacity of the ith resource group ($i = 1, \ldots, N$),
f	–	the contribution margin of the product,
b_i	–	the fixed cost increase due to the enhancement of the ith resource group ($i = 1, \ldots, N$),
M	–	the maximum number of products that can be sold on the market,
$\boldsymbol{x_i}$	–	**decision variable**, the number of enhancement units of the ith resource group ($i = 1, \ldots, N$).

The objective function (3) uses the contribution margin of the total produced quantity, the increase of fixed cost due to the enhancement, and the cost of unused capacity to generate the objective function of which the maximum is sought. Condition (4) can be used to obtain the quantity passing through the system bottleneck (B). Condition (5) calculates the magnitude of the unused capacity expressed in product units (e.g. pieces, tons, etc.). Condition (6) specifies the maximum output quantity. *Eqs.* (4) and (5) can be transformed into a set of linear constraints (HILLIER – LIEBERMANN, 1986).

5. Illustration of the Capacity Balancing Model

It was mentioned in the previous chapter that the objective function (3) is questionable from an accounting point of view. To obtain the process profit, you have to drop the second term incorporating the cost of unused capacity, and include the fixed costs of the system prior to enhancement. However, this latter is a constant value having no impact on the outcome of optimization. The objective function, having no accounting interpretation, can nevertheless assist in the definition of the efficient direction of capacity enhancement. To make decisions on capacity enhancement, you work with an objective function incorporating the cost of unused capacity, while the results must be evaluated using – in accounting terms – correct elements. We wish to demonstrate this by using a simplified version of the actual production process that is an elementary and transparent model of the true situation duly modified in order to respect data security.

Fig. 3 shows the three main resource groups of sugar production. In this example, the actual and potential bottlenecks are given by juice filtering, distillation and thick juice technologies. In the case of juice filtering, the present capacity (K_i) is 6000 tons of sugar beet (TSB) per day. An enhancement can permit the purchase of 800 sugar beet tons daily capacity (ΔK_i) units. The increase in fixed costs due to the enhancement (b_i) is \$40 per unit per day. It must be pointed out that this

Table 1. Input data of the example

x_1	x_2	x_3	s_1	s_2	s_3	B		
−40	−100	−22	−0.05	−0.1	−0.2	0.4		
−800	0	0	0	0	0	1	≤	6000
0	−1000	0	0	0	0	1	≤	4500
0	0	−1100	0	0	0	1	≤	5500
−800	0	0	1	0	0	1	=	6000
0	−1000	0	0	1	0	1	=	4500
0	0	−1100	0	0	1	1	=	5500
0	0	0	0	0	0	1	≤	10000

Table 2. Solution of the sugar industry example

Cost of capacity	x_1	x_2	x_3	s_1	s_2	s_3	B	z	f
$c_i \neq 0$	5	6	4	100	600	0	9900	3007	0.4
$c_i = 0$	5	6	5	0	500	1000	10000	3090	0.4

high value is due to the projection of the annual cost onto the 90 day long average seasonal period. The estimated cost of unused capacity (c_i) is $0.05/sugar beet ton. By determining the data relevant to the distillation block and the thick juice technology the same way, one can draw up the model (3)–(6). The coefficient matrix and right hand side elements of the model are given in *Table 1*.

The model leads to a mixed integer valued programming problem that can be solved without great difficulty with the aid of operational research software developed for this purpose.

The solution of the mixed integer valued programming model is shown in *Table 2*. Assuming a contribution margin of $0.4/sugar beet ton, the model suggests the purchase of 5 enhancement units for juice filtering, 6 units for the distillation block, and 4 units for the thick juice technology, respectively. This would permit the production of 9900 sugar beet tons/day. If we neglected the cost of unused capacity from the objective function ($c_i = 0$), then the resulting values for the number of enhancement units would be 5, 6 and 5. The 10000 sugar beet tons/day capacity obtained this way exceeds that of the $c_i \neq 0$ model, but still the result incorporating the cost of unused capacity gives a better result in terms of the efficiency of the enhancement. The result contains different x_i values (that is, enhancement is done in a different way when capacity costs are neglected), because the decision is based on the combination of capacity and enhancement costs. When the algorithm attempts to approximate the theoretical market limitation to the greatest extent possible, the degree of under–utilization of the individual resources is also taken into account.

It goes without saying that the resource getting closest to maximum capacity will be the one with the highest fixed cost paid for operation. This also includes the fact that in the case of enhancements, there is an increase of fixed costs associated with the extra capacity units. Therefore, the model will optimize the results using the enhanced, newly determined capacity and the new costs. A careful study of the Table reveals that the model provides different solutions depending on the inclusion or absence in the objective function of the cost derived from unused capacity.

It proves to be instructive to examine in what instances does the inclusion of the *costs of unused capacities* influence management decisions. As the contribution margin is increased, the data will attain a point where the yield influences the objective function so much that it becomes worthwhile to produce at maximum output notwithstanding the cost of unused capacity. This yield to total costs ratio (that in making the decision includes the *cost of unused capacity*) will determine whether or not the model gives a solution that depends on the cost of unused capacity.

According to *Fig. 1*, the relationship between c_i and b_i of the model can be simply written as follows:

$$c_i = \frac{b_i}{\Delta K_i}. \qquad (7)$$

This assumption means that the difference between the fixed specific costs of the enhanced and the already existing resource is small. This serious restriction can be relaxed easily at the expense of making the model more complex. In order to perform the sensitivity test, it proves to be convenient to introduce the following quotient:

$$m = \frac{f}{\sum c_i} = \frac{a - k_p}{\sum c_i} = \frac{a}{\sum c_i} - \frac{k_p}{\sum c_i}, \qquad (8)$$

where
a – the unit price,
k_p – the variable cost.

The contribution margin is nothing else but the difference between the unit price and the cost of the product. As it is well-known, the role of the specific product contribution margin is to contribute to the corporate level contribution margin, which actually appears in the objective function. The contribution margin is in the numerator, whereas the total specific fixed costs go into the denominator. It is likely that for higher values, that is, for increased contribution margin, the cost of unused capacity will be less significant, because the ratio of unused fix costs referred to above becomes so small that it is better to produce at full capacity regardless the penalty engendered by them. However, the diminishing ratio means that in our decisions, the *cost of unused capacity* will be a major influencing factor, therefore it will be beneficial to select a production strategy wherein there is no significant unused capacity on the machines. Thus this formula also expresses the rate of fixed to proportional costs. The sensitivity analysis of integer mathematical programming problems can seldom be done analytically, so we will analyze the impact of the objective function coefficients on the optimum solution empirically. However, it is hoped that in practice the test based on the m measure can also

Table 3. Sensitivity analysis of the sugar industry example

Models		x_1	x_2	x_3	s_1	s_2	s_3	B	z	m
M1	$c_i = 0$	5	6	4	100	600	0	9900	16372	5
	$c_i \neq 0$	5	6	5	0	500	1000	10000	16590	–
M2	$c_i = 0$	5	6	4	100	600	0	9900	19540	5.91
	$c_i \neq 0$	5	6	5	0	500	1000	10000	19790	–
M3	$c_i = 0$	5	6	5	0	500	1000	10000	19640	5.94
	$c_i \neq 0$	5	6	5	0	500	1000	10000	19890	–
M4	$c_i = 0$	5	6	5	0	500	1000	10000	19840	6
	$c_i \neq 0$	5	6	5	0	500	1000	10000	20090	–
M5	$c_i = 0$	5	6	5	0	500	1000	10000	23340	7
	$c_i \neq 0$	5	6	5	0	500	1000	10000	23590	–

Table 4. Cost analysis of the sugar industry example

Models		Profit increase	Cost increase	Ratio
M1 ($m = 5$)	$c_i = 0$	1.75* (9900 – 4500) = 9450	40*5 + 100*6 + 22*4 = 888	10.64
	$c_i \neq 0$	1.75* (10000 – 4500) = 9625	40*5 + 100*6 + 22*5 = 910	10.57
M2 ($m = 5.91$)	$c_i = 0$	2.07* (9900 – 4500) = 11178	40*5 + 100*6 + 22*4 = 888	12.59
	$c_i \neq 0$	2.07* (10000 – 4500) = 11385	40*5 + 100*6 + 22*5 = 910	12.51
M3 ($m = 5.94$)	$c_i = 0$	2.08* (10000 – 4500) = 11440	40*5 + 100*6 + 22*5 = 910	12.57
	$c_i \neq 0$	2.08* (10000 – 4500) = 11440	40*5 + 100*6 + 22*5 = 910	12.57
M4 ($m = 6$)	–	2.1 * (10000 – 4500) = 11550	40*5 + 100*6 + 22*5 = 910	12.69
M5 ($m = 7$)	–	2.45* (10000 – 4500) = 13475	40*5 + 100*6 + 22*5 = 910	14.81

provide useful information as to the significance of the cost of unused capacity. The solution of the mixed integer programming model including different values of the measure incorporating contribution margin and fixed costs per sugar beet ton are given in *Table 3*.

The values displayed in the *Table 3* reveal that up to the point $m \leq 5.91$, there exists a contribution margin/fixed cost ratio for which decisions are indeed influenced by the unused capacity. In our case, the model provides different conclusion (x_3) for the enhancement of the third resource, the thick juice technology. If m is large enough, then the contribution margin suppresses the costs to a point where the latter can no longer influence the enhancement decision. For the contribution margin value of our example, $m = 1.14$. The value of m is thus far below the limit given above for which the cost of capacity does not count any more. In conclusion, this is important in our example, which is also supported by the results of the calculation, i.e., the different x_i values obtained.

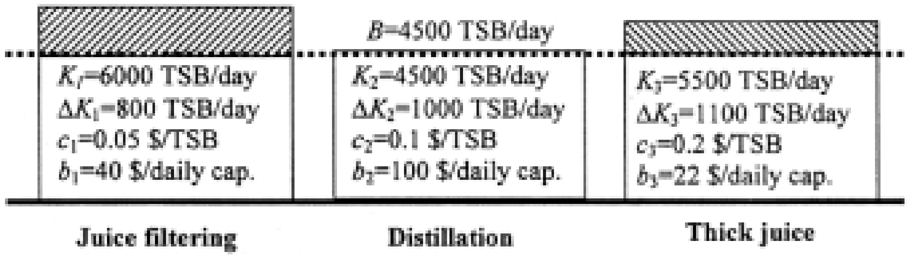

Fig. 3. Graphical illustration of the capacity balancing problem

Table 4 examines the profit increase to cost increase, also called specific yield increase. It can be seen that below the $m \leq 5.91$ point already mentioned, it is worth paying attention to unused capacity when making decisions. Where the c_i values were included, the specific dividend increase systematically turned out to be larger. Above the $m = 5.91$ point, both models suggest the same enhancement option irrespective of the cost of capacity, therefore it is useless to calculate the specific yield increase.

$$Bf \geq \sum_{i=1}^{N} c_i s_i - \sum_{i=1}^{N} b_i x_i . \tag{9}$$

Substituting the *m* measure thus derived into the objective function, one obtains the following expression:

$$z = \max \left(Bm \sum_{i=1}^{N} c_i - \sum_{i=1}^{N} c_i s_i - \sum_{i=1}^{N} c_i \Delta K_i m \right) . \tag{10}$$

Because the only other variable besides *m* in the objective function is s_i, the measure can be applied under the previous assumptions if a certain error is understood. That is, the contribution margin must be examined in proportion to c_i because eventually it is these two factors that determine the final result in the objective function indirectly, through many other factors depending on the result of the calculation.

6. Summary

Within a certain framework, the *cost of unused capacity* has proved to be a method lending itself very well to practical applications concerning management decisions. Its use allows one to develop a more efficient capacity enhancement strategy, and at the same time to avoid the problems associated with conventional measures. The applicability of the mixed integer-programming model including the cost of unused capacity was analyzed through a sensitivity analysis. The measure used for the study, also incorporating the contribution margin-to-fixed cost ratio made it possible to identify the group of processes for which it is useful to use a model including the cost of unused capacity for enhancement decisions.

The calculation was done with several simplifications and used modified data. In order to guarantee data security, the data used in the example were altered. The daily capacity was assumed to be constant for the entire period examined. No distinction was made between the different costs of the old and the new, enhanced capacity units. Further research will be needed to develop the model to differentiate between the specific cost of enhanced resources and that of the original ones. As presented, the model is only suitable to study continuous production. The generalization of this situation is also a topic of future research.

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