DYNAMIC APPROACH TO THE PLANNING OF CONTRACTING ENTERPRISE CAPACITIES*

By

M. SARLÓS—T. TÖRÖK

Department of Building Management and Organization, Technical University, Budapest
(Received: March 15, 1981)

Presented by Associate Prof. Dr. István KÜRTI, Head of Dept.

Planning of the development of the capacity of an enterprise cannot be simulated by a single, closed model. Namely, there exist not too many real development plans, and by no means an infinity of them like in continuous models on mathematical programming. To speak of optimizing the plan, and of an optimum plan, would be deceptive, in view of the predominance of estimations, intuition and subjective likelihoods both in the collection and production of starting data, and in the analysis and evaluation of development plan varieties.

Nothing but a complex efficiency analysis or complex evaluation and selection of a reasonable, advantageous plan can be spoken of.

The presented sequence is interactive of character, separate parts may be automated and computerized but at certain points questions arise that need to be answered by managerial decisions. Thus, the mechanism of investment decision preparation at the contracting enterprise comprises itself decisions concerning given partial domains.

These analyses presuppose the continuity of accessory investments for the upkeep of resources.

In the following, enterprise resources will mainly be understood as building machinery and equipment, but of course, there is no objection to integrate other kinds of resources — maybe affecting the entrepreneurial stratagem. Establishment of the resource development needs has to reckon with eventually disponible subcontracting capacities. Enterprise asset investments influence the activity of the enterprise over a long period, about 10 to 15 years — in view of the time of purchasing, amortization etc. The timely course of this process can be accounted for with either of two methods. Either the analysis is made for every year within the period, scheduling the needed asset investments accordingly. Or, dividing the period to a few intervals — e.g. of five

* Abridged report of a research-development work made at the Department of Building Management and Organization, Technical University, Budapest, under the guidance of Prof. Dr. *Géza Jándy*

years corresponding to the plan period of national economy — the analyses refer to interval ends. Building demands raised in each year of an interval may significantly be influenced by the activity of the enterprise — e.g. by equalizing them — permitting to schedule the asset investment established for the interval end in conformity with its interests.

The laboriousness of the first mentioned computation method and the uncertainty of inputs argue for the second method.

1. Information needed for investment decisions

1.1 Prognostication of building demands

The better founded the development decisions of the building enterprise are, the longer the perspective it foresees its future, its tasks, expectations facing it. This foresight is facilitated by the knowledge of its past, the adequate precision and reliability of the relevant statistical data.

1.11 *Decomposition into periods and building types*

As a solid frame of the prognostics of building demands and tasks, the morphology system of tasks and main operation processes of the enterprise may be applied. Classification according to building categories expressing main characteristics of the building task has to be begun with.

The enterprise being unlikely to be acquainted with every construction item and site involved in its building activity throughout the expedient period of forecast — at least ten or fifteen years — eventually, knowledge of the global volume of its tasks decomposed into building categories throughout the period and annually has to be made up with. Precision has to be of a degree permitting to measure the volume of the tasks within a building category in the same natural unit, production unit. Yearly decomposition requires a means to predict the work schedule along the period facilitated by the knowledge of part of the building demands decomposed to years as soon as at the survey of the building demands.

Opposite to the hitherto structural approach, itemization within building categories advisably refers to constructional part processes. The itemization degree has again to be chosen to permit expression of the volume within a part process item in terms of identical units, besides, to impose an essential technology change within the item.

In composing both outlined categories, maximum consideration is due to peculiarities of the enterprise, to the character of its past projects and to the kind of its expected commissions.

1.12 *Prognostication methods*

An efficient prognostication of building demands is conditioned by the acquaintance with the past 10 to 15 years of the enterprise, in particular, concerning former building commissions, besides, actually solvent customers in the field of competency have to be detected. In either case, prognostics rely on investigations at building category level.

Among investigations relying on the former activity of the enterprise, recognition of correlations, time series analysis are of importance, but also simulation, morphology and operation research methods may be involved. Especially, recognition of alternatives has to rely on the *Delphi* method, that is, on the checked professional intuition, partly reckoning with, then confronting, personal opinions, and partly involving, for its weighted preferences, the opinions of specialist groups interested in the subject.

Of course, any prognostic statement can predict future processes and events only at a restricted probability.

Essentially the same is true of building marketing methods, but with a much lesser stress laid on mathematic methods. In this case, building projects involved in actual investments planned at long or medium range by potential investors belonging to the field of activity of the enterprise have to be predetermined. From the derived building demand, the enterprise can outline his likely tasks.

Combining both outlined trains of thought, a resultant of the factual building demands and of the building tasks projected from earlier data series has to be drawn. The building demands in each building category are expected to fluctuate during the period of ten to fifteen years. Therefore it is advisable to represent the relation between the volume of building demands in each category and the time by an equalizing trend function. Determination of the development demand at the examined times (e.g. last years of five-year-plan periods) may rely on the pertaining trend function value. In the years between the examined times, production volumes in each building category may be controlled by the enterprise — via its activity — in knowledge of the given trend function value, of course, always within the frames of entrepreneurial strategy resulting from the investigation. Its own investments have to be scheduled accordingly.

1.13 *Reduced building demand*

A fundamental aim of the enterprises' own investments is to create possibilities for a long-range entrepreneurial strategy controlling the development trends — resulting from the favourable product structure — toward profitable products, taking the change of actual demands into consideration.

This analysis of the prognosticated building demands aims partly at separating expected profitable and lossy products.

A motive of the aforesaid is to continuously, systematically increase the personal incomes of employees — a fundamental aim of socialist enterprises. Obviously, because of the priority of national economy interests, this aim can only be realized by an efficient production of socially useful products.

The arising building demands may comprise products inconditionally undertaken by the enterprise, irrespective of the expected profit, because of social necessity, sociology, building policy etc. aspects, to be called *socially preferred building tasks.*

Another group of building demands — of expected profitable or lossy products seen under the angle of the enterprise — comprises constructions depending on entrepreneurial decisions.

The course of determining the reduced building demand involves the following steps:

— analysis of price returns, costs, profits for any building category within the building demand;
— determination of returns in case of the expected maximum demand in each building category of the building demands;
— values of building volumes pertaining to the profitable building categories at the security points, to be reckoned with later, in establishing the entrepreneurial strategy;
— among products likely to be unprofitable, it is advisable to reckon with the needed minimum of volume of the preferred building categories;
— full admission of a maximum volume of building categories likely to be profitable into the reduced building demand.

The resulting reduced building demand is expressed by vector **d** of elements b_j $(j = 1, \ldots, n)$ showing the size of reduced solvent demand in the building category j.

Stress should be laid, however, on the features of the price system in virtue even for such estimation-like, approximate profit calculations. Such investigations are only realistic if price ratios truly reflect volumes, qualities and structures of socially necessary expenditures.

Enterprise-level analyses rely in any case on a given price system, making the appreciation of a product as to be profitable on enterprise level and as to be economical on the level of national economy not absolutely coincident.

Profit estimations maintaining the rentability of the enterprise have to be remade if the price system changes.

1.2 *Planifiable capacity in enterprise resources*

Development of the entrepreneurial and development strategy requires to know the capacity to be planned for the future of the available enterprise assets. Since confrontation of building demands and enterprise capacities — in a later phase — will involve a technology matrix, it is sufficient to calculate the yearly total service hours in machine groups via determining the planifiable yearly working time basis of each machine group.

1.3 *Establishment of an enterprise data system*

According to the morphology system under 1.1, the enterprise has to prognosticate its tasks in two dimensions:

a) dimension of building categories;

b) dimension of constructional part processes.

Prognosticated volumes of each building category have to be divided to part processes, and part process volumes determined.

Again, constructional part processes and enterprise resources have to be correlated. Transition in a given direction between the three levels of building categories, constructional part processes and enterprise resources is facilitated by the enterprise data system to be described below.

1.31 *Enterprise-level analysis of itemized relations between building categories and constructional part processes*

Again, past activity of the enterprise has to be started from, including yearly volumes to be constructed in each building category, and statistical work quantities of part processes h needed to produce unit volume of each building category j; b_j is the volume of work to be done in building category j, and f_h is the total quantity in part process h (summed up for each building category). The transfer factor shows the work quantity to be taken from part process h in order to realize unit task in building group j. Coefficient f_{hj} expresses the average specific part process quantity:

$$\dim f_{hj} = \frac{\dim f_h}{\dim b_j} .$$

For $\mathbf{b}' = [b_1, \ldots, b_j, \ldots b_n]$,

$\mathbf{f}' = [f_1, \ldots, f_h \ldots f_l]$ and

$\mathbf{F}_{(l,n)} = [f_{hj}]$

then

$$\mathbf{Fb} = \mathbf{f}.$$

Coefficients f_{hj} are normally constant for long times, hence are independent in wide time intervals. Their changes are related to major technology changes. Coefficient f_{hj} (transfer factor) is an average of all tasks in building category h.

Thereby building demands predicted at building category level could be transformed to constructional part processes.

1.32 *Analysis of itemized relations between constructional part processes and enterprise assets*

The global activity program at a construction part process level, decomposed to years, has to be confronted to the expected capacity of enterprise assets (see under 1.2) in a corresponding decomposition. This confrontation requires a technology matrix $\mathbf{G} = [g_{ih}]$, $i = 1, \ldots, p$; $h = 1, \ldots, l$ of as many rows p' as there are resource types filed by, or involved in the capacity development plan by the enterprise, and as many columns l as there are construction part processes in the global activity program. Itemized listing of resource types (establishment of the asset register) has to keep in mind an admissible degree of screening out interchangeable resource types that integrate each other. Constructional part processes and their asset demands are not the same in each building category. Thus, the technology matrix $\mathbf{G}$ to be applied involves significant technology averages. Provided these averages are inadmissible, technology matrices $\mathbf{G}_j$ have to be established for each building category, together with their specifics. Decision between both solutions has to rely on the unified accuracy of the calculation, taking the given enterprise circumstances into consideration.

Elements of the technology matrix are indices of how much of a resource has to be consumed by unit quantity of a part process group, hence — to a precision of decomposition according to the asset register — a specific machine time, (specific) volume etc. of the output of some auxiliary equipment or central plant as required by unit of part process. Components f_h ($h = 1, \ldots, l$) of the vector of constructional part processes $\mathbf{f}$ represent the extension of each part process in a given unit. Accordingly, the actual technology matrix $\mathbf{G} = [g_{ih}]$.

These simply yield the resource requirement for the entire sphere of constructional part processes where components g_i ($i = 1, \ldots, p$) of the resource vector $\mathbf{g}$ represent quantities of resources i needed for the construction:

$$\mathbf{G}\,\mathbf{f} = \mathbf{g}.$$

Thus, the technology matrix makes the building task transformable from part processes to the level of enterprise resources.

Elements of the presented enterprise data system require to be continuously updated.

2. Confronting building demands and available resources

2.1 *Resources for the reduced building demands*

The reduced building demand has to be determined at the level of building categories as described under 1.13. Transfer factors established in the enterprise data system help to transform the building demand at the level of constructional part processes, of course decomposed to years:

$$\mathbf{F}\,\mathbf{b} = \mathbf{f}.$$

Thereby the reduced building demand transformed to part processes can be transformed by means of the technology matrix to the level of enterprise resources, by forming the product of constructional part process vectors $\mathbf{f}$ by the technology matrix $\mathbf{G}$, yielding the quantity of resources needed to meet the reduced building demand:

$$\mathbf{G}\,\mathbf{f} = \mathbf{g}.$$

Thereby the mechanical operations contained in the building task can be expressed within the structure of enterprise resources in terms of yearly consumption from each kind of resources in hours.

2.2 *Capacity investigation*

Resource requirement vector $\mathbf{g}$ of the reduced building demand compared to the vector $\mathbf{q}$ of the available resources of the enterprise points out the capacity development $\mathbf{u}$ needed to meet the overall reduced building demand:

$$\mathbf{u} = \mathbf{g} - \mathbf{q}.$$

It is simply obtained as the difference between the resource requirements of the building task and the planifiable capacity of enterprise resources for each kind of resources and for each interval, at predetermined times of the investigation.

If most of the important resources yield a negative result, that is, the given kinds of resources exhibit capacity excesses, then in general, the following may be considered:

- enlargement of the product assortment at the enterprise;
- extension of the enterprising readiness;
- ponderation of undertaking slightly lossy works in the event of temporary capacity excess in order to preserve assets;
- machinery redistribution between enterprises;
- sorting out machinery of low utility;

— handling potential reserves as capacity. These reserves provide for the flexible satisfaction of capacity demands often changing in the short run, and enhancing competitiveness of the enterprise in the "investment market".

The effect of reserve capacity to reduce the enterprise profit can be much mitigated by a more than average utilization of fundamental capacities, and by a more flexible entrepreneurial activity.

3. Possibilities of optimizing the product structure and the capacity structure in planning the entrepreneurial strategy

The long-range entrepreneurial strategy has possibly to be developed on the basis of the most favourable product composition, markedly affecting, in turn, long-range development and investment decisions of the enterprise. Provided the former linear transformations are valid and the preferential characteristic (here the enterprise fund) linearly depends on the issue, the best product composition at the given development level can be determined — in knowledge of the preference index of each building category — in terms of a LP (Linear Programming) model. Of course, to different possible development levels (volumes) different optimum product compositions belong.

Comparative analysis of the resulting developments is advisably made by price return—costs—profits analysis, always within the limits of available development funds.

Some favourable, detailed development alternatives obtained according to this train of thoughts may be of help to the enterprise management in preparing realistic decisions.

3.1 *Establishment and analysis of enterprise development alternatives*

3.11 *Preferential enterprise resources*

Application of the described LP model is conditioned by that the number of variables and restrictions does not exceed the available computer program capacity. Since the list of enterprise resources may contain as much as hundreds of asset types, their range must not be restricted by more than to truly reflect the machine stock of the enterprise.

The imposed restriction underlying the preferential resource list $\mathbf{g}^x$ may be done in either of two ways:

a) taking exclusively the principal machines in a chain or set into consideration;

b) aggregating machines in a set, forming so-called fictitious preferential resources.

Planifiable enterprise resources determined as under 1.2 have to be converted to preferential resources ($\mathbf{q} - \mathbf{g}^x$).

Now, matrices $\mathbf{G}^x$ of part processes and of preferential enterprise resources are obtained from technology matrix $\mathbf{G}$ of the relationship between constructional part processes and enterprise resources

in case a) by omitting rows in matrix $\mathbf{G}$ other than referring to principal machines or preferential resources,

in case b) by summing rows of matrix $\mathbf{G}$ containing specifics of resources in the same machine set.

If matrix $\mathbf{G}$ is available for each building category, a single, general, weighted matrix $\mathbf{G}^x$ has to be produced.

This condensed technology matrix $\mathbf{G}^x$ suits further calculation, permitting to determine the itemized relationship between building categories and preferential resources.

$$\underset{(\bar{p},\, l)}{\mathbf{G}^x} \cdot \underset{(l,\, n)}{\mathbf{F}} = \underset{(\bar{p},\, n)}{\mathbf{K}}$$

where elements k_{ij} of matrix $\mathbf{K}$ refer to the quantity needed from preferential resource type i for realizing a unit of building type j.

3.12 *Stating the* LP *problem*

Decision variable x_j ($i = 1, \ldots, n$) shows the quantity to be produced from building category j in natural units. Thus, vector $\mathbf{x}$ equals vector $\mathbf{b}$ under 1.13 both by magnitude and by dimension. But while $\mathbf{b}$ refers to the reduced solvent demand in each building category in the given interval, x represents an entrepreneurial policy, namely how much of each building type should be built at a given level of resources.

One group of restrictions refers to the preferential enterprise resources $\mathbf{g}^x$, the other group points to lower or upper bounds of the decision variables, hence, that of a building category a quantity at least x_j but at most $\bar{x}_j = b_j$ can be produced.

Part of the prescriptions refer to preferential resources $g_i^x = a_{0i}$ ($i = 1, \ldots, p$), the other to building groups j with respect to bound $\bar{x}_j = a_{0i}$ or $x_j = a_{0i}$ ($i = \bar{p} + 1, \ldots, n$).

Objective function of the model serves for establishing an entrepreneurial policy of higher funding value for a given level of resources. To this aim, preference indices c_j of each building category, understood as funding values of each building type, have to be formed as follows:

— determination of the linear function of price return vs. variable cost function characteristic of each building category based on the price return — cost — profit analysis for each building category within the reduced building demand (see under 1.13);

— taking the fund, that is, the difference between the specific price return for unit production volume and the specific variable cost as preference index for the given building category.

(Permanent costs having been omitted in its calculation, the Q(max) value obtained in optimizing the objective function is not identical to the expected profit of the given production alternative.)

Thereafter, mathematical model of the LP problem becomes:

$$\mathbf{A}\,\mathbf{x} \lesseqqgtr \mathbf{a}_0 \qquad \mathbf{x} = \{x_j\,(j = 1, \ldots, n)\}$$

$$\mathbf{c}'\cdot\mathbf{x} = Q\,(\max) \qquad \mathbf{a}_0 = \{a_{0i}\ (i = 1, \ldots, \bar{p}, \bar{p}+1, \ldots, n)\},$$

$$\mathbf{x} \geqq \mathbf{0} \qquad \mathbf{c} = \{c_j(j = 1, \ldots, n)\}.$$

where $\mathbf{A}$ is the coefficient matrix of the problem, containing two blocks:

$$\mathbf{A} = \begin{bmatrix} \mathbf{K} \\ \mathbf{N} \end{bmatrix}.$$

Matrix $\mathbf{K}$ is that under 3.11, and matrix $\mathbf{N}$ contains coefficients of conditions of the lower and upper bounds for building categories, having a single non-zero element in each row, of a value 1, in column j for building category j the prescription refers to.

3.13 *Establishment of enterprise development alternatives using the* LP *model*

The LP model formulated above may be used for an examination series, by assigning the first block a_{0i} $(i = 1, \ldots, \bar{p})$ of the prescription vector to determined resource levels. As a first step, the actual quantity $\mathbf{q}^x$ of the preferential resources is given as resource bound. Solution of the problem yields a favourable enterprise policy at the given resource level. Based on production volumes in each building category, the pertaining effective and total demand of assets $\mathbf{g}$ is:

$$\mathbf{F}\,\mathbf{x}^{(1)} = \mathbf{f}^{(1)} \qquad \mathbf{G}\mathbf{f}^{(1)} = \mathbf{g}.$$

Confronting it with $\mathbf{q}$, correctness of the preference given is examined, that is, if the asset types without preference did not become important bottlenecks.

In the second step, a somewhat raised (2 to 10%) value of the actual preferential resource quantity is given as resource bound, and the LP problem solved, again resulting in an optimum enterprise policy at the raised resource level the requirement in assets will be determined for. Confronting it to the actual asset capacity (see under 1.2) yields the asset investment $\mathbf{u}^{(1)}$ needed for the enterprise policy, and its purchase cost B_1 (Ft).

The presented procedure is continued — with determined increments of the resource levels — until every element of the resulting entrepreneurial

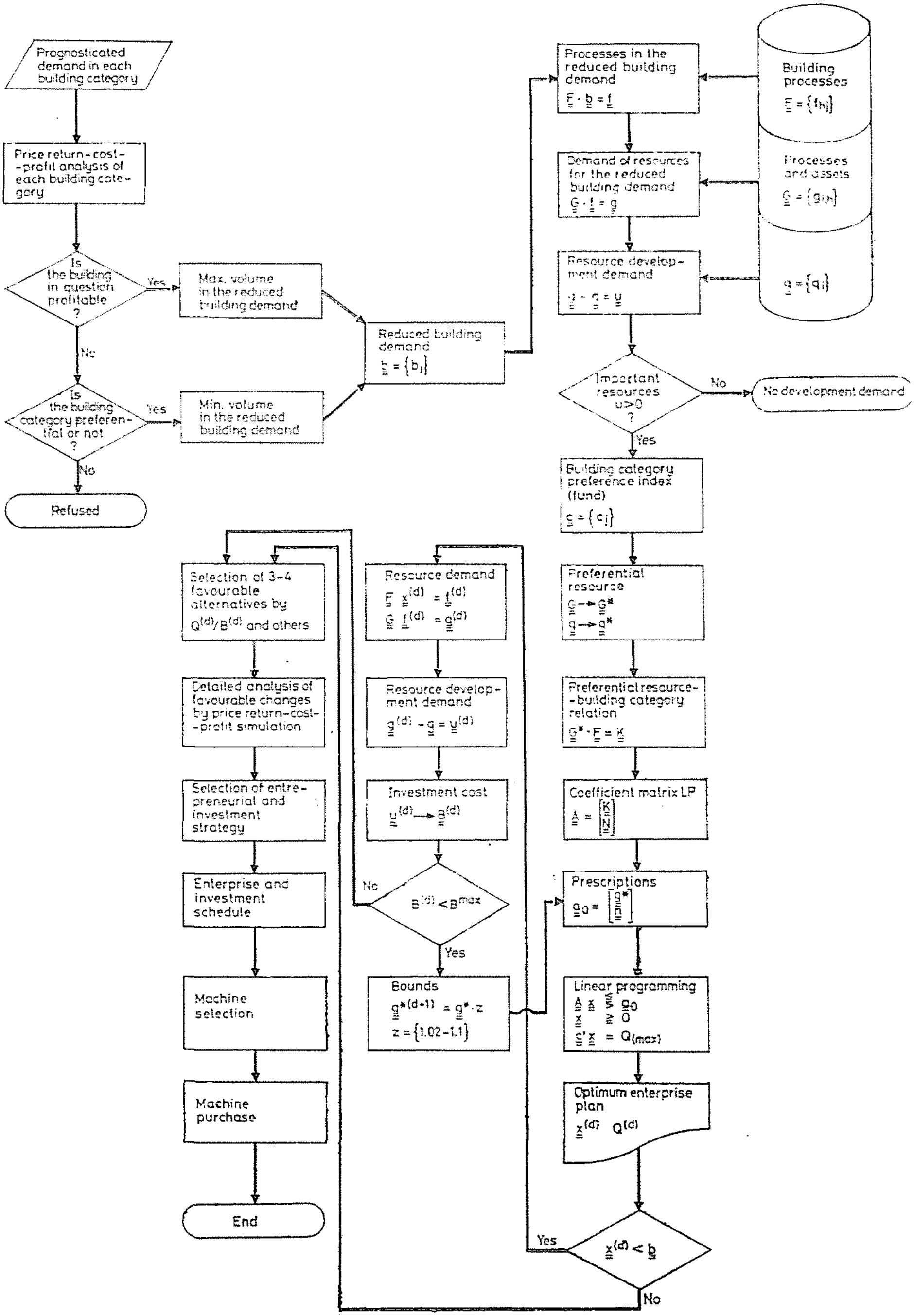
Prognosticated demand in each building category
Price return-cost-profit analysis of each building category
Is the building in question profitable ?
Yes
No
Max. volume in the reduced building demand
Is the building category preferential or not ?
Yes
No
Min. volume in the reduced building demand
Refused
Reduced building demand
Processes in the reduced building demand
Building processes
Demand of resources for the reduced building demand
Processes and assets
Resource development demand
Important resources u>0 ?
No
No development demand
Yes
Building category preference index (fund)
Preferential resource
Preferential resource-building category relation
Coefficient matrix LP
Prescriptions
Linear programming
Optimum enterprise plan
Yes
No
Resource demand
Resource development demand
Investment cost
No
Yes
Bounds
Selection of 3-4 favourable alternatives by Q(d)/B(d) and others
Detailed analysis of favourable changes by price return-cost-profit simulation
Selection of entrepreneurial and investment strategy
Enterprise and investment schedule
Machine selection
Machine purchase
End

Fig. 1.

policy attains the reduced building demand, while, of course, the development investment cost B is kept within reasonable, feasible limits.

After the solution of all LP problems, preference given the resource kinds $\mathbf{g}^x$ has to be checked for correctness, and the arising product and resource compositions have to be examined for an eventual change caused in specifics of **F** and **G**.

In establishing the alternatives, in building categories where decision variables x_j soon attain the relevant building demand — to be incorporated in the entrepreneurial policy in a share as big as possible — further, still undiscovered solvent demands have to be detected. In the positive case, vector **b** of the reduced building demand has to be modified accordingly.

Among the numerous enterprise and development alternatives, those opposite to the long-range enterprise realizations or those the needed development credit is not available for have to be excluded. Besides, for all alternatives, the Q/B ratio has to be established, to rely on in appointing the few ones to be further examined by entrepreneurial decision on managerial level.

Thereby the number of alternatives is much reduced, in fact, to three or four favourable ones.

3.2 *Detailed analysis of favourable entrepreneurial and investment alternatives*

A well-founded choice between favourable alternatives established above has to be preceded by a detailed efficiency analysis. The analysis of the expected economical efficiency of investments is advisably made by entrepreneurial price return-cost-profit simulation. In fact, the enterprise price return—cost—profit determination has to be made first for the time before the investment. Their resultant yields the profitability of the proposed investment.

The two-step analysis of price return—cost—profit affecting all favourable alternatives yields further information such as time of recovery of the given investment alternative, change of the structure and volume of the production and resource stock at the enterprise, influence ranges of the investment at various organizational units of the enterprise etc.

This detailed analysis of the favourable entrepreneurial and investment alternatives is an important item of the preparation of a well-founded managerial decision, determining, over a long run, the proficiency of the entrepreneurial and productional policy of the enterprise. This decision unambiguously defines the development requirement, followed by the examination and purchase of machines in the building machinery market.

Summary

A procedure has been developed for the establishment of the medium and long-range entrepreneurial and investment strategy of a Hungarian building enterprise, coordinating building tasks and enterprise assets. Building demands are sorted according to building categories and main part processes, then assets assigned to these latter. Capacity planning has to rely on the enterprise output fitting strategies and expectations. The percentage of known tasks and reliability of information is inversely proportional to the time parameter.

A dynamic model has been established for the product and capacity structure of the enterprise. A flowchart is presented for the determination of the optimum development plan

Dr. Miklós SARLÓS } H-1521, Budapest
Dr. Tamás TÖRÖK