Staff Paper

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FOR BIOTECHNOLOGICAL PROCESSES

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SUMMARY

The investment model enables an assessment of the economical feasibility of any biotechnological project. This model consists of five interactive parts: market volume (which determines the plant size), price, investment costs, production costs and an economic analysis. Return on investment (ROI) is used to measure the profitability of the project. The final solution concerning investment potential is carried out as a sensitivity analysis.

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INTRODUCTION

In the past, land use has focussed on food and feed production. Positive results include a high degree of food security and relatively high quality food production as well. But there are also some negative consequences: the tendency in developed nations to produce agricultural surpluses and a growing cost of subsidies which will become very difficult to finance in the future.

On the other hand, agricultural commodities can serve as raw materials for biotechnological and natural product chemical processes. Biotechnological processes for the production of an abundant amount of products have been developed. However, many of these projects are not yet economically feasible.

OBJECTIVE

The main objective of this work is to examine the market and production possibilities for chemical and food products manufactured from agricultural raw materials through biotechnological processes. After calculation of an expected return on investment based on this developed investment model, an investment decision can be made with more certainty. The main variables which are taken into consideration in determining the economics of a biotechnological process are the market place, the technology, and the production costs. The practical usefulness of the investment model is given special attention in this study.

PURPOSE OF THE MODEL

This model is a valuable tool in decision making for:

- Selection of research projects
- Starting up of research work (based on literature data)
- Scaling up the research results into the pilot plant.

For this kind of decision making there should be an economic incentive, if a research group is market oriented. It is necessary to know if there is actually an economic potential for a considered process, and under which circumstances a favorable ROI (Return on Investment) can be expected.

For the decision making listed above, it is most likely that an entire economic study would be too expensive. For example, the investment costs of pre-investment studies in terms of percent of total investment are approximately (UNIDO, 1985):

1. An opportunity study, 0.2 - 1.0%
2. A pre-feasibility study, 0.25 - 1.5%
3. A feasibility study, related to the magnitude of the project from 1.0 - 3.0% for small industries to 0.2 - 1.0% for large industries with sophisticated technology.

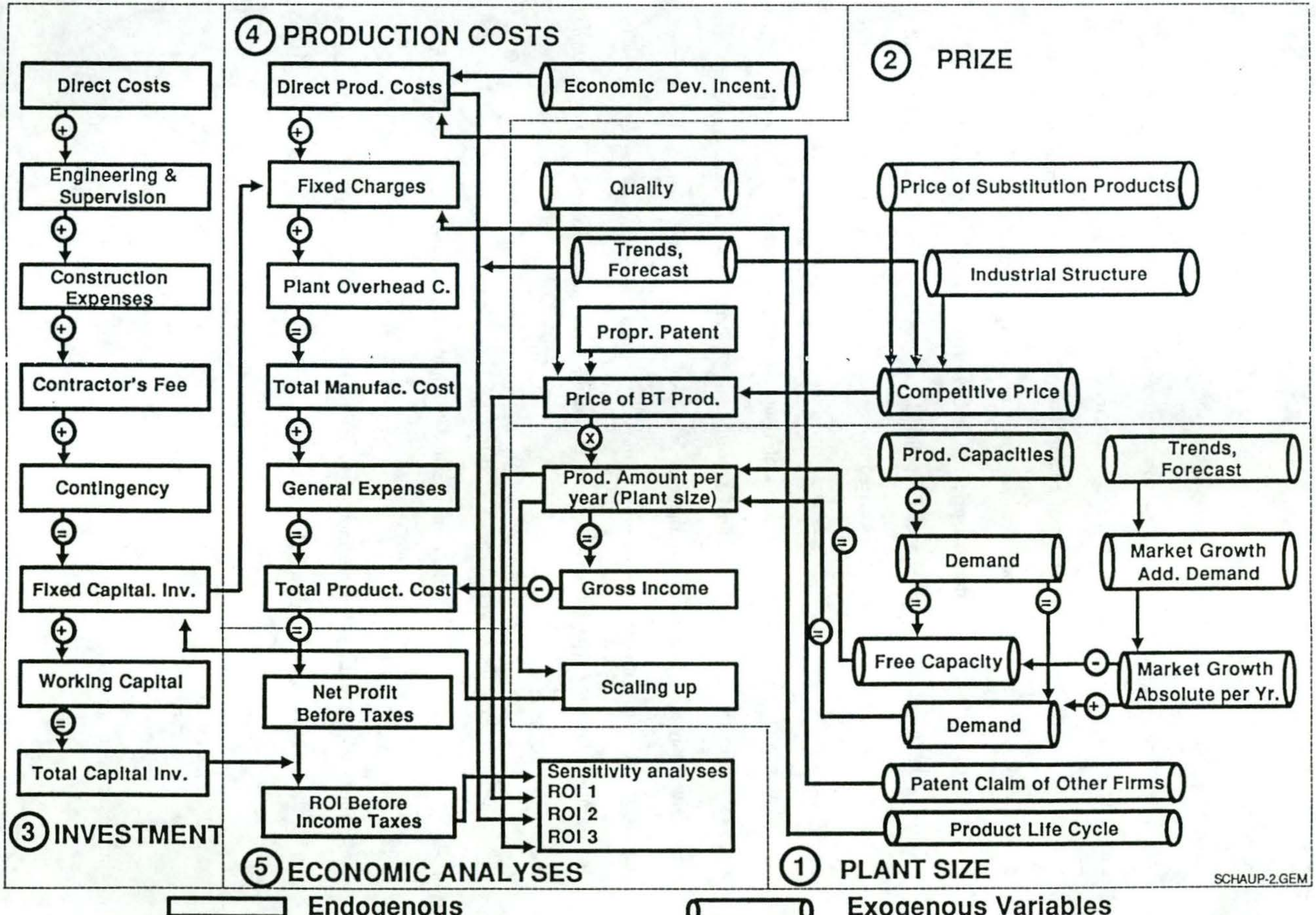
These kind of studies are essential if a project is going to be realized.

MODEL CONSTRUCTION

The established model is an investment model designed (1) to focus the most salient variables for production costs and market possibilities and (2) to assess the production feasibility of products which are produced by means of biotechnology. The model applies generally to any new biotechnological product. Different products, however, imply different parameters. Therefore, parameters must be selected with a particular product in mind. The parameters should give a realistic representation of the behavior of the real system.

The basic structure of the model is presented in Fig. 1. The conceptual model is intended to highlight the importance of accurate estimation of production costs (with different technologies) and the achievable price of the product within a determined plant capacity. The calculation of ROI finally is a good tool to evaluate the economic feasibility of a project. In this investment model, it is assumed that the ROI provides enough information to fit the model. Thus, the decision to invest in a new plant should be evaluated on the basis of its risk-adjusted net present value (NPV). The first criterion of interest, the net present value, has already been

Fig. 1. Investment Model for Biotechnological Processes - Basic Structure (Schaup, A., J. Ferris, 1989).



defined by others as the cumulative sum of the discounted cash flows. In other words, NPV corresponds to the total discounted net return, above and beyond the cost of capital and the recovery of the investment (WARD, THOMAS J., 1989).

In this model there are macroeconomic aspects that will be ignored for reasons of simplicity, even though there is evidence that they may be important in some types of analysis. For instance, the influence of the form of competition on the achievable price of the product is not explicitly considered. Also, transportation costs are not explicitly considered in this model.

The model focusses on the real price of an identifiable biotechnological product, which may be dependent on various economic, political and social environments. The verified production scale, sale price and the calculated costs of the production enables one to determine if production could be economically feasible.

Any model is only an approximation of reality, and there will always be errors in its absolute prediction. Therefore, the final solution will be carried out as uncertainty analysis (sensitivity analysis). Particularly in the case where the data may be weak or non-existent, sensitivity testing is a method for determining how responsive the outputs of the model are to uncertainties about the data incorporated into the model (e.g., sales price, cost of raw material or energy, scale effect, etc.).

Particularly for the newer, unestablished technologies, the data are estimates and subject to considerable uncertainty. Results from the model should be interpreted with this limitation in mind.

The model is static -- but the input data can be altered (within limits) to suit the user's view of the best values for the data. The model is comprised of five interacting sectors (Fig. 1).

1. Plant size
2. Price
3. Investment
4. Production costs
5. Economic analysis

which enables an economic evaluation of a project.

The model can be used as a simplified model or as an extended model for expanded analyses. It should be noted that the simplified model does not predict the economic feasibility of a project in the future. It is a representation of present circumstances. The extended model includes an approach to possible future conditions (market price forecasts, raw material forecasts, etc.).

MODEL REALIZATION

Model realization needs to transform the most important variables mentioned in the basic structure at Fig. 1. into tangible numbers. Below is shown an introduction for a general approach.

1. Plant size

   A. Production capacities, Demand, Free capacities, Market growth: Data are available from different sources, e.g.: Chemical Marketing Reporter (CMR); International Trade Commission, Bureau of Census and CMR Industry survey; etc. Market growth and market share can be determined by the share/growth matrix (product portfolio) developed by the BOSTON CONSULTING GROUP (1970). Each product is classified jointly by rate of present or forecast market growth (a proxy for stage in the product life cycle) and a measure of market share dominance. The product portfolio assumes that the primary objective of the firm is the maximization of return on investment (ROI). This data is very important to estimate the plant size of a new production plant.

   B. Scaling up:

   A commonly used scaling relationship for the estimation of cost data for both individual equipment and whole plant construction costs is the power factor rule or the so-called six-tenth factor (PETERS, M. S., TIMMERHAUS, K.D., 1980):

$$\text{Cost of plant a} = \text{cost of plant b} * \left(\frac{\text{capacity of plant a}}{\text{capacity of plant b}} \right)^{x}$$

where the scaling factor (the exponent x) is a constant. In absence of other information, it is common practice to assume a rule-of-thumb value of 0.6 for the scaling factor.

C. Patent claim of other firms:

- whether other technology is available
- whether a joint venture is possible
- if the technology can be licensed
- when the patent will expire
- whether other possibilities are available to solve the problem.

D. Product life cycle:

It is not possible to measure the product life cycle for this model. But an entrepreneur should know in which stage of the cycle a product already is or what life time of a new product can be expected. The product life cycle can influence the depreciation time.

2. Price

A. Price Trends and Forecasts:

Price trends and forecasts of the product such as raw materials, energy, market growth, will not be calculated in this model. The data are external data for this model and will be derived from different sources like CMR, AGMOD (FERRIS, J.N., 1989), FAPRI (1987), Petroleum Econometrics, Wharton Econometrics, and so on. The forecasts are the input data for the sensitivity analysis, which reflect the changing environment of the future.

B. Proprietary patent:

If there is a proprietary patent available, its influence on the market price and the consequences of its expiration are important considerations.

C. Product quality:

A product can be characterized by a "quality" concept which incorporates all factors that the market appreciates. It seems reasonable to assume that there is an upper limit to quality, and the quality never decreases with time. Some products rapidly increase to maximum quality, while other products require more basic research before attaining high quality. Let us arbitrarily assume that the quality of the product can vary from 1 to 10 quality units. The next step is to verify which quality unit our product has, and what the market demand and market price for this quality are.

Quality criterions include purity, biodegradability, naturally versus chemically derived, etc.

D. Substitution price:

Which substitution products are on the market and what is their market price.

E. Domestic price (Competitive price):

The real domestic price of a biotechnological product can be deduced from literature sources such as "Chemical Marketing Reporter".

F. Industrial Structure (Form of Competition):

The number of existing producers influences market entry of a new firm or the price of a product if a new firm enters the market. The industrial organization of a market is generally measured by the Concentration Ratio (CR): Percent of an industry's sales controlled by the top x number of the largest firms in the industry.

G. Expected price of the (new) biotechnological product:

The expected price can be found thru consideration of the variables cited above; it also depends on the plant size.

3. <u>Investment</u>

A. The following items are covered through direct costs:

Land
Yard improvement
Buildings (including services)
Service facilities
Purchased equipment
Purchased equipment installation
Instrumentation and controls
Piping
Electrical equipment and materials

B. Fixed capital investment (FCI):

Data from the literature will be adapted with the "Chemical Engineering Plant Cost Index" (MATLEY, J., 1982). A "grass-roots" plant is defined as a complete plant erected on a new site. Investment includes all costs of land, site development, battery-limit facilities, and auxiliary facilities. A geographical boundary defining the coverage of a specific project is a battery limit. Usually this encompasses the manufacturing area of a proposed plant or addition, including all process equipment but excluding provision of storage, utilities, administrative buildings, or auxiliary facilities unless so specified. Normally this excludes site preparation and therefore may be applied to the extension of an existing plant (PETERS, M.S., TIMMERHAUS, K.D., 1980).

If there are not accurate numbers available, some "rules of thumb" can be very useful (DONALDSON, T.L. and O.L. CULBERSON, 1983):

Battery limit costs are multiplied by 1.4 to obtain fixed capital investment. Working capital is taken to be 14% of the fixed capital for non-seasonal raw materials processes, and 25 % of fixed capital for processes using seasonal raw materials.

4. Production costs

The various cost elements are presented in the order shown in Fig. 2 (PETERS and TIMMERHAUS, 1980).

A. General expenses:

Sales, administration, and research can be estimated as 12% of revenues from sales of products (DONALDSON T.L. and O.L. CULBERSON, 1983), or

Fig. 2. Costs Involved in Total Production Cost for a Typical Chemical Process Plant

PLANT DESIGN AND ECONOMICS FOR CHEMICAL ENGINEERS

- Total product cost
  - Manufacturing costs
    - Direct production costs
      - Raw materials
      - Operating labor
      - Operating supervision
      - Power and utilities
        - Steam
        - Electricity
        - Fuel
        - Refrigeration
        - Water
      - Maintenance and repairs
      - Operating supplies
      - Laboratory charges
      - Royalties (if not on lump-sum basis)
      - Catalysts and solvents
    - Fixed charges
      - Depreciation
      - Taxes (property)
      - Insurance
      - Rent
    - Plant overhead costs
      - Medical
      - Safety and protection
      - General plant overhead
      - Payroll overhead
      - Packaging
      - Restaurant
      - Recreation
      - Salvage
      - Control laboratories
      - Plant superintendence
      - Storage facilities
  - General expenses
    - Administrative expenses
      - Executive salaries
      - Clerical wages
      - Engineering and legal costs
      - Office maintenance
      - Communications
    - Distribution and marketing expenses
      - Sales offices
      - Salesmen expenses
      - Shipping
      - Advertising
      - Technical sales service
    - Research and development
    - Financing (interest) (often considered a fixed charge)

Gross-earnings expense

General expenses can be taken as the sum of 15% of the operating labor, 16% of the total product cost and 5% of the total capital investment (GANGL, I.C., WEIGAND, W.A. and F.A. KELLER, 1989).

B. Economic development incentives:

There can be many regulations and restrictions which have a direct effect on the costs. For example: Market protection (import and export tariff regulations), income tax rules (tax holidays), policy on subsidies, environmental regulations, etc.

5. Economic Analysis

For the purpose of this work it is important to evaluate (new) projects in economic terms:

Gross income = Price x Production per year

Net profit before taxes = Gross income - Total production costs (TPC)

Net profit after taxes = Net profit before taxes - Income tax

ROI before taxes = Net profit before taxes: Total capital investment x 100 (in percent).

ROI after taxes = Net profit after taxes: Total capital investment x 100 (in percent)

ROI Base Case:

The most elementary profitability parameter is the annual return on investment (ROI). Companies often base investment decisions on this criteria.

The ROI should reflect the influence of project novelty, risk, uncertainty, and the many external factors that can effect a venture during its lifetime.

In general, a 20% return of fixed and working capital before income taxes would be the minimum acceptable return for any type of business with established technology and a 35% return for unproven technologies to reflect uncertainty and attend financial risk.

If capital is available for investment in a proposed enterprise, it would also be available for use in other ventures. Therefore a good basis for determining an acceptable return is to compare the predicted return and the risks involved with returns on other types of investments.

ROI before taxes is a better reflection of the real performance of a firm, because income taxes are different from country to country. From a shareholders point of view the ROI after taxation is more important. Profit or performance comparison of firms are often made in terms of "return on invested capital of after-tax net income as a percentage of sales.

MODEL APPLICATION (Lactic Acid)

Lactic acid production by means of biotechnology was chosen as an example to illustrate this investment model in a practical case (Fig. 3). Data for this example was obtained from several sources:

1. Note from Raiffeisen Bioforschungs/Ges.m.b.H (Sei/Go, Wien, 1988-10-24)
2. "Lactic Acid and 2,3 Butanediol". A short study prepared for Österreichische Agrar-Industrie, May, 1986; LIBRA.
3. Chemical Marketing Reporter, March 6, 1989.

Lactic acid is produced both by fermentation and chemical synthesis. Lactic acid finds its chief use in the food industry. It is also used to manufacture lactate esters, such as ethyl lactate and n-butyl lactate. Salts are used chiefly in pharmaceuticals, but also in foods. The acid can be used in leather tanning. Organic derivates are used as plasticizers and in adhesives. This most exciting feature should maintain growth into the next decade.

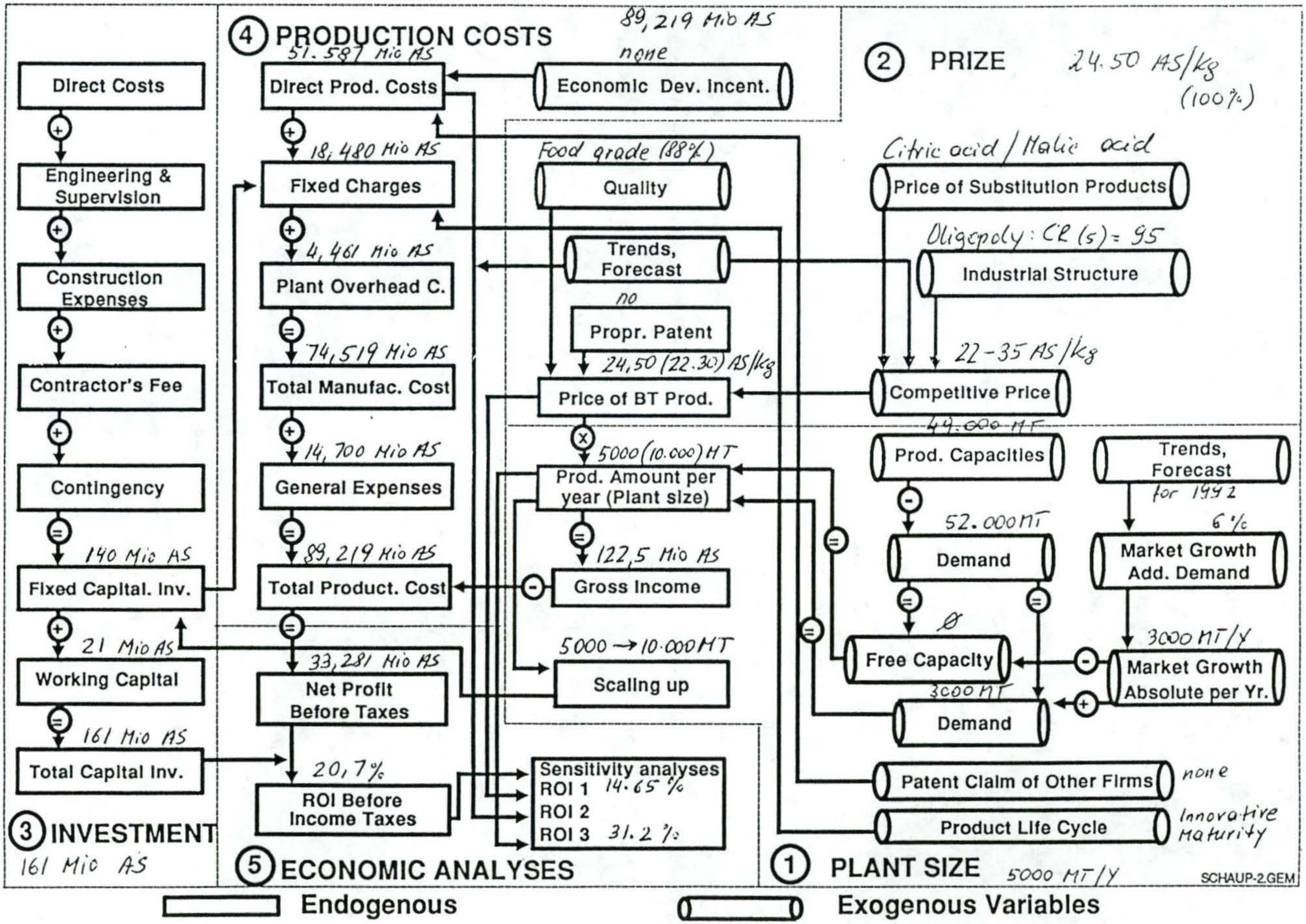
1. PLANT SIZE:

With growth continuing at 6% per year, the demand in future years will be as follows:

World	Demand	Capacities
1986	35-49,000 MT	38,000 MT
1988	41,500 MT	
1990	46,000 MT	
1992	52,000 MT	49,000 MT
1993	55,000 MT	

There are now five major producers in the world who supply over 95% of demand (CR(5)=95) for a product in which the economies of scale are not usually considered to

Fig. 3. Investment Model for Biotechnological Processes - Basic Structure (Schaup, A., J. Ferris, 1989).



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be critical. According to the data given above, further increases in capacity will therefore be required in 1990.

Plant size: 5000 MT (100% lactic acid).

2. PRICE:

Price according to the CMR (Chemical Marketing Reporter, June, 1989): $1.03/lb, tech, 88% = Austrian Schillings 35.00/kg, 100% Lactic acid (1 US $ = 13.456 AS). Price has been very stable in recent years. Lower prices can be negotiated by large quantity purchasers (quantities greater than 1 MT). In the base case calculation we assume a price according to CMR minus 30% for covering retail margins or dealing with large quantities.

35 AS/kg 100% Lactic Acid - 40% = 24.50 AS/kg 100% Lactic Acid

The following calculations are in Austrian Schillings (AS) and based on a 100% lactic acid.

3. INVESTMENT:

Plant size: 5000 MT/year.
Battery limit costs: 100 Mil AS

Total plant cost (Fixed Capital Investment (FCI)) =
Battery limit costs x 1.4

FCI = 100 Mil AS x 1.4	=	140 Mil AS
+ Working capital (15% FCI)		21 Mil AS
Total capital investment		161 Mil AS

4. PRODUCTION COSTS:

(Price for Saccharose: AS 3.00/kg

Energy: AS 0.94/KWH

Price: 1 kg 100% Lactic Acid = 24.50 AS)

	AS/kg	Mil AS/5000 MT
Direct production costs		
Raw material + energy + utilities	6.885	34.425
Operating labor + direct superv.	2.190	10.950
Maintenance + repair	1.064	5.320
Laboratory charges (1% TPC)	0.178	0.892
Total direct production cost	10.317	51.587
+ Fixed charges		
Depreciation (10 years)	2.800	14.000
Local taxes (2,5% FCI)	0.700	3.500
Insurance (0,7% FCI)	0.196	0.980
	3.696	18.480
+ Plant overhead costs		
5% TPC	0.892	4.461
= Total Manufacturing Cost	14.905	74.519
+ General expenses		
Sales, administration and research costs, 12% of sales revenues (1kg=24,50 AS)	2.940	14.700
= TOTAL PRODUCTION COST (TPC)	17.845	89.219

5. ECONOMIC ANALYSIS:

Gross income: 5,000 MT Lactic acid x 28.50 AS/kg = 122.5 Mil AS

Net profit before taxes: 122.5 Mil AS - 89.219 Mill AS = 33.281 Mi AS

A. BASE CASE:

ROI before taxes: 33.281 : 161.000 = 0.207 = 20.7%

B. SENSITIVITY ANALYSES:

1. Sensitivity of selling price to ROI:

Selling price +- 1.00 AS/kg: --- +- 2.71% ROI before taxes

For example: Price for Lactic acid according to the Austrian Import Price (Note DI SEI/88-10-24) at 22.30 AS/kg:

ROI before taxes: 14.65%

2. Sensitivity of scale-up to production cost:

Price for Lactic acid: 24.50 AS/kg (100% lactic acid).

a. Plant size: 5,000 MT p.a. --- 10,000 MT p.a.

Investment Formula

$$\text{Cost of plant a} = \text{cost of plant b} * \left(\frac{\text{capacity plant a}}{\text{capacity plant b}}\right)^{0.6}$$

Investment =	212.20	Mil AS (FCI)
+ Working capital	31.83	Mil AS
Total capital investment	244.03	Mil AS

b. Plant size: 5,000 MT p.a. --- 20,000 MT p.a.

Investment =	212.20	Mil AS (FCI)
+ Working capital	48.24	Mil AS
Total capital investment	369.88	Mil AS

Table On Production Costs

	1. 10.000 MT	2. 20.000 MT
Direct production costs	Mil AS	Mil AS
Raw material + energy + utilities	68,850	137,700
Operating labor + direct superv.	21,900	43,800
Maintenance + repair	10,640	21,280
Laboratory charges (1% TPC)	1,689	3,234
Total direct production cost	103,079	206,014
+ Fixed charges		
Depreciation (10 years)	21,220	32,164
Local taxes (2,5% FCI)	5,305	8,041
Insurance (0,7% FCI)	1,485	2,251
	28,010	42,456
+ Plant overhead costs		
5% TPC	8,447	16,172
= Total Manufacturing Cost	139,536	264,642
+ General expenses		
Sales, administration and research costs, 12% of sales revenues (1kg=24,50 AS)	29,400	58,800
= TOTAL PRODUCTION COST (TPC)	168,936	323,442
TPC in AS/kg Lactic Acid 100% (= Cost/unit)*	16.89	16.17
Gross income in Mil AS	245,000	490,000
Net profit before taxes	76,064	166,558
ROI before income taxes	31.2%	45.0%

* Cost/unit does not include interests for capital investment.

Comment:

Both selling price and plant size have a very big influence on the ROI. If the selling price according to the "Chemical Marketing Reporter" minus 30% is achievable on the world market, a production plant of 5,000 MT per year seems profitable. Prices above 24.25 AS/kg and 26.10 AS/kg gives reasonable ROIs (before income taxes) of 20 and 25%, respectively. The available data do not allow calculation of the sensitivity of raw material or energy prices to ROI.

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REFERENCES

BOSTON CONSULTING GROUP (1970): "The Product Portfolio", Boston, The Boston Consulting Group.

CMR: Chemical Marketing Reporter. ISSN 0900-0907; Published weekly on Monday by Schnell Publishing Company Inc., 80 Broad Street, NY 10004-2203.

DONALDSON, T.L. and O.L. CULBERSON (1983): "Chemicals from Biomass: An Assessment of the Potential for Production of Chemical Feedstock from Renewable Resources"; ORNL/TM-8432, OAK RIDGE NATIONAL LABORATORY, Oak Ridge, Tenn. 37830.

FAPRI (1987): "Ten-Year International Outlook"; FAPRI Staff Report #4-87. 578 Heady Hall, Iowa State University, Ames, Iowa 50011.

FERRIS, J.N. (1989): "A Description of "AGMOD" - an Econometric Model of US and World Agriculture"; Agricultural Economics Staff Paper #89-19, February 1989, Department of Agricultural Economics, Michigan State University, MI.

GANGL, I.C., WEIGAND W.A. and F.A. KELLER (1989): "Economic Comparison of Calcium Fumarate and Sodium Fumarate Production by Rhizopus arrhizus"; Chemical Engineering Department, Illinois Institute of Technology, Chicago, IL.

MATLEY, J. (1982): "CE Plant Cost Index - Revised"; Chemical Engineering, April 19, 1982.

PETERS, M.S. and K.D. TIMMERHAUS (1980): "Plant Design and Economics for Chemical Engineers"; Third Edition, McGraw-Hill Book Company.

UNIDO (1985): "Manual for the Preparation of Industrial Feasibility Studies"; 1985, Sales #E 78.II.B.5.

WARD, J.T. (1989): "Estimate Profitability using net return rate"; Chemical Engineering/March 1989.