

Working Paper 93-16
Economics Series 03
June 1993

Departamento de Economía de la Empresa
Universidad Carlos III de Madrid
Calle Madrid, 126
28903 Getafe (Spain)
Fax: 34-1-624-9875

CAPITAL BUDGETING AND FLEXIBLE MANUFACTURING

María J. Alvarez Gil*

Abstract

The lack of measurement and evaluation of flexible manufacturing possibilities seriously handicaps the appraisal and justification of investments in flexible technologies. It is the goal of this paper to formulate a comprehensive definition of manufacturing flexibility which can be explicitly translated into economic and financial variables. Further translation is based upon the financial instruments of cash budgeting and capital budgeting.

The sensitivity of the economic and financial variables to shifts in manufacturing/operational flexibility will be discussed from a theoretical point of view. It is concluded that operative variables for flexible technologies can become indicators of economic and financial aspects.

Key Words

Manufacturing Flexibility, Capital Budgeting, Cash Management, Advanced manufacturing technologies

* Alvarez, Universidad Carlos III de Madrid. Research partially supported by SEC93-0835-C02-02 and SEC93-0835-C02-01 (Spain)

CAPITAL BUDGETING AND FLEXIBLE MANUFACTURING

María J. Alvarez Gil ¹
Universidad Carlos III de Madrid

Abstract

The lack of measurement and evaluation of flexible manufacturing possibilities seriously handicaps the appraisal and justification of investments in flexible technologies. It is the goal of this paper to formulate a comprehensive definition of manufacturing flexibility which can be explicitly translated into economic and financial variables. Further translation is based upon the financial instruments of cash budgeting and capital budgeting.

The sensitivity of the economic and financial variables to shifts in manufacturing/operational flexibility will be discussed from a theoretical point of view. It is concluded that operative variables for flexible technologies can become indicators of economic and financial aspects.

Key Words

Manufacturing Flexibility, Capital Budgeting, Cash Management, Advanced manufacturing technologies

¹ Research partialled supported by SEC93-0835-C02-02 and SEC93-0835-C02-01 (Spain)

1.-Introduction

Considerations of improved productivity and production flexibility have assumed major importance in the design and operation of manufacturing systems. The globalization of competition has clearly underlined the need for greater manufacturing effectiveness. Moreover, shorter product life cycles, and greater product proliferation and market fragmentation indicate that manufacturing flexibility should be considered for the long-term viability of many firms [2].

It is well recognized that Advanced Manufacturing Technologies are not inherently profitable. Everything depends on their strategic selection and creative development. Large payoffs await companies willing to experiment with new managerial approaches to these technologies. Realizing the full potential of new computer-controlled design, production, and manufacturing planning and control requires developing (the knowledge of) the technical and infrastructural elements which create flexibility. This implies that the need to understand the sources and uses of flexibility has never been greater.

Although manufacturing flexibility has generally been recognized as an important competitive weapon in Operations Management [3], it seems that the concept itself has not yet been clearly understood in industry [4]. If this is so or if its value cannot be ascertained in a way that is meaningful to Operations Management, it is less likely to be incorporated into the OM strategy [5].

To explore the links between strategy and flexibility, it is useful to work within a broad context [6], as suggested by the conceptual framework illustrated in Figure 1. This framework is a modified contingency model that came forward from organization theory and

manufacturing strategy literatures [7], [8]. Manufacturing strategy and investments in production technology, such as in Advanced Manufacturing Technology, are related by virtue of their interactions with environmental uncertainties, manufacturing flexibility and performance measures. The driving force is an organization's task environment; management has to learn to cope with uncertainties arising in the product market or in the production process and its inputs. Managerial learning is reflected in a manufacturing strategy that tries to adapt to the uncertainties and /or attempts to proactively control uncertainties [9]. Manufacturing flexibility is needed to adapt to uncertainties; it allows a corporation to respond effectively to changing circumstances [10].

----- insert Figure 1 about here -----

Figure 1: Conceptual framework - links between strategy and flexibility

In the above conceptual model, any need for flexibility is supposed to be met through capital investment in production technology, thus making the design and justification of Advanced Manufacturing Technologies a salient issue. However, this does not imply that other means can not be used to create flexibility, for instance by product design, subcontracting, work organization, materials management and so on.

A majority of plant managers identify flexibility as a critical task for future competitiveness [11]. However, none of the plants included it among their top three formally tracked objectives for planning and control. This observation was reconfirmed by the research conducted in 1987 by The Manufacturing Roundtable of Boston University [12]: Flexibility

was ranked from fourth to eight (depending on the industry) in importance for future competitiveness, and first in the size of the strategic gap (i.e., the difference between current capability and future needs). Typically, flexibility did not appear at all in a list of ten key performance measures. The 1990 Boston University Manufacturing Futures Survey [13] also confirms it. Two explanations were proposed for the discrepancy between the strategic role of flexibility and the little, if any, attention paid to the development of flexibility performance measures. First, in contrast to cost, delivery and quality, which have been the cornerstones of manufacturing planning and control for many years, flexibility as a top priority has only recently come to the fore. Consequently, even on a conceptual level, it tends to be discussed relatively less often and, if discussed, usually on a somewhat abstract basis. Second, and linked to the first argument, the technology for measuring flexibility is poorly developed. That is, in spite of its importance, flexibility is rarely explicitly measured and is often excluded from the operational control systems of manufacturers. From these observations, it is concluded that there is a strong necessity to develop a measure of manufacturing flexibility, both conceptually and operationally [11].

The problem of understanding and measuring manufacturing flexibility has received considerable attention in recent years. Further research has pointed out that major hurdles to our understanding of manufacturing flexibility are the lack of a consensus on the terms used to describe flexibility [9]:

- (i) the scope of flexibility related terms used by various authors overlap considerably;
- (ii) some flexibility terms are aggregates of other flexibilities terms;
- (iii) identical flexibility related terms used by more than one author do not necessarily mean the same thing.

A large number of studies have looked at the various types of flexibility in manufacturing systems and have proposed different approaches to measure it. In an extensive survey of the studies on the issue of flexibility in manufacturing [14], it was observed that at least fifty different terms for various types of flexibilities can be found in the manufacturing literature and that several terms are used to refer to the same type of flexibility.

The multitude of flexibility measures contributes a great deal to our understanding of the multi-dimensional nature of manufacturing flexibility [5]. However, many of the measures suffer from the following limitations:

1. They are nonfinancial measures, except for a few in which dollar values have been suggested for the shadow prices of resources or for product switching costs.
2. They are local measures, i.e., they look at only a few dimensions of manufacturing flexibility and thereby ignore possible trade-offs that may exist between the different dimensions.
3. They are isolated measures, i.e., they are formulated independent of the environment in which the manufacturing system functions.

Further complicating factor, these authors comment, is the fact that an appropriate time horizon must be specified to measure the value of any type of flexibility. It is thus evident that it perhaps is impossible to find a general measure of flexibility that captures its value along all dimensions and that is appropriate over all time horizons.

Although there is as yet no complete consensus on the definition of the dimensions of manufacturing flexibility, insight has advanced to the point where the focus of research on

flexibility should shift [15]. However, much less has been done to make these measures operational [16], [17].

So far, there is an imperative need to ascertain the value of the flexibility of a manufacturing system as a whole; this value has to be stated in such a way that managers can appraise and justify the flexible technology investments. With this need in mind, it is the goal of this paper to propose (1) a value-based approach for the measurement of a manufacturing system's flexibility which focuses on the manufacturing variables that are particularly relevant in the economic and financial justification of manufacturing flexibility; this approach will consider both long-term and short-term manufacturing/operative and financial variables, and (2) an early warning system for the study and sensitivity analysis of the financial and economic variables to shifts in manufacturing flexibility.

The remainder of this paper is organized in the following manner:

I first characterize the specific nature of the manufacturing flexibility that is being evaluated and identify the different types of flexibility that are included in this characterization. A capital and treasury budgeting-based approach is then proposed to measure and justify the investments in flexible technology. Next, an early warning system is suggested that can be used to help management efforts in translating manufacturing variables into economic and finance variables. Finally, a summary and some concluding remarks are provided.

2.-Flexible manufacturing: operative variables (characterization and measure)

The starting point for the development of a value-based approach to the measurement of the flexibility are studies by Gupta and Somers [1] and Sethi and Sethi [14]. This approach will

simplify the financial justification of flexible manufacturing technologies investments. According to the outcomes of the study by [1, pp 170-171], it can be suggested that the manufacturing flexibility is a compound of the following flexibilities:

MACHINE FLEXIBILITY deals with the variety of operations that a machine can perform without incurring high costs or using prohibitive amounts of time in switching from one operation to another. Machine flexibility allows small batch sizes which, as a result, result in lower inventory costs, higher machine utilizations, ability to produce complex parts, and improved product quality.

MATERIAL HANDLING FLEXIBILITY is defined as the ability of material handling systems to move different part types effectively through the manufacturing facility, including loading and unloading of parts, intermachine transportation and storage of parts under various conditions of manufacturing flexibility. In the end, material handling flexibility may increase machine availability and reduce throughput times.

PROCESS FLEXIBILITY is defined as the ability of a manufacturing system to produce a set of part types without major set-ups, which is sometimes referred to as mix flexibility [18], [19]. Process flexibility is useful in reducing batch sizes and, as a result, inventory costs. Since it allows the sharing of machines, it minimizes the need for duplicate machines.

PRODUCT FLEXIBILITY is defined by the ease with which new parts can be added or substituted for existing parts, i.e., the ease with which the current part mix can be changed at relatively low cost in a short period. Product flexibility helps the firm to be market responsive by enabling it to bring newly-designed products quickly to the market.

ROUTING FLEXIBILITY refers to the ability of a manufacturing system to produce a part by alternate routes through the system. The purpose of routing flexibility is to continue to produce a given set of part types,

albeit at a lower rate in the event of unexpected machine breakdown. It allows for efficient scheduling of parts via improved balancing of machine loads.

VOLUME FLEXIBILITY is the ability of a manufacturing system to be operated profitably at different overall output levels, thus allowing the factory to adjust production within a wide range.

EXPANSION FLEXIBILITY is the extent to which overall effort is needed to increase the capacity and capability of a manufacturing system. Expansion flexibility may help shorten implementation time and reduce cost for new products, variations of existing products, or added capacity.

PROGRAMMING FLEXIBILITY is the ability of the system to run virtually unattended for a long enough period. Program flexibility reduces the throughput time via reducing set-up times, improving inspection and gauging, and better fixtures and tools.

PRODUCTION FLEXIBILITY is the universe of part types that the manufacturing system can produce without adding major equipment. This type of flexibility is dependent on several factors such as variety and versatility of available machines, flexibility of material handling systems, and the factory information and control systems.

MARKET FLEXIBILITY can be defined as the ease with which the manufacturing system can adapt to changing market environments. It allows the firm to respond to changes without seriously affecting the business and to enable the firm to out-manoeuvre its less flexible competitors in exploiting new business opportunities.

Gupta and Somers' study deals with the development of a standard measure of manufacturing flexibility. The authors analyze, by means of the factor analysis technique, how the different items measuring manufacturing flexibility have been incorporated by the literature; they sum up 34 items, explaining the different types of flexibility suggested by [14] and their relative relevance for companies. This standard measure of manufacturing flexibility only considers

21 items from the above 34. The 21 manufacturing variables to be considered in the model are described in the following terms:

- A: Time required to introduce new products is extremely low;
- D: Time required to add a unit of production capacity is low;
- E: Shortage cost of finished products is extremely low;
- F: Cost of delay in meeting customers orders is extremely low;
- G: Size of the universe of parts the manufacturing system is capable of producing without adding major capital equipments is extremely large;

- H: The manufacturing system is capable of running virtually unattended during the second and third shift;
- I: Cost of doubling the output of the system is likely to be extremely low;
- J: Time that may be required to double the output of the system is likely to be extremely low;
- K: The capacity of the system can be increased when needed with ease;
- L: The capability of the system can be increased when needed with ease;
- N: The range of volumes in which the firm can run profitably is extremely high;
- P: Cost of the production lost as a result of expediting a preemptive order is extremely low;
- Q: Decrease in throughput because of a machine breakdown is extremely low;
- S: Number of new parts introduced per year is very high;
- X: Changeover cost between production task within the current production program is extremely low;
- Y: The ratio of the total output and the waiting cost of parts processes is extremely low;

- Z: *The ability of material handling system to move different part types for proper positioning and processing through the manufacturing facility is extremely high;*
- AA: *The ratio of the number of paths the material handling systems can support to the total number of paths is very high;*
- BB: *The material handling system can link every machine to every other machine;*
- CC: *The number of different operations that a typical machine can perform without requiring a prohibitive time in switching from one operation to another is very high;*
- DD: *The number of different operations that a typical machine can perform without requiring a prohibitive cost in switching from one operation to another is very high.*

According to the outcomes of the study by [1], it can be suggested that the manufacturing flexibility is a compound of the following flexibilities:

- *Expansion and Markets flexibilities;*
- *Volume flexibility;*
- *Product and Production flexibilities;*
- *Market flexibility;*
- *Machine flexibility;*
- *Process flexibility;*
- *Programming;*
- *Routing; and*
- *Material Handling flexibility.*

See figure 2 for an illustration of Gupta and Somers' model.

----- insert figure 2 about here -----

Figure 2: Model for measuring manufacturing flexibility

In order to translate the above mentioned manufacturing/operative variables into financial variables, it is necessary to identify first the types of flexibility which have relationships with various decisions [20]. This can be achieved by classifying the types of flexibilities according to their impact on long-term and short-term decisions [20]. Conventionally, long-term decisions are financially associated with long-term capital budgeting, while short-term decisions are associated with cash management and treasury budgeting.

Long-term decisions concerning flexible technology acquisitions are strategic decisions and involve substantial investments. They relate to Design flexibility and are concerned with the decisions that must be made before installation of the system/technologies. This flexibility reflects, or should reflect, the needs of flexibility directly derived from the strategy of the firm with reference to its markets (see Figure 1). Accordingly, it relates to the capacity of the production technology to introduce changes in the product mix, in the design, and in the scope of new products and new products generation [21]. So far, Design flexibility refers to the ability to vary production across a greater range of volumes; to attain faster a new production level within its volume range; to increase the breadth of the product line; the extent of product variety, etc.

Coming back to Figure 1, Design flexibility would influence the strategic type of production technology investments that a firm should accomplish.

Short-term decisions concerning flexible technology implementation and control, are involved with the operation of the plant and linked to Operational flexibility [21]. This Operational flexibility relates to the capability of the equipment/production process/plant to respond on time to changes in plans, programmes and schedules, within the requirements set by the operations strategy, and thus influencing the performance of the firm. (See Figure 1).

Thus, although both types of flexibility are tied closely and interdependent, they refer to complementary stages in the appraisal of the new production technology investments process: Design Flexibility has to be incorporated into the assessment, justification and financing of the investment (ex-ante justification), while Operational Flexibility has to be taken into account for the monitoring and control of performance (ex-post justification).

It is assumed that investments leading to a higher Design flexibility should be appraised as long-term capital investments given the nature and content of such flexibility. This implies that (1) capital budgeting techniques are suitable for their financial justification and that (2) a linkage has to be made between the financial variables used by those techniques, and the manufacturing variables measuring the strategic or long-term performance of the flexible investments. It is also assumed that financial monitoring and control of these investments should be performed by cash budgeting and control techniques, i.e., a second linkage has to be established between the financial short-term variables and the operative or manufacturing variables measuring the daily performance of the flexible investments, i.e., the Operational flexibility.²

This distinction between long and short-term flexibilities and capital and cash budgeting techniques will allow the ex-ante and ex-post justifications of investments in flexible equipments. It tries to show in an easy way the likely consistency between the measures of the productions process and the organization's actions and strategies. According to Nanni's comments [29, pp 7 and 8], and to the fact that senior management will more readily accept

² There is a big controversy on the suitability of conventional capital budgeting techniques for the Advanced Manufacturing Technology investment appraisals. The main pitfalls of DCF's procedures have been widely discussed, see for instance [22],[23],[24],[25],[26],[27], and [28].

a new radical technology if it is justified on familiar grounds rather than with a completely new approach, simplicity has been pursued: the classification here proposed focus attention such that there are enough measures to reveal and solve critical problems, but no so many as to create confusion.

Design Flexibility provides data that helps to calculate the Net Present Value, the Internal Rate of Return, or any other capital budgeting index. If the strategy of the firm is to acquire flexible equipments, one action to perform will be to determine its economic and financial feasibility. Operational Flexibility provides data on wheter the strategic objectives are succesfully completed, the manufacturing activities are being done wastefully or not, and on the way the firm is organized to do those activities.

Next step then is to identify those manufacturing or operative variables related to Design flexibility and those related to Operational flexibility.

Most of the firms that already have acquired flexible technologies have employed conventional justification techniques like NPV or IRR ³, and the tangible and quantifiable benefits of the new technology have been taken into account. These benefits are summarized as [32, pp. 205]:

- Increased market share*
- Increased sales volume*
- Increased production volume*
- Succesful development of new products*

³ See the empirical evidence provided by [22], [30] and [31].

- Reduced product development time
- Development of new markets
- Fewer customer complaints
- Reduced defect costs and reduced scrap costs
- Shortening of delivery time
- Direct labor savings
- Reduced work-in-process and finished-goods inventory levels
- Reduced floor space requirements
- Improved product quality leading to reduced inspection, rework, scrap, warranty, and service costs.
- Reduced tooling, utilities, maintenance, production control, fixturing, and material costs.

The economic value of these benefits can be known with certainty or at least up to a probability distribution. According to [6, pp. 52] this type of benefits can be categorized as "zero-order intangibles". For the purpose of this paper, the ex-ante quantification of these benefits are well suited. If a direct linkage can be found between the above benefits and the nine flexibilities suggested by Gupta and Somers [1, pp. 17], then a group can be formed that relates to Design flexibility. Equally, a second group can be formed relating to Operational flexibility. The latter will include all flexibility types that are not linked to the above benefits. Consequently, this second group contains a limited chance, if any, to estimate ex-ante their tangible benefits. As a result, the second Operational flexibility group can be considered to comprise all intangible benefits, which can be summed as [32, pp. 205]:

- Increased product uniformity
- Increased ability to quickly enter new markets
- Increased goodwill generated through the new reputation the firm adquired
- Synergy with other equipment
- Better scheduling/workflow
- Increased strategic options and reduced risk of obsolescence.
- Improved product quality leading to improved market image

- Ability to respond quickly to future technology advances
- Offset technology adoption by competitors
- Increased employee morale
- Better customer service
- Reduced training and supervision
- Increased utilization of manpower and equipment
- Reduced expediting
- Reduced materials handling
- More disciplined manufacturing process, and
- Increased safety.

According to the definitions given for the nine different types of flexibility and to their direct relationship with the tangible benefits, the Design Flexibility category will consist of the following types:

- Machine Flexibility
- Process Flexibility
- Product and Production Flexibility
- Volume Flexibility, and
- Expansion and Market Flexibility.

The Operational flexibility category will include:

- Material Handling Flexibility
- Routing Flexibility
- Programming Flexibility, and
- Market Flexibility ⁴.

⁴ It is assumed that direct linkages can be traced between Routing, Programming, Market, and Material Handling Flexibilities and those benefits classified as intangible ones [32] or, as:

The proposed classification gives way to a modified version of Gupta and Somers [1] model.

This proposed modified version is illustrated by Figure 3.

-----insert Figure 3 about here-----

Figure 3: Proposed model for measuring manufacturing flexibility

3.-Flexible Manufacturing and Capital Budgeting

Once the flexibility identification has been completed, both types of manufacturing flexibility (Design and Operational) variables can be linked to corresponding financial variables, thus leading to the translation of operative measures, i.e., the 21 manufacturing variables identified by [1], into financial and economic measures.

Investment in flexible manufacturing equipment is expected to modify the Design and/or Operational flexibilities of the investing company. No matter how relevant these changes can be for that firm's survival, if they are not financially justified, the investment will not get the approval and the go-ahead; the justification process is largely strategic in nature but must also involve finance issues.

-"first-order" intangibles, i.e., those whose economic value is not quantifiable but can be readily stated in physical terms with certainty or by using probabilities.

-"second-order" intangibles which are nonpecuniary factors that can be enumerated but are not measurable in physical terms except perhaps on a qualitative basis.

-"third-order" intangibles which represent factors producing unanticipated benefits and costs that are typically not measurable. [6, pp.52]

In this regard, it can only be assumed that these intangible benefits properly fit the ex-post justification of the flexible technology investment.

Consequently, the main objective of the here proposed translation system will be to provide both financial and operations managers with a tool that indicates them:

- Which of the operative variables explaining Design flexibility may modify the estimates of the long-term capital budgeting variables. (See Figure 3)
- Which of the operative variables explaining Operational Flexibility may vary the estimates of the short-term cash and treasury budgeting and management variables. (See Figure 3).

Once this correspondence is defined, next step will be to develop a procedure to determine when such linkages should be considered in the NPV and/or IRR computations and how. This will be done in section 4.

3.1.-Design flexibility and Capital Budgeting Techniques

Capital budgeting techniques, such as the Net Present Value (NPV) or the Internal Rate of Return (IRR), are often used for capital investments appraisals. They do concentrate in the appraisal of long-term assets being mainly financed with long-term funds. The financial variables used by these techniques are initial investment outlay, expected cash-flows, residual or salvage value and discount rate. These variables are the ones which have to be linked to operative variables associated to the Design flexibility ⁵.

⁵ As it previously stated, this proposal is aware of the many pitfalls of DCF procedures. The main goal of the suggested approach is to provide management with more accurate and operative-oriented data so that they can avoid some of the inherent weaknesses of the cash and capital budgeting techniques.

The initial investment outlay information to be gathered refers basically to the acquisition cost of the new production capacity, with the acquisition cost depending upon both the time needed for the completion of this new capacity, and the alternative uses of such capacity. Next, what needs to be estimated is the incremental initial investment outlay, which can be computed as the initial investment outlay needed for the "rigid" (i.e., non-flexible) technologies less the investment outlay referring to flexible technologies or vice-versa if the initial investment needed for the flexible technology is higher than the one required by the "rigid" technology acquisition.

The proposed model assumes that machine, process, production and product, volume, and expansion and market flexibilities associated to both flexible and rigid technologies, may help in the assessment of their acquisition cost, as well as the time needed for the achievement of new production capacity and the alternative uses of such capacity. These flexibilities can provide insight information on the variety of products and volumes that the firm may offer, thus indicating which markets can be served. According to the outcomes of the study by [1], these types of flexibilities are explained by the manufacturing variables DD, CC (machine), X, Y (process), S, G (production and product), N (volume), and J, I, K, L, A, and D (expansion and market). (See their definition in the previous section of this paper and Figure 2).

Appart from depreciable assets, the investment in flexible technologies, as any other type of investment, often requires an investment in working capital. The financial items underlying working capital relate to the current dealings of the organization [33]. In general, it is depicted as a cycle, tied to the operating cycle of production [26]. It is in this operating cycle that some types of Design flexibility (process flexibility) and of Operational flexibility,

(programming, routing and material handling flexibilities), relate to working capital, having their effects mainly on cash outflows.

The question to assess then is how investments in working capital associated with flexible technologies, differ from those of rigid technologies investments, so that the incremental working capital (being it positive or negative) can be estimated. According to our flexibility definition (see section 2), Operational Flexibility may lead to reduced throughput times via a reduction of the set-up times, the continuity of the production process and the increase of the machine availability. This may lead to lower work-in-progress inventories [6, pp 21-42]. Process flexibility (included in the Design Flexibility group) also contributes to explain lower work-in-progress inventories, because it is useful in reducing batch sizes and, in turn, finished goods inventories [6, pp 21-42]. Equally a lower amount of current assets can be expected, other balance sheet related accounts remaining unchanged, giving way to a decreased need of working capital. The manufacturing variables to analyzed will be X, Y (process), H (programming), Q, P (routing), and Z, AA, BB (material handling). (See Figure 2 again)

Reliable estimates of the incremental need of working capital will not be available until a first manufacturing cycle has taken place. Since more reliability is advisable, the estimates should be made ex-post, i.e., once the new flexible equipment has been acquired and implemented. Nevertheless this does not imply that ex-ante estimations will not have to be performed. For example, additional long term capital funding could be needed for the first new manufacturing cycle or, vice-versa, financial resources can be freed and, thus, employed for alternative purposes [34]. At minimum, aggregate estimates are revised on a yearly basis, and information provided by Operational flexibility can be of significant help, as will be discussed in a later section of this paper.

Design flexibility may significantly influence the expected cash-flows. Once again, the relevant information is tied to the differences between the expected cash-flows of the firm when employing rigid technology (the "base case") and the expected cash-flows due to the use of flexible technology. Typically, data to take into account refer to the expected increments in sales, costs of goods sold, and operating expenses. It can be assumed that all flexibilities explaining the Design and Operational flexibilities are likely to influence the cash-flows figures. However, for the ex-ante calculations, data will only be available on the manufacturing variables explaining Design Flexibility. Revised estimates of the actual cash-flows figures will be influenced by Operational Flexibility related data. It means that for incremental NPV and/or IRR calculations, manufacturing variables to be considered will be the ones related to Design Flexibility, i.e., DD, CC, (machine), X,Y (process), S,G (production and product), N (volume), and J,I,K,L,A, and D (expansion and market). (See their definition in the previous section of this paper and the linkages illustrated by Figure 2).

The incremental initial investment outlay -acquisition costs plus or minus the working capital needed- equals the incremental funds that will need to be sourced. During the expected life of the new flexible equipment to be acquired, funds can be provided by the potential increase in self-financing, to be obtained if higher incremental cash-flows (after taxes) are expected to occur and the dividend payout and non-distributed benefits policies remain unchanged. As a result, the amount of external funds needed can be lower, which in turn may influence the cost of capital. Therefore, the discount rate to be used for the NPV computations should be equal to the cost of capital for the incremental funds. ⁶

⁶ [22], [30] and [31] provide empirical evidence related to this point:

-The surveyed U.K. companies permit a longer payback time for AMT investments, this way contradicting the suggestions made by some commentators that, owing to the perceived level of risk, shorter required paybacks

It is difficult to estimate how future residual or salvage values of flexible technology, as well as assessing the gap between continuing to use rigid technology equipment and flexible technology. It is assumed that the depreciation of machines can be estimated from their usage rate, and their residual value; aggregate estimates can be obtained by considering the Design Flexibilities ⁷. The manufacturing or operative variables to be analyzed will be **CC, DD, X, Y, S, G, N, J, I, K, L, A,** and **D**. (See their definition in the previous section).

3.2.-Operational Flexibility and short-term capital budgeting

The short-term budget of a firm is the cornerstone of the control of its short-term capital expenditures. In fact, except for firms of very moderate size, some sort of short-term budget appears to be a necessity if management is to control its capital expenditures [30]. Short-term capital expenditures follow from the operating cycle of production requirements. Under Operational Flexibility, the operating cycle is expected to respond in a timely fashion to changes in plans, programmes and schedules. Such capability may lead to a improved linkage between manufacturing requirements of short-term capital and the forecasted total current liabilities position of the firm as expressed in the firm's balance sheets.

are usually set by investing companies.

-For the same companies, very little difference emerged between the rate of interest applied to AMT and non-AMT investments which may imply that there is a negligible difference between the perceived less of risks of the forms of investment when discount rates are applied. There is no evidence from the surveys to support the popular assertion that excessive discount rates are used for AMT investments.

⁷ By definition, higher Design flexibility allows higher usage rates provided a higher uncertainty in the demand side. Nevertheless, for accurate (and ex-post) estimates, data on the Operational flexibility of the investment should be used.

Whenever a flexible equipment investment leads to increased material handling, routing, and programming flexibilities, special attention should be paid to cash management: additional incomes and lower outcomes can be expected as a consequence of the increased steadiness of the cash outflows. Manufacturing variables to be analyzed will be H, Q, P, Z, AA, and BB. Observed changes in the manufacturing cycle incomes and/or outcomes' levels provided by Operational Flexibility can be employed in the re-calculation of the investment's NPV and/or IRR.

So far, what is being proposed is an integrated model for the financial justification process, comprising long and short-term interactions, to be used not only during the pre-acquisition stage, but also on a continuous basis, as long as the life of the investment. Data on each manufacturing cycle yields, as they are affected by Operational flexibility provide the required feedback for the consecutive revisions.

It is also worth noting that the here suggested conceptual framework helps to avoid one of the most important problem associated to DCF procedures: They are not suitable for the evaluation of the intangible benefits, while flexible technologies explicitly seem to promote and ease the creation of intangible benefits, e.g. technological competencies. Consequently, expected benefits related to these technologies are not likely to be translated into financial variables, nor taken into account for investments appraisals. The here proposed model incorporates the intangible benefits, by mean of their referrance to the Operational flexibility, as far as computations of the cash budget may take them into account.

The financial controller has traditionally played an important role in the evaluation process, especially in the budgeting process and in setting the budget control procedures, in defining

the type of financial performance criteria for the different responsibility centers, and in developing administrative procedures. The here suggested approach has a different and complementary aim. Shifts in operative variables are likely to change the operative procedures and, consequently, the expected yields of the production process. The financial variables will have to incorporate such changes. Thus, shifts in operative variables show whether the "ex-ante" budget has become unrealistic and it does have to be revised. The difference between this approach and the conventional one is that this revision is driven by the way acted by plant managers and employees, while it has been traditionally accepted that the way financial performance is measured directly affects the way managers act [35, pp 4].

4.-The early warning system

The acquisition of flexible equipment will influence the firm's manufacturing flexibility. If its impact is to be properly evaluated, information on the flexibility that the firm already possesses, prior to its investment in flexible technologies, is clearly necessary. Those flexibilities which can be translated into financial variables provide an improved measurement of the manufacturing flexibility of the firm.

For measurement purposes, a Likert scale is proposed, with values varying from 5 to 1 [1]. The obtained values will function as the "base case" value since it is assumed that, rigid technology being acquired, manufacturing flexibility is not likely to vary.

Next, the flexibilities expected to increase as a consequence of investing in flexible equipment have to be assessed. Clearly, differences among values can be observed easily, due to the use of the same Likert scale.

Differential values for all the operative values (calculated as the "new" flexibility value less the "base case" value) can be tabulated and ranked. What is suggested is a three- group

ranking: the first group includes differential values belonging to the interval $(|-5|, |-4|)$ ⁸, the second group includes values in the interval $(|-3|, |-2|)$, and the third group refers to values in the interval $(|-1|, 0)$.

Those operative variables belonging to the first group are likely to be the first ones to consider, since they indicate the need to revise and/or refine the associated financial variable calculations. Next, second group differential values have to be analyzed given that they may lead to a revising of non-previously computed financial variables, and/or to a refinement of the computations already performed. If not relevant changes are appreciated after revising the previous computations, the firm can stop the process because no better estimates may result. However, a third revision may be needed if those operative variables included in the third group relate to financial variables not revised before and/or if they affect previous estimates.

Not only may this early warning system lead to improved computations of the financial variables and, consequently, improved Net Present Values for the flexible technologies investment proposals, but it can also be used as a standard/guideline for the monitoring and control of the production and budgetary processes. This guideline shows the main types of flexibilities the company is looking for as well as their related expected values (measured as the differential value). Monitor and control help is provided by indicating whether if the degrees and types of flexibilities the company is achieving, are the desired ones and, if so, how big the gap between actual and target is. Whenever a significant gap is indicated, corrective measures can be taken, being either of operative or financial nature.

⁸ | | means absolute value

To this extent, an important change takes place in the role played by performance measurement systems and budgeting techniques: they become tools with a capability to forecast, or, at least, to anticipate, what is likely to happen and why. Corrective actions can then be taken before the "damage" is done.

5.-Summary and concluding remarks

It is the objective of this paper to construct a translation system of manufacturing flexibility in such a way that its related advantages can be assessed both financially and operatively. More specifically, operative/manufacturing variables, are to be considered as the starting points in capital budgeting calculative practices. In short, the proposed approach indicates that a variation/deviation in a performance relevant manufacturing variable has to be valued and translated into a corresponding variation/deviation of the related financial variable. The latter modification of the financial variables then can be used consequently for the financial and economical justification of the investment in flexibility.

Variations/deviations in the operative variables are grouped and ranked, giving way to an early warning system. It has the implicit advantage of its simplicity: operations and financial managers can concentrate their efforts on the selected variables, thus leading to important savings of management time, i.e., indirect costs.

The simplicity of the approach is also important for other reasons:

- (i) -it helps the "plant" people (not only management or staff people) to figure up their contribution to the company's profitability while it also allows the "office" people to

understand where the strengths and weaknesses of the business are located. Consequently, efforts to improve the plant performance can be profitability oriented and budget allocations and re-allocations can be performed more efficiently.

(ii) -the firm can enjoy an increased and more timely capability to respond to potential investment opportunities, given that only relevant variables (being them operative or financial ones) are likely to be paid attention to.

(iii) -it helps to avoid the development of complex performance measurement systems whose inherent difficulty may prevent management and employees from being involved into "paralysis by analysis".

(iv) -more accurate, updated and reliable estimates of the relevant financial variables are obtained because of:

-the data used , i.e., directly from the daily operations of the company (**nota:** valores alcanzados por las flexibilidades operativas, traducidos a términos monetarios)

-no new techniques, nor new capital budgeting models, nor new and/or complex performance measurement systems for flexibility models are suggested, thus avoiding adverse reactions and taking benefit of the skills of the personnel.

(iv) -it makes it easier to argue that linkages between flexible manufacturing and financial figures can be anticipated by the firm, thus leading to a fresh approach to the financial justification of AMT investments.

(v) -a successful implementation of the system can be expected: it is based upon the conventional capital budgeting techniques, it does not require "advanced knowledge" to deal with it and to understand it.

Other advantages of the suggested translation system are related to:

- Sensitivity analysis: The response of the financial variables to shifts in the manufacturing variables can be obtained from simulation studies. The outcomes can be used to determine how much flexibility the firm can financially afford itself, and how much the firm is willing to pay for different levels of flexibility.
- Inexpensive system. It does not need additional expenditures during the implementation phase, nor during its operational time. It does not need to stop the firm activities, nor even to develop pilot studies. Furthermore, common software appliances, such as spreadsheets, can be used for the computations of the revised financial variables.
- Capital investment tool for both financial and operational management: They are able to participate proactively in the strategic decision-making process of the firm because they have access to capital investment information, i.e., the likely outcomes of the investments in flexible technologies.

6.-Suggestions for further research

There is still a lot of work that remains to be done before all the cited advantages of the here suggested approach can be realized. First, the validity of the proposed classification of flexibilities types into Design and Operational flexibility, as indicative of the long-term and short-term decisions associated with flexibility, has to be tested. Second, the suitability of conventional capital budgeting techniques for the appraisal of flexible technology investments

has also to be tested. Third, all the implicit assumptions concerning the linkages between operative variables and financial variables have to be empirically tested.

Other questions to be addressed relate to the valuation process itself. First, the firm can be more interested on achieving a limited number of preferred flexibilities than on all types of flexibility. This problem may be solved by adopting a scoring system so that those operative variables related to the preferred flexibilities can get higher values in the Likert scale. An avenue for better solutions is opened given the associated problems of selecting the optimum scores. Second, a sound doubt may arise: would not the evaluators try to influence the values achieved by the operative variables, thus leading to biased changes of the financial variables?. This has been the common situation under conventional approaches. One solution can be to involve more people in the process, belonging to different levels of the hierarchy, others than strictly related to "plant" level here suggested. However, this solution will likely lead to higher complexity while higher accuracy can not be granted: further research is imperatively needed to deal with this point. Third, a certain level of subjectivity involves the whole process. While it can be easy to translate some flexibilities into values of the Likert scale, it may be quite difficult for others. Furthermore, it can be quite complex to assign adequate values for both initial (or base case)-perhaps the firm does not have any flexibility at all, and this will simplify the process-and the new manufacturing flexibility that the firm expects to achieve by investing in flexible equipments. No solution has as yet been proposed to solve this problem. As [35] note, is more useful for data to be approximate and relevant than precise-but irrelevant. According to this remark, a strong effort is needed to identify the different factors leading the valuation factors so that, at least but not last, relevant values can be obtained in spite of their inaccuracy.

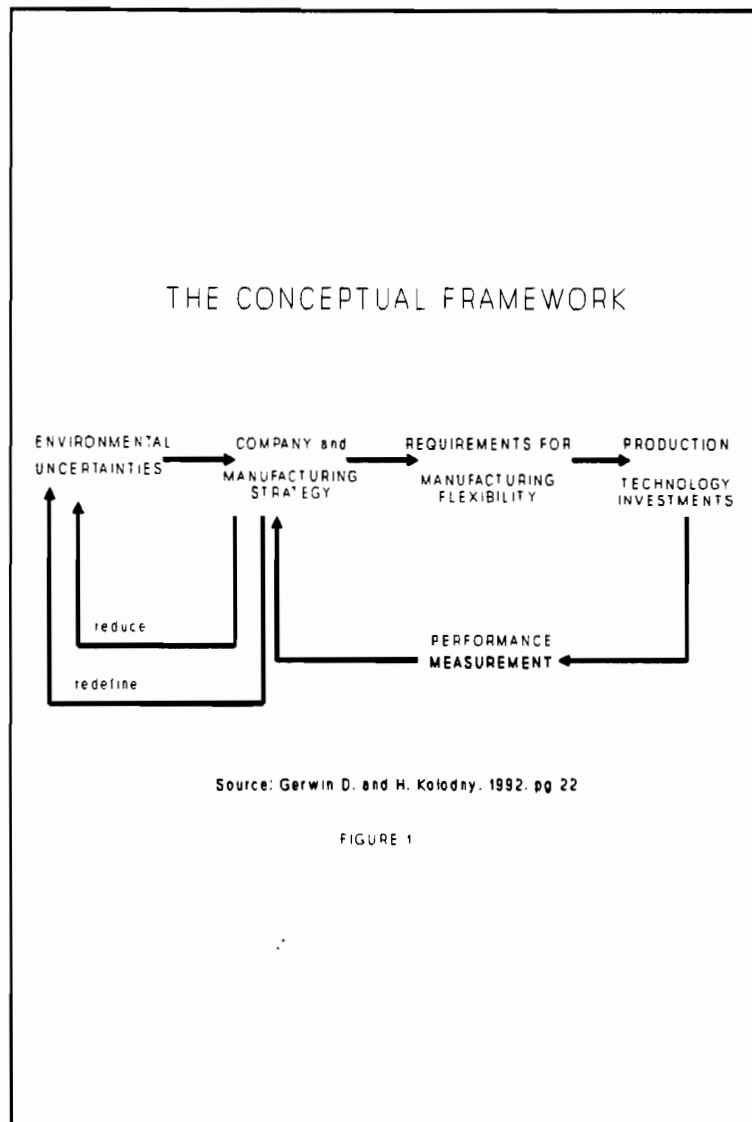
In spite of the many shortcomings of this approach, the theoretical assumptions upon which it is based might be considered worthwhile, making it a starting point for further research efforts. It should be noted that the above system, as it has been conceived, might easily become a test for itself. If the assumptions in which the system is based are wrong, the outcomes will be a far cry from actual operational numbers.

References

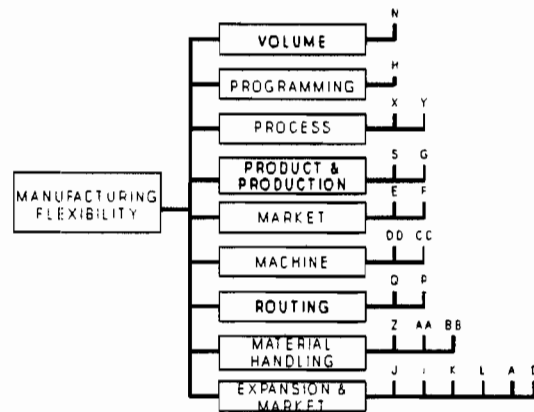
- [1]. Gupta Y.P. and T.M. Somers (1992). The measurement of manufacturing flexibility. *European Journal of Operational Research*. vol. 60, pp. 166-182.
- [2]. Stecke K.E. and N. Raman (1986). Production Flexibilities and their Impact on Manufacturing Strategy. University of Michigan. Graduate School of Business Administration. Working Paper no. 484.
- [3]. Hayes R.H. and S.C. Wheelwright (1984). *Restoring Our Competitive Edge: Competing Through Manufacturing*. New-York: Wiley
- [4]. Ettlie J.E. (1988). Implementation Strategies for Discrete Part Manufacturing Technologies. University of Michigan/Ann Arbor
- [5]. Ramasesh R.V. and M.D. Jayakumar (1991). Measurement of Manufacturing Flexibility: A Value Based Approach. *Journal of Operations Management*. Vol 10, no 4, pp. 446-465.
- [6]. Gerwin D. and H. Kolodny (1992). Management of Advanced Manufacturing Technology: Strategy, Organization & Innovation. In: Dundar F. Kocaoglu (ed), *Wiley series in Engineering and Technology Management*. New-York: Wiley
- [7]. Child J. (1972) *Organizational Structure, Environment and Performance: The Role of Strategic Choice*. *Sociology*, Vol. 6, pp. 1-22.
- [8]. Skinner W. (1985). *Manufacturing: The Formidable Competitive Weapon*. New York: Wiley.
- [9]. Swamidass P.M. (1988). *Manufacturing Flexibility*. Monograph no 2, Texas Operations Management Association.
- [10]. Zelenovic D. (1992). Flexibility: A condition for effective production systems. *International Journal of Production Research*, Vol. 20, no. 3, pp. 319-337.
- [11]. Cox T. (1989). Toward the measurement of Manufacturing Flexibility. *Production and Inventory Management Journal*. First Quarter 1989, pp. 68-72.

- [12]. Miller J.G. and A.V. Roth (1987). *Manufacturing Strategies. Executive Summary of the 1987 North American Manufacturing Futures Survey*. Boston: Boston University.
- [13]. Miller and Kim (1990). *beyond the quality revolution: U.S. Manufacturing strategy in the 1990s*. Research Rport of the Boston University Manufacturing Roundtable.
- [14]. Sethi A.K. and S.P. Sethi. (1990). *Flexibility in Manufacturing: A survey*. *International Journal of Flexible manufacturing Systems*, Vol. 2, no. 4, pp. 289-328.
- [15]. Dixon J.R. (1992). *Measuring manufacturing felxibility: an empirical investigation*. *European Journal of Operational Research*, Vol. 60, pp. 131-143.
- [16]. Kumar V. (1987). *Entropic Measures of Manufacturing Flexibility*. *International Journal of Production Research*, Vol. 25, no. 7, pp. 957-966.
- [17]. Brill P. and M. Mandelbaum M. (1989). *On measures of flexibility in manufacturing systems*. *Omega*, Vol. 14, no. 6, pp. 465-473.
- [18]. Gerwin D. (1982). *Do's and Don'ts of Computerized Manufacturing*. *Harvard Business Review*, March-April, pp. 107-116.
- [19]. Carter M.F. (1986). *Designing Flexibility into Automated Manufacturing Systems*. *Proceedings of the Second ORSA/TIMS Conference on Flexible Manufacturing Systems*. Ann Arbor, pp. 107-118.
- [20].Bernardo J.J. and Z. Mohamed (1992). *The measurement and use of operational flexibility in the loading of Flexible Manufacturing Systems*. *European Journal of Operational Research*, Vol. 60, pp. 144-155.
- [21]. Adler P. (1988). *Managing Flexible Automation*. *California Management Review*, Vol. 30, pp. 34-56.
- [22]. Lefley F. and F. Wharton. (1993). *Advanced Manufacturing Technology investment Appraisal: a survey of U.K. manufacturing companies*. *Proceedings of the 4th International Production Management Conference*. London, pp. 369-382.
- [23]. Meredith J.R. and M.M. Hill (1987). *Justifying New Manufacturing Systems: a Managerial Approach*. *Sloan Management Review*, Summer 1987, pp. 49-61.
- [24]. Berliner C., D.A. Hendricks, D.E. Keys, and E.J. Rudnicky (1987). *Cost Accounting for Factory Automation*. Montvale: National Association of Accountants.
- [25]. Alvarez-Gil M.J. and H.J.E. Roberts (1993). *The Financial Implications of Lean Production*. *Proceedings of the 4th International Production Management Conference*. London U.K., pp. 11-28.
- [26]. Kulatilaka N. (1988). *Valuing the Flexibility of Flexible Manufacturing Systems*. *IEEE Transactions on Engineering Management*, Vol. 35, no. 4, pp. 250-257.

- [27]. Gold B. (1982). Revising Managerial Evaluations of Computer-Aided Manufacturing Systems. Proceedings of the Autofact Western Conference. Dearborn, MI.: Society of Manufacturing Engineers, pp. 157-169.
- [28]. Kaplan R.S. (1990). Limitations of Cost Accounting in Advanced Manufacturing Environments. In: Robert S. Kaplan (ed.). Measures for Manufacturing Excellence, Boston: Harvard Business School Press, pp. 15-38.
- [29]. Nanni A.J. (1993). Developing a process for changing performance measurement. Paper presented at The International Seminar on Manufacturing Accounting Research. Eindhoven. The Netherlands, May 16-19, 1993. paper n° 21, pg 7.
- [30]. Tayles M. and C. Drury (1993) New Manufacturing Technologies and Management Accounting Systems: Some Evidence of the Perceptions of U.K. Management Accounting Practitioners. Paper presented at The International Seminar on Manufacturing Accounting Research. Eindhoven. The Netherlands, May 16-19, 1993. Paper n° 16.
- [31]. Berliner C. and J.A. Brimson (Eds). (1987). Cost Management for Today's Advanced Manufacturing: The CAM-I Conceptual Design. Harvard Business School Press, Boston.
- [32]. Noori H. (1990) Managing the Dynamics of new Technology: Issues in Manufacturing Management. Prentice Hall. Englewood Cliffs, New Jersey, pp 192-221.
- [33]. Levy H. and M. Sarnat (1990). Capital Investments and Financial Decisions. Prentice Hall International (UK) Ltd. 4th Edition, pp 24.
- [34]. Szendrovits A.Z. and W.G. Truscott (1989). Fundamentals of Scheduling: The Manufacturing Cycle Time. In International Handbook of Production and Operations Management, Wild R. (Ed). Cassel Educational Limited, London.
- [35]. Bruggeman and Van der Stede (1993) Fitting Management Control Systems to the competitive advantage. Proceedings of the International Seminar on Manufacturing Research. Eindhoven, The Netherlands, May 16-19, 1993, Paper n° 2.
- [36]. Nanni, Miller and Vollman (1987). What we shall account for?. Management Accounting. January, 42-48, pp 48.



GUPTA AND SOMERS' MODEL FOR MEASURING MANUFACTURING FLEXIBILITY



Source: Gupta, Y. P. and T. M. Somers (1992) pg 17

FIGURE 2

A NEW APPROACH TO THE MEASUREMENT OF MANUFACTURING FLEXIBILITY

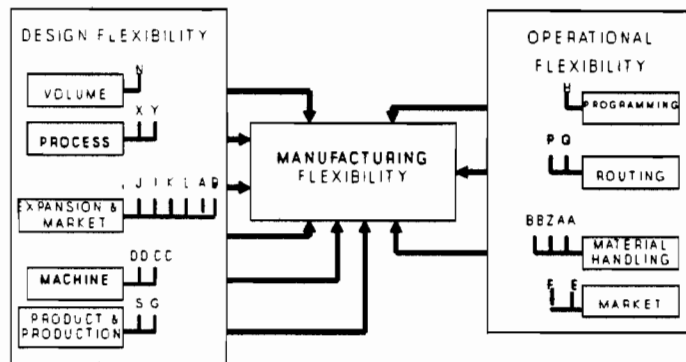


FIGURE 3