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A SYSTEMS METHODOLOGY FOR EVALUATING INDUSTRIAL PROJECTS IN THE CONTEXT OF NATIONAL STRATEGIES

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In their rush for industrialization many developing nations are undertaking some projects that will never be completed, others that will cost more than they are worth even if completed, and still others that will conflict with national objectives even when the stated project goals are achieved. How are these common occurrances possible when industrial projects are evaluated with such care and detail?[1] To be sure some of these projects fail because of wholly unforeseen changes in the social, economic, or political environments; others fail due to shortage of the skills needed to implement basically sound industrial ideas. This paper suggests that most industrial project difficulties, however, arise out of faults in the early planning and evaluation process.

Faults in Industrial Project Evaluation Methods

Despite the large number of factors included in the typical project appraisal (as referenced above), the evaluation methods are oversimplified in the analytic schemes that they encourage. Some faults in the project evaluation methods are:

1. they generally assume a static, rather than dynamic view of the project environment;

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[1] As examples of the depth employed in such evaluations, see "Check List for Feasibility Appraisal of a Proposed Industrial Establishment", U.S. Department of State, Agency for International Development, or "Questionnaire for Industrial Projects", International Bank for Reconstruction and Development.

2. the evaluation methods used are non-integrative, treating multiple considerations separately except as each impacts the pro forma balance sheet of the project;
3. they are nonrigorous, in that many assumptions, arguments, and conclusions are based wholly on qualitative, nonquantified estimates;
4. the techniques are not flexible, requiring extensive redoing of the analyses whenever key aspects of the proposed industrial projects are changed;
5. they are not sensitivity-oriented, relying largely on single-point estimates of both influences upon and consequences of the project;
6. the evaluations produced are one-shot in character, and do not contribute modules that might simplify later related industrial project evaluations;
7. the methods are not feedback-oriented, and the intermediate effects of changes contemplated during the project's implementation cannot adequately be considered;
8. finally, and partially as a result of the above, the methods are strongly geared to the passive role of evaluation of already existing industrial opportunities rather than to the active creation of new project possibilities.

Each of these failings is discussed below.

Static view. Although industrial projects being evaluated are often five to ten years from initial operation and even longer from industrial maturity, the bases for cost and market forecasts are usually current or historic data. Little attempt is made to establish the influences underlying the cost structure and market demands, their interrelationships, and the expected time-behavior of these influences and their consequences. For example, the past year has witnessed a major increase in the world price of mercury, suggesting the possibilities of desireable mining and processing projects in this area. However, deeper examination of the structure underlying mercury price behavior would reveal that no significant changes have occurred in world demand for many years; marginal mines have been closing during the past few years due to below "breakeven point" operation; and finally, as enough mines closed to bring world production below world demand, inventories have been reduced gradually and the pressures have pushed prices skyward. Further analysis of this same situation would also reveal that the price increases have encouraged some existing mines to increase output and to begin reopening the previously closed marginal operations, suggesting an oversupply condition within the next several years with resultant price declines. But a static view of recent and current profitability in mercury operations would fail to detect this force structure that underlies the price-profitability dynamics.

Non-integrative techniques. Despite (perhaps because of) the thoroughness of the details considered in industrial project evaluations, little possibilities exist for integrating the effects of the various factors. For example, the World Bank suggests the multiple aspect approach to evaluation, considering economic, technical, managerial, organizational, commercial, and financial aspects.[2] But the examination of several points of view separately does not necessarily lead to the same conclusions as when their interrelationships can be studied. In a new manufacturing endeavor the timing of marketing requirements may demand extensive management attention just when production start-up problems occur. Neither of these demands, considered separately, may be sufficient to strain the organization's limited skilled resources. But should the two areas of marketing and production interact, as they usually do, the resultant manpower bottleneck may be the key problem needing attention during the early project evaluation. This type of interaction of superficially separate aspects of a project under evaluation would seldom be reflected in the pro forma balance sheets prepared for the project, usually the only integrative tool used in the evaluation. Yet crises in the allocation of management time occur even more frequently than do crises in the allocation of cash, leading to many of the failures found in industrialization attempts.

Nonrigorous methods. Few evaluations of industrial projects rely upon rigorously specified assumptions. Costs are projected with certain optimistic ideas in mind, but these are seldom specified. The project initiator may hold beliefs about the kind of workers who will be available, and may base his productivity calculations on such implicit assumptions, but hardly ever are these spelled out. Going one step further, it is a rarity for notions such as the price elasticity of demand for a product being considered

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[2] Documentation of the World Bank schema has been clearly presented in regard to projects of all types, including industrial projects. See, as example, Hugh B. Ripman, of the International Development Association, "Appraisal and Supervision of Projects" (mimeographed manuscript of speech presented in Taipei in March, 1961).

for manufacture to be presented in a project proposal in mathematical or geometric form. If possible variations in price are even contemplated, market reaction is usually handled in a qualitative manner. The same is true for effects of quality variations upon possible demand level changes. With such factors indicated in a nonquantitative fashion, arguments and conclusions on the project's merits are often unresolvable.

Inflexibility. The evaluation methods used almost always require extensive manual processing of large amounts of empirical data and assumptions. Should one of the key assumptions change, or should it be desired to consider alterations in the project proposal, all of the evaluation computations need to be redone, again by manual means. Lack of computer-programmed evaluation methods thus adds considerable time to the evaluation of alternatives and discourages the posing of many new assumptions about a project. This fault ties in with the next limitation.

Point vs. range estimates. The project evaluation techniques in use encourage single-point estimates of cost and market factors, and single point determination of the cost/benefits balance of the project. This procedure is foolhardy in that it overlooks the strong possibility that the project's attractiveness may be very sensitively dependent upon one or more critical features. A more intelligent basis for industrial project evaluation should rely upon tests of variations in numerous assumptions within a reasonable range. The resultant project estimates would then constitute a range of values that would suggest the extent of risk of failure possible in the proposed undertaking. Of course, a shift to range estimates from single-point estimates demands extensive additional data processing and evaluation computations, probably far more than is feasible using manual techniques.

Lack of evaluation modules. Each industrial project being evaluated is regarded as somewhat unique. To be sure such uniqueness is one of the sources of difficulties during the early stages of experience development in the field of industrial project evaluation. Yet, on the other hand, major groups of projects apparently are regarded as somewhat similar, leading to various sets of evaluation guidelines for educational projects, water resource projects, industrial projects, and others. Why should such a guideline be the only common element shared by several projects? Is it possible that other aspects of project groups can be found, and isolated as evaluation modules for use in later evaluations of other different or more complex projects? This notion will be considered at greater length later in this paper.

Lack of feedback-orientation. The purpose of industrial project evaluation is to better select projects that will have impact on their environment, changing employment, output, standard of living, et al. Yet, too often the evaluation methods ignore the intermediate effects of these and other changes that may be brought about by the initial stages of project implementation. For example, if the potential labor force in an African community is still uncommitted to an industrial way of life, the initial period of plant construction may provide enough income to satisfy temporarily the consumption requirements of many, thereby encouraging quitting by many of the workers on the project, and causing an unexpected shortage of labor. In a more industrialized society the construction phase of a large industrial complex may encourage increased labor organization and effective labor demands, perhaps shifting labor costs upward to an extent sufficient to undermine the planned project. As another example, initial production and distribution of consumer goods for local consumption may create demand-generating effects that would have justified a larger more economical production unit. All of these possible intermediate effects of industrial projects should be fed back for consideration during the initial project evaluation.

Passive role of evaluation. Perhaps as a result of all of the limitations listed above, the project evaluation phase is too often seen as a passive analytical response to other industrial planning phases that include search for and discovery of industrial opportunities. With greater flexibility to determine consequences of modified project proposals, with access to evaluation modules that might permit experimentation, the project evaluation activity may be naturally broadened into a design phase for creating new project possibilities. This should permit an appropriate iteration between initial project proposal and initial evaluation, followed by proposal redesign and reevaluation, further redesign and reevaluation, etc.

Having identified the several faults described above as characteristic of today's usual industrial project evaluation methods, it is apparent that improved methods are possible. The general theme of the proposed approach to industrial project evaluation is threefold:

1) one cannot evaluate a proposed project without explicitly taking into account the expected complete life cycle of the project establishment process;

2) the evaluation of projects large enough to impact the economy of the region or nation in which it will be established requires economic-demographic analysis as well as industrial analysis;

3) these two analysis requirements call for a broadening of both the time and spacial dimensions of the problem, provided at least in part by a systems approach to industrial project evaluation.

The Life Cycle of an Industrial Project[3]

Many industrialists, financiers, and project analysts view the evolution of an industrial project as a discrete set of activities, separated in time and integrated only as each independently affects the final project. What is apparently ignored by such people is that the basic project activities can also be viewed as a set of continuous streams, each affecting and affected by the other activities throughout the project life. These activities occur within the framework of potentially shifting world and local conditions. The changing environment for the industrial project has the two dimensions of value and cost related to the potential undertaking.

Potential value. In Figure 1 is pictured the potential value through time of any industrial project. Note that for a given environment the potential value (i.e., potential benefits or possible market) of a project may be near zero at some early point in time. (Consider, as an example of this low value phenomenon, the worth of a project for producing advanced consumer goods in an underdeveloped economy. Such a manufacturing enterprise might have no local market for its output and, because of transportation costs, might be priced out of export markets.) To be sure, as time elapses the market value of a potential project's output usually increases as the need

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[3] The views presented here derive from the observed similarity of projects for industrial purposes and those intended as research and development undertakings. Many of the ideas to be described in this section are based on Edward B. Roberts, The Dynamics of Research and Development (New York: Harper and Row, Publishers, Inc., 1964). The similarities between R & D and industrial projects were first expounded in a graduate thesis performed under the author's supervision: Clement Vaturi, Establishing Industries in Underdeveloped Countries (unpublished Master of Science thesis, M.I.T. School of Industrial Management, 1962).

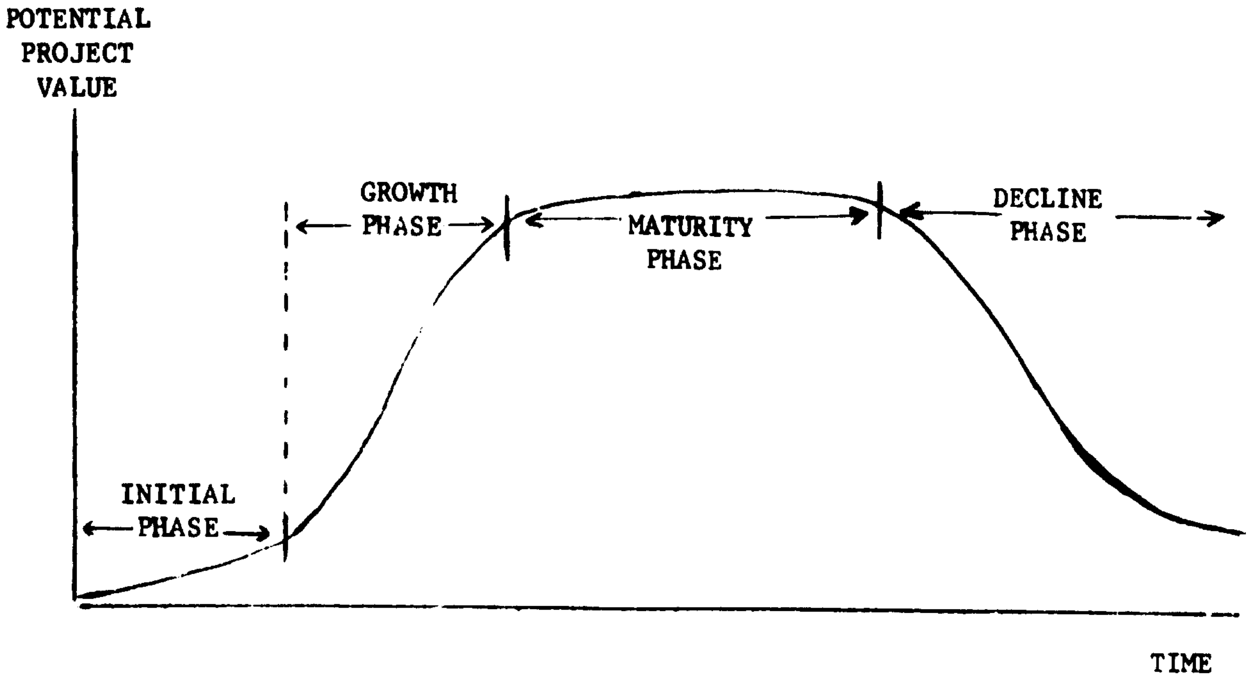

Figure 1. Changing Project Value

for, appreciation of, and ability to afford a particular product all increase. Ability to service this growth phase of a project's demand cycle is highly desirable, sinc competition tends to be relatively weak during this phase, keeping both prices and profits high.

Each product eventually enters a market value maturity stage, during which demands are relatively stable at a high level, or but slowly growing. Most industrial projects in a developing nation come to fruition during the mature phase of the product life cycle. Whereas demands are high, this phase of the market is characterized by increasing competition by larger numbers of producers, usually with production over-capacity, causing intensified promotion activities with attendant higher costs and lower prices. As profit margins fall, marginal producers with higher-than-average costs or with insufficient capital reserves to withstand competitive pressures begin to go out of business. It is an enigma of world competition that during the market maturity period when the over-all level of product demand is most stable, the business conditions of price and profits are often least stable as seen by the individual company.

Eventually, of course, although perhaps not for decades, the market demand for a product begins to decline. This decay in market value is caused by gradual elimination of the need for the function performed by the product, or by replacement of the product by an improved substitute. The latter process of product substitution by technological advancement is occurring in all fields: nuclear fuels are gradually replacing fossil fuels as sources of energy; artificial sweeteners are fulfilling the needs once met by sugar; synthetic fibers are causing upheaval in markets previously serviced by cotton and wool. The developing nation that lacks technological innovation skills often suffers by being left with little alternative but to enter markets during their late stages of maturity, with technologically-induced market decline soon to occur.

Potential cost. In addition to these market dynamics that alter the potential value of a project, environmental changes also affect the potential cost of implementing the project as well as the potential unit cost of the output to be produced. Whether or not a particular industrial project is undertaken, certain changes are likely to occur, for example in the education level of the labor force, that will gradually lower both implementation and production costs. Many manufacturing processes require steady flows of water of specified quality. If sufficient time is allowed, there is a possibility that reservoirs and water treatment will be developed for local population requirements, eliminating these cost elements from the potential in-

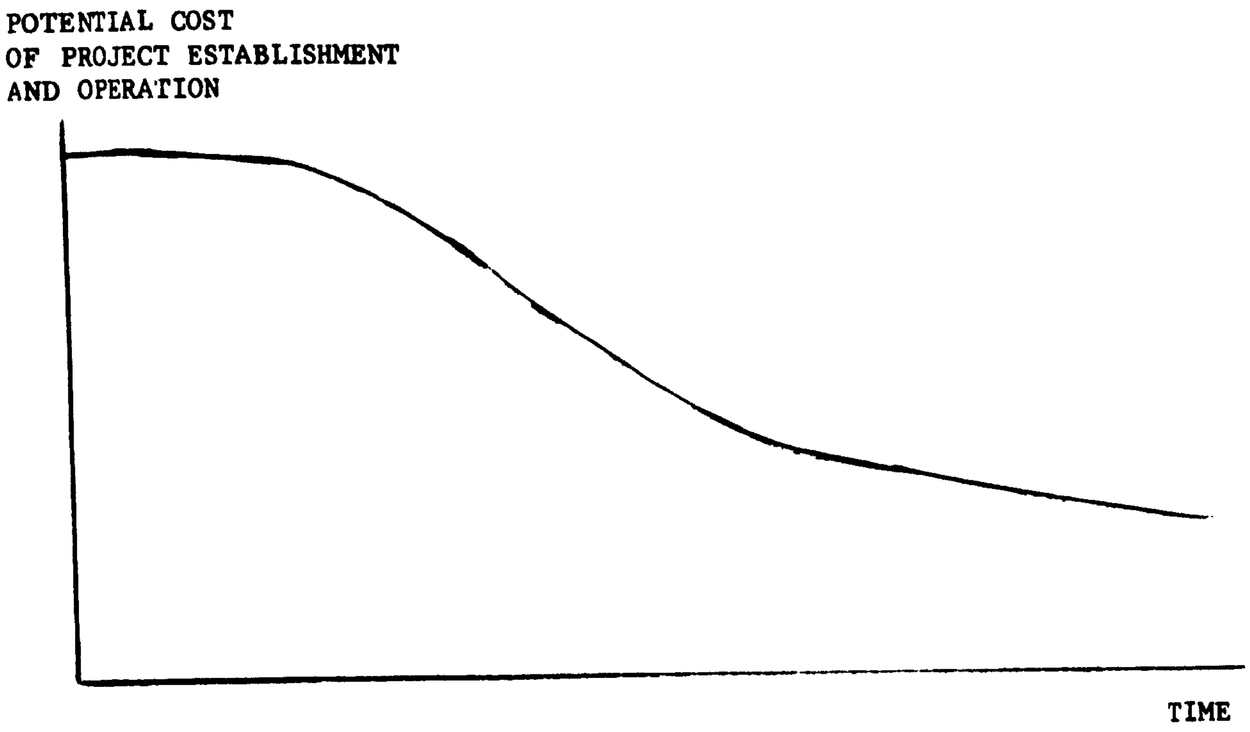

Figure 2. Changing Project Cost

dustrial project. Similarly, instead of utilizing its own electric power generation, an industrial project might save money by waiting until sufficient lower-cost power is available from municipal utilities. There is also the option of waiting for technological advances to reduce plant and unit production costs. All of these forces result in the gradually decreasing project costs pictured in Figure 2.

From consideration of just these two dynamic environmental forces of potential project value and potential cost of the project establishment and operation, an overview can be developed of the appropriate time period for initiation of an industrial project. Figure 3 reveals the importance of project timing when project value and project cost are considered jointly. During the early potential existence of a project, cost is liable to be too

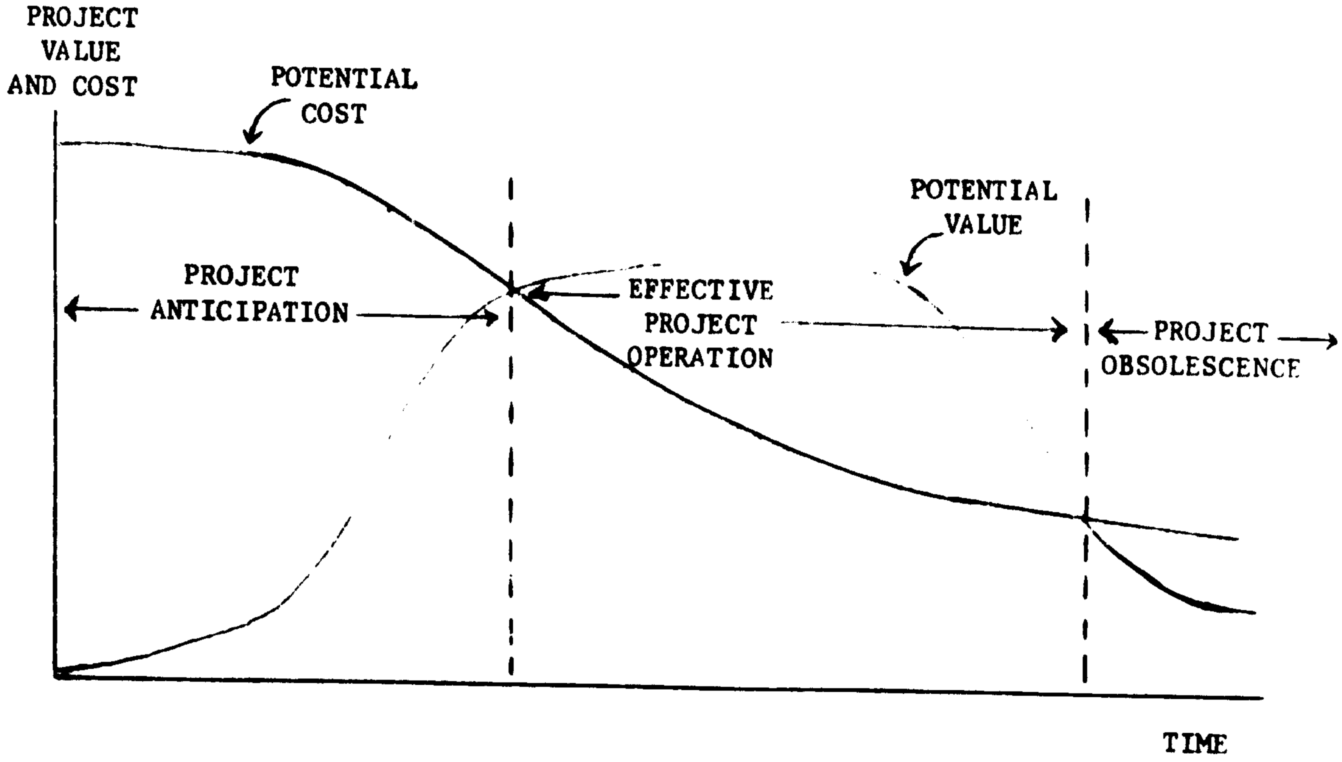

Figure 3. Environmental Phases of Project

high and market value too low for effective project operation. It is appropriate during this phase to engage in activities that anticipate the more opportune environmental conditions expected to occur during later years. Forward planning and initial evaluation activities are possible in this phase of project anticipation. As potential cost falls and project value rises, the phase of effective project operation occurs. For many projects the lengthy construction and start-up periods may demand initiation of the project during the "anticipation" phase in order to achieve project operation during the "effective" phase. This of course entails risk-taking by the project entrepreneurs. Finally, if the project is delayed too long, perhaps in waiting for some of the cost savings described above, the project opportunity is lost. The project enters a phase of obsolescence during which costs of implementation and operation may be low but the value of project output has declined even further to the point of eliminating attractiveness of the industrial undertaking.

Project system. Despite the importance of these changing environmental conditions, however, they provide only the uncontrollable portion of an industrial project. Far more important to an active role in project determination are the controllable activities of a project life cycle that affect and can be affected by project evaluation and response. Three roles are seen as usually dominant in these activities:

1. principal project implementor, often a foreign technical firm, that has both the technical **capability for detailed** project design and the managerial capacity to bring the project into reality and to operate the resulting enterprise;
2. a financial organization, often an outside institution, whose resources would permit provision of any desired amount of funds needed for the industrial project; and,
3. a local government agency that provides approval, political sponsorship, and sometimes additional funding to the project.

Sometimes one organization fulfills two or even all three of these project roles, but the roles of implementor, financier, and sponsor are different even when the persons carrying out the various activities are the same.

In response to the changing market value and cost potentials, a series of continuous and related activities are undertaken, listed below in the order they appear in an industrial project's life cycle.

1. The potential of a given industrial development is perceived by an initiating organization, either the potential implementor or the potential sponsor of the project. Even when national or regional development corporations are charged with the responsibility of creating worthwhile industrial investments, it is often a foreign technical organization that first perceives the project opportunity. As this initiator recognizes more features of a potentially effective (i.e., profitable or beneficial in other ways) project, his interest is stimulated into more detailed investigation of the project.

2. With interest advanced sufficiently to justify further investigation, the initiating organization begins to estimate in approximate manner the expected capital requirements and operating costs of the industrial establishment.

3. At this point both possible market value and expected cost considerations have been made, albeit only with preliminary estimates. An initial evaluation is therefore made of the merits of the project, producing both an attitude regarding the priority of the project and a decision on the appropriate course of futher action.

4. Several alternatives are available at this stage when the project implementor is different from the financier. The initiating organization may decide that the project is not worthwhile and discontinue further actions and expenditures. Should the project look promising, the organization might extend its investigations and project initiation activities, using its own financial resources in so doing. Alternately, the initiator may seek financial support from an outside financial organization or project approval from the local related government agency.

5. The potentially affected organizations, faced with proposals for financial support or government authorization, will also evaluate the project. Each organization is likely to be requested to fulfill a different "partnership" role in the industrial project and will consider its role as well as the expected roles of the other potential "partners".

6. In the project that is eventually undertaken the financial participants make an initial commitment of funds that are sufficient to accelerate the project process. In addition the government organization will eventually grant or obtain approval and any "special considerations" for the project.

7. Given a commitment of funds other project-related resources are acquired and employed. These resources include the technical skills for final planning, contractors for buildings, and production equipment. Personnel recruitment and, in the later pre-production phase, personnel training is also undertaken.

8. After the construction is completed, production starts slowly, moving up to higher rates as machinery is checked out, operators are employed, and orders are received. Sales, service, distribution and other aspects of operation are also initiated.

9. Results of the project are continuously being evaluated. During the construction period, progress and capital costs are monitored. As production and other operational activities are undertaken, actual output attainments, labor productivity, unit costs, sales effectiveness, price stability, and other indicators are observed and compared with previously expected levels.

10. The continuous reassessments change expectations for the enterprise, modifying previous forecasts of project potential, capital requirements, profitability, and over-all desirability of the industrial project. These adjustments essentially regenerate the activities indicated above, which continue at least implicitly throughout the project life cycle.

The described cycle of industrial project activities is shown in Figure 4 on the next page. These activities were presented as a sequential set of occurrances, but it can be seen from the diagram that they are continuously linked through on-going feedbacks of effects. For example, earlier or later decisions to undertake project sponsorship are not acts independent of the project status. They are affected by prior investments by the project originator that may alter project attractiveness. In turn, such sponsorship decisions affect the pacing of resource acquisition, initiation of operations, and over-all effectiveness of the project, as was previously illustrated in Figure 3.

Any one of the project activities listed above might affect the outcome of the project and should be considered in a thorough project evaluation. An active approach to the design of project opportunities would consider the implications of alternative decisions at each stage on broad classes of project types.

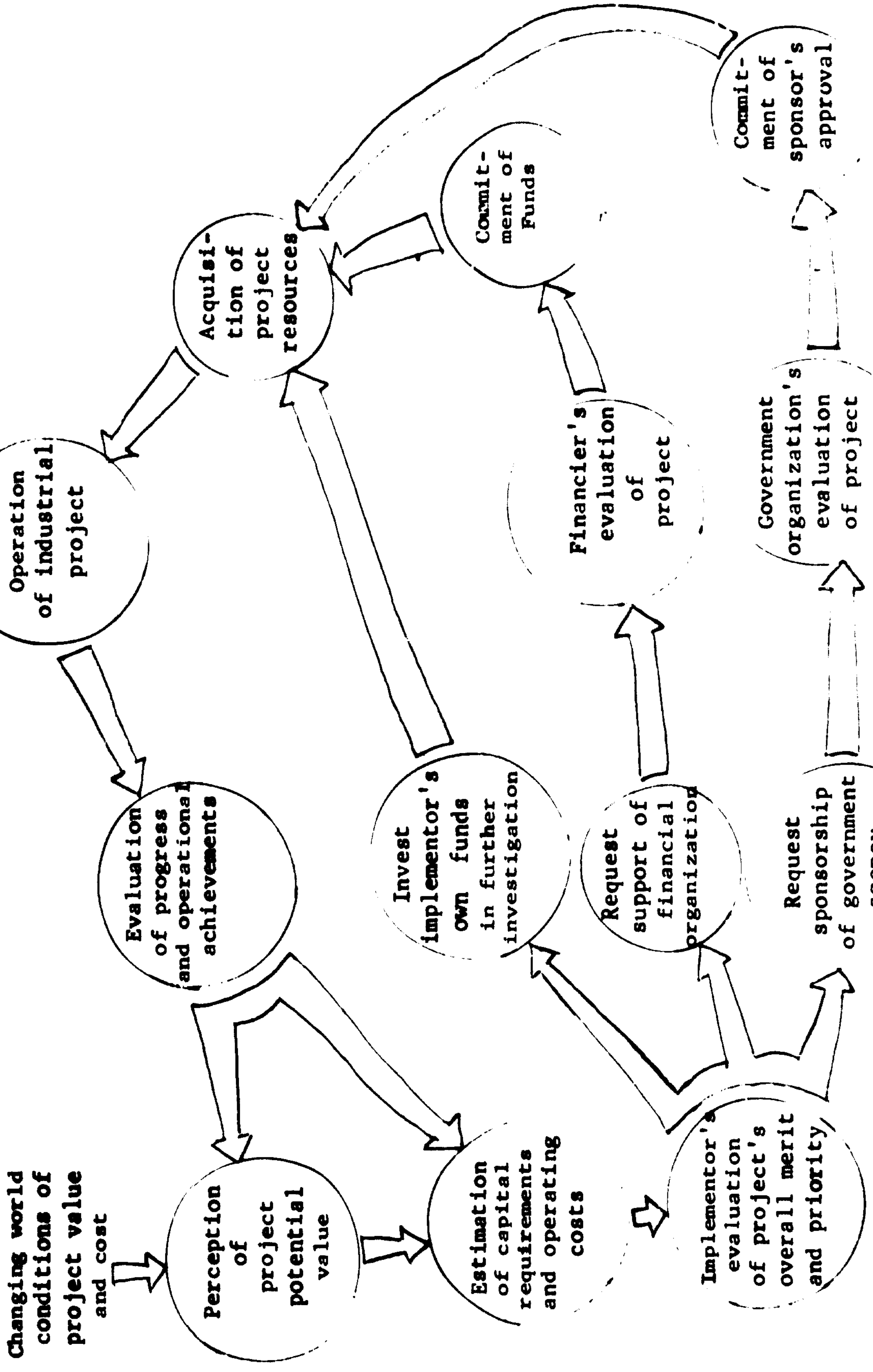

Figure 4. Life Cycle System of Project Activities

Models of Industrial Project Life Cycles

Figure 4 presented a closed-loop system representation of the activities underlying industrial project results. With this conceptual framework available, further aspects of the proposed approach to project evaluation may now be described. It should be emphasized, however, that the existing more simplified schemes of project analysis are probably preferable to the proposed methods if the project is too small or the outcome of the evaluation too obvious to justify the investment in more extensive (and possibly more expensive) evaluation. But for large industrial ventures, and for projects in which the advisability of investment appears to be critically dependent on a complex array of relationships, the new methods show promise.

Philosophy of the approach. The underlying philosophy of the approach to be presented is an emphasis upon the structural determinants of project behavior. Three aspects of structure are stressed:

1. the principal industrial, economic, political, and sociological causes and their direct effects;
2. the important time delays between the causes and effects; and
3. the key information flows from the initial effects back to the causes, closing several intra-project feedback loops (as described in Figure 4 for the progress evaluation activity).

It is believed (and confirmed in past applications of the approach to industrial management and regional analysis problems) that these three structural features are the vital ingredients of a time-varying system.

Most important of the three elements is the notion of feedback. Two types of feedback are possible: positive or self-amplifying feedback, and negative or self-correcting feedback. Under conditions of positive feedback, an unbalanced state of affairs can feed on itself, growing in magnitude until the project is destroyed. Poor management in the project, for example, leads to high costs and low sales; these produce low evaluation of the project's worth, leading to little investment in new equipment, techniques, and people; competitive pressures thereupon force still higher relative costs leading to even lower sales, and so on. With negative corrective feedback, system reactions tend to counter any disturbing tendencies that arise. In the example case of poor project management, the high costs and low sales might produce pressures to replace the initial management team with a more effective group. It is obvious that in a real system, an array of positive and negative feedback loops might produce unstable oscillatory behavior of costs, sales, profits, and project effectiveness, superimposed upon longer term patterns of growth and decline.

The philosophy requires that the representation of a project's system be sufficiently broad to include the key variables. Thus the causes and effects of all major variables that affect the industrial project's success must be defined in a consistent manner and their interdependencies noted. Furthermore, breadth of consideration must be complemented by depth of detail considered, to the extent that empirical support is available or that functional forms of system relationships can be argued consistently by available advisory personnel.

Requirements upon representation schema. From the above discussion it is apparent that a system for representing, analyzing, and preparing evaluations of large industrial projects has several characteristics.

1. It clearly contains many variables, tens or even hundreds that need specification to accurately portray an industrial project life cycle.

2. The variables must have a complex interactive set of relations, interdependent particularly through the positive and negative feedback linkages described.

3. Both linear and nonlinear effects of one variable on another must be possible of representation. An example of a nonlinear relationship is the effect of the number of looms on the profits possible in a textile mill. Economies of scale cause profits to rise rapidly above some threshold minimum factory size. This nonlinear effect is sharpened by limitations on the effectiveness of managerial control of the plant; these only begin to show up as the size of the enterprise gets large. Similar nonlinear effects arise in all areas of industrial project evaluation.

4. For further realism a representation of an industrial project must be able to include time-varying factors, such as population size and age distribution, skill and education levels of the labor force, income and taste changes.

5. These first four requirements preclude the possibility that an industrial project might be represented by a closed-form mathematically-analytic structure that might be analyzed for optimum solution or optimum project selection. The features of system size, feedback complexity, nonlinearity, and time dependence produce problems that lie outside the possilities of today's mathematical knowledge. It is possible, however, that a realistic project model be developed that can be used for the creation of alternate simulated project histories. With the ability of

modifying the assumptions (for both parameters and functional relations) of such a model, a proposed project might be changed until it produced favorable results; failing to meet such a criterion, the proposal might be dropped after the computer evaluation period of simulated life, instead of after the disappointments of real-life experimentation.

Methodology of the approach. Models of the form required above have already been developed for use in numerous industrial studies. They are based on the Industrial Dynamics approach created by Professor Jay W. Forrester and his associates at the Massachusetts Institute of Technology.[4] The first application of this general approach to problems of developing nations was an economic analysis performed by Holland as part of the studies of the Indian economy carried out by the M.I.T. Center for International Studies.[5] As indicated earlier a direct application of the Industrial Dynamics methods to industrial project planning and evaluation was described by Vaturi.[6]

In all of these studies a flexible and interactive methodology is used. As first step an explicit set of goals is established, for example the evaluation of impact of a proposed project upon the economic growth of a developing nation. The assumptions to be made in the model are then based explicitly

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[4] See Jay W. Forrester, Industrial Dynamics (Cambridge, Massachusetts: The M.I.T. Press, 1961).

[5] Edward P. Holland with Robert W. Gillespie, Experiments on a Simulated Underdeveloped Economy: Development Plans and Balance-of-Payments Policies (Cambridge, Massachusetts: The M.I.T. Press, 1963).

[6] Vaturi, loc. cit.

on goal considerations, with aspects of the environment excluded from the model if they do not materially affect the stated goal.

Secondly, an initial mathematical model is created using the flow-diagramming and equation-writing techniques of Industrial Dynamics.[7] This initial model is based on the preliminary data gathered prior to serious project evaluation, including the beliefs and experiences of the proposers and the evaluators.

It is important, as a third step, to examine the requirements for additional empirical evidence. With a tentative model framework established, initial data required are often the approximate values of parameters or functional relationships included in the model structure. This need cannot be predicted until an initial structure is postulated.

Given an initial model with initial values, the model is tested to improve understanding of it and of the real world it represents. At this stage of model test and refinement, new perspectives are gained on the assumptions previously made, the sensitivity of model (hence, project) results to changes in parameters or relationships is discovered, as is the criticality of improved data. Additional data gathering is undertaken as seems needed, followed by model revision and further testing. This leads iteratively to still more data gathering and model testing until the model (hence, project) evaluator is satisfied with results obtained.

Finally, with the project model acceptable to the evalutor, extensive tests are conducted to investigate model (hence, project) performance under a wide range of possible business, economic, and/or political variations. Experimentation might be conducted with modifications in the project's proposed characteristics to see if improved performance results.

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[7] See Forrester, op.cit., pp. 47-133, or Alexander L. Pugh III, DYNAMO User's Manual, Second Edition (Cambridge, Mass.: The M.I.T. Press, 1963).

A case study of project life cycle modelling. In the Vaturi study referenced earlier, a model of an example project was created, describing the expected life cycle of a textile mill being constructed in Africa. The model contains a large array of interrelated factors, described here to illustrate the process of industrial project modelling. A number of forces influence the overall attractiveness of the project to the potential entrepreneur, investor, or project evaluator. These include: (1) a local demand factor, measured by the extent to which local product demands are supplied by imports rather than local production; (2) tariff protection influences, dependent upon the percentage duty (or other restriction) that helps the local project in its own market; and (3) manpower cost considerations, enhancing a project's overall attractiveness to the extent that expected labor costs are lower than those in developed countries. Each of these three influences has a nonlinear effect on the overall project attractiveness, with the project rising rapidly in attractiveness as either unsatisfied local market needs, tariff assistance, or low manpower costs lend assurance of project profitability.

Whereas the above influences affect the project's intrinsic attractiveness, a project implementor or financier is influenced by other considerations, particularly by his knowledge of the venture situation. To gain knowledge and confidence in the proposed undertaking, the potential project "partner" must invest time, effort, and consequently at least some support funding. Initial project attractiveness influences the initial investment of this information-gathering effort, but as the knowledge of the project increases it feeds back to affect further study and evaluation effort. The attractiveness of an industrial project can vary greatly during the life span, altering the willingness of the implementor, financier, and/or sponsor to continue support of the project.

As interest level heightens to the point of detailed project and plant design, considerations begin to arise that may reflect conflict between an entrepreneur's objectives and national goals. For example, in the textile case study the government preferred a fully integrated firm in order to reduce the total volume of material imports. However, the overall size of the undertaking, as well as the availability of management and manpower skills and investment funds determine the advisability of such vertical integration for the project implementor or financier. Thus national pressures from import volumes at each textile finishing stage attempt to counter pressures from market prices and profitability prospects at the several stages of production allocation. It is important that these forces be included in the industrial project evaluation model. In the context of national goals it is apparent that a single stage textile plant might add to the industrial base of the country while possibly worsening the balance of payments difficulties faced by most developing nations.

With the detailed technical relationships of plant design and operating costs included in the model, it then is necessary to model the financial acquisition-commitment process. For example, the tendency toward low debt to equity ratios in industrial projects in developing nations indicates proportionately larger needs for equity funds, with longer delays in raising these funds. Initial financial commitments are based on initial capital requirement estimates, which often rise during the project life. The project model must include the possible reevaluation time that follows signs of increasing capital needs, as financiers hesitate to take additional risk in the project.

The operating characteristics of the project must also be reflected in the model since they produce the project's performance, the source of continuing evaluation of the project merits. Such things as hiring and training policies alter the project dynamics and ought to be modelled, as well as the effect of higher wages on the availability of labor supply. In the case study of the African textile mill, it was important to include the impact of fluctuations in village income on the willingness of the villagers to work in the factory. Internal management "self-evaluation" policies are added to a project model to test the suitability of planned managerial responses to trouble indicators.

It is obvious even from these few examples that the case study model is complex and multi-variabled, containing several hundred equations. But there are economies in this scale, since the model structure permits easy and extensive experimentation, modification to change special features of the proposed project, and more thorough alteration to make the model suitable for evaluation of a different project.

Advantages of project life cycle modelling. Upon examination it becomes clear that the approach outlined above meets the objectives to existing evaluation methods that were presented at the outset of this paper. The systems approach, employing project life cycle modelling, overcomes each of the eight faults listed.

1. The project model is a dynamic, rather than static, approach to analyzing an industrial project. The equation structure presents a simulative capability of projecting time histories of project life cycles, based on varying influences of the project's environment and structure.

2. The technique is by nature integrative, since all causes and their direct (and indirect) effects are represented explicitly. The simulations calculate at each point in time all new values of outcomes, the new outcomes becoming immediately available to affect future decisions and actions.

3. Rigor is implicit in the method's insistence upon formal mathematical or functional expression of assumed relationships and parameter values. The qualitative argument, in order to have effect on the project evaluation, must be quantified for the model's sake. This act of quantification of notions previously treated in only loose casual terms is itself a major source of improved understanding of the project and its prospects.

4. The project life cycle model has great flexibility. A change in parameter value or cause-and-effect relationship requires the substitution of one or a few cards in a computer model deck, with new results available within minutes from the computer processor.

5. With a computer-oriented model it becomes an easy task to evaluate the sensitivity of project results to small or large shifts in assumed environment, cost factors, market conditions, etc. A range of predicted outcomes for various sets of probable occurrences, a more reasonable basis for evaluating an industrial project, becomes immediately attainable to replace the single-point estimates now used.

6. Model construction activities can gradually produce modules (e.g., market response mechanisms, cost evaluation routines, and production start-up sequences) that are common features of many industrial projects. This means that once industrial project modelling is undertaken, the effort required for each successive new project evaluation is reduced. Eventually, a number of general evaluation models (similar to the present general evaluation guidelines) may be availabe for use in several common project fields, needing only the proper input data for producing ranges of evaluated project results.

7. This approach is inherently feedback-oriented, recognizing project changes as they are produced in time and incorporating the new values as inputs to determination of further project behavior.

8. Finally, and as a result of the above characteristics, it becomes possible with the industrial project modelling approach to adopt the more active role of project design and evaluation. In the textile case study, for example, it is now possible for the evaluator to consider alternate degrees of vertical integration instead of merely responding to one particular proposed approach. The evaluation organization now takes on a more integral position in the project planning-to-implementation sequence.

Evaluation of a Large Industrial Complex

An earlier part of this paper included the comment that improved industrial project evaluation is desired in order to better select projects that will impact their environments, by means of increased employment and output, enhanced standard of living, et al. Yet the evaluation of a project sufficiently large to have so important an effect, or of a series of small projects that comprise a proposed large industrial complex, must obviously take into account regional or national economic-demographic analysis as well as industrial analysis. However, even when economic analysis becomes an integral consideration in a project complex evaluation the same system modelling approach that has been presented in this paper can be applied. This has already been demonstrated in an extensive evaluation of proposed water resource programs in the Susquehanna River Basin of the United States. It is clear from this nearly completed study that a wide array of alternative programs, their justifiability and their impact, might be examined in the same regional context. Among other alternatives that might be considered are power, transportation, education, or industrial projects. A brief review of the Susquehanna River Basin system model is presented here as an illustration of a possible evaluation scheme for a large industrial project.[8]

The research study was performed for the Susquehanna River Basin Utility Group[9] by a team from Battelle Memorial Institute, supplemented by systems consulting services provided by Pugh-Roberts Associates, Inc. The area analyzed includes parts of the states of Maryland, New York, and Pennsylvania and has a population of over five million inhabitants. For the model construction, the river basin was divided into eight subregions, each similar in model equations but varying in initial values of population and industrial development, with different coefficients of growth and other key modelled relationships. (The modular approach was adopted here, as proposed earlier, and only one basic subregion model was needed for the study, each new subregion requiring only input changes.) Similarly, the demographic aspects of the evaluation were handled by breaking population in each subregion into six age groups. (One age group equation module sufficed for all population groups, the differences in fertility and death rates, propensity to migrate, etc., being treated by different parameter values in the equations.)

Empirical analyses of the industrial composition of the Susquehanna River Basin suggested that economic activities in each subregion be aggre-

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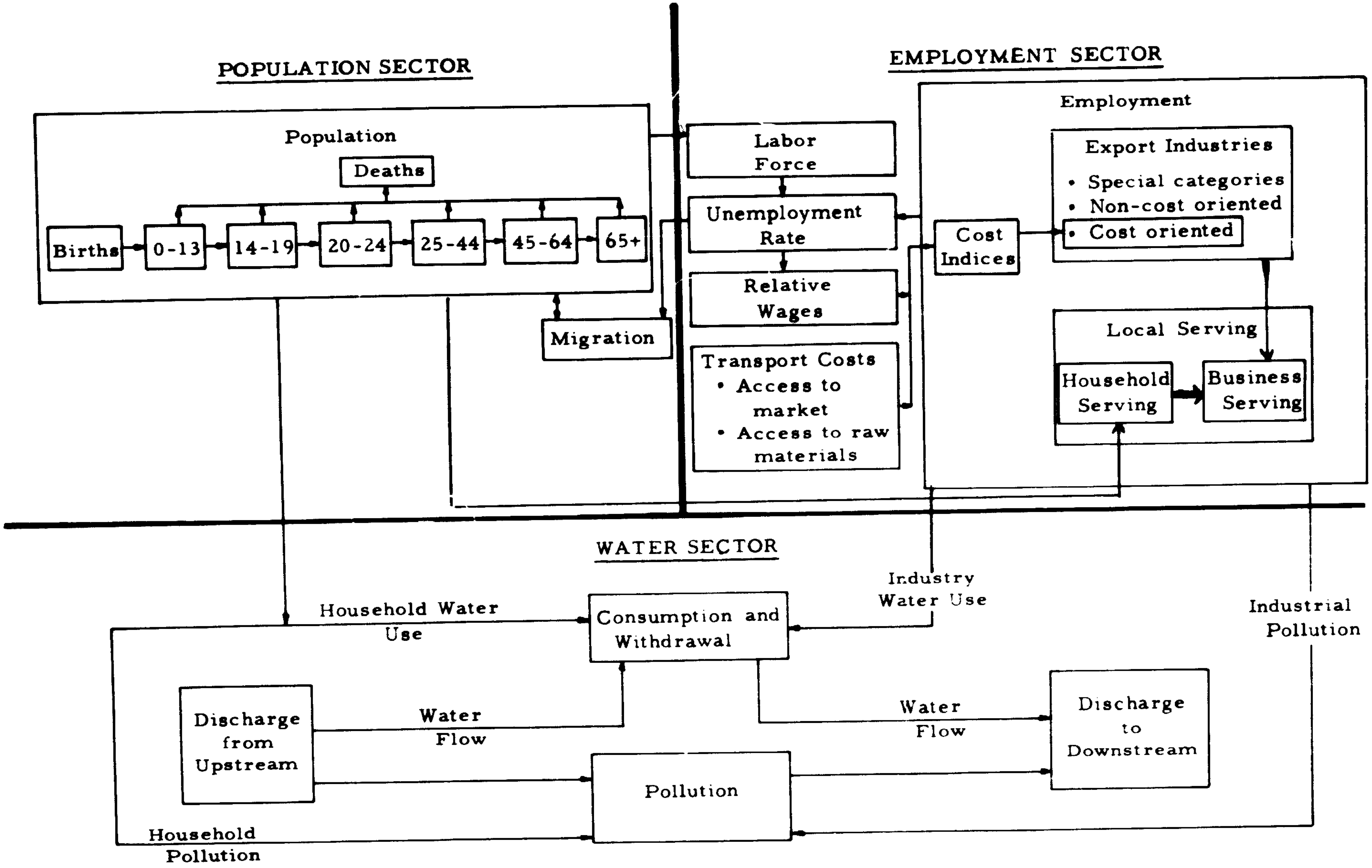
[8] For complete documentation of the research study see: H.R. Hamilton, *et al.*, *A Dynamic Model of the Economy of the Susquehanna River Basin* (Columbus, Ohio: Battelle Memorial Institute, November 13, 1964).

[9] This group of stockholder-owned power companies serving the region includes: Baltimore Gas & Electric; Delaware Power & Light; Luzerne Electric Division of United Gas Improvement; Metropolitan Edison; New York State Electric & Gas; Pennsylvania Electric; Pennsylvania Power & Light; Philadelphia Electric; Public Service Electric & Gas; and West Penn Power.

gated into nine general groups: two local-serving groups, including those that are household-oriented and those that are business-serving oriented; four export manufacturing classifications including transport-intensive processing, capital-intensive processing, durable fabricating, and nondurable fabricating; and three special groups, mining, agriculture, and general government employment (including education and armed forces). In addition, since the study evaluates possible water-works projects in the Susquehanna River Basin, explicit employment categories are included in the model for water-works construction workers and for employment in water-based recreational activities. (The addition of these special categories illustrates how the explicit goals of the model affect the model contents. Even a supposedly general model needs at least some modification for adaptation to a particular study.)

There are, of course, many more aspects of the model which with all eight subregions activated utilizes over 1300 mathematical equations and several hundred constant parameters. Its overall structure is diagrammed in Figure 5 on the next page, including the water-works sector. (Incidental to this paper's purpose is the finding from numerous model simulations that alternative systems of river works have only an insignificant effect on the economic and demographic projections for the next fifty years. Water in the Susquehanna River Basin has been found to be no constraint upon the growth of the Basin's economy.)

If one wished to evaluate the extent of impact of a steel mill or a large petrochemical complex on the growth of a developing nation or one or more of its regions, a model similar in orientation to that shown in Figure 5 might be developed. Instead of the illustrated emphasis upon a water sector, the subject of the evaluation in the case of the Susquehanna River Basin, appropriate details would be added to the model for the inputs, outputs, and performance structure of the proposed industrial project.



MODEL OF A SUBREGION

Figure 5.

This approach would also provide the eight benefits listed previously. In addition when the region or nation is itself included in the analytic framework, conflicts between national purpose and a proposed project become immediately obvious. For example, skilled labor requirements for the proposed venture might draw away needed scarce manpower from other industries, lowering overall output. As another possibility the intense construction phase of the project might attract workers to the region who would be unemployable once the project moves into its operational period. Still another possibility is that tighened labor market conditions caused by the new project's magnitude might raise wage costs and lower profitability of other industrial groups to the detriment of the region.

On the positive side are the possible indications that the system modelling would provide of indirect benefits to national or regional goals. For example, a large industrial project would no doubt include provisions for extensive training and skills development. These activities not only directly affect industrial productivity but also improve mobility of the population and its commitment to an industrial economy, both features desirable for long-term industrial development. Other indirect but regenerative benefits that might be shown by a regional-industrial project evaluation model are effects of higher incomes on nutrition and health, or on the ability of the local communities to afford improved services, each of which feeds back to increase the venture attractiveness to potential project implementors and financiers.

But in adopting this approach the time and effort required are much larger than that spent in present more narrow less,ambitious evaluation schemes. Project evaluation organizations should not delude themselves into thinking that major benefits are obtainable in return for minor resource inputs. This does not occur either in new industrial projects or in new methods for evaluating industrial projects. However, the numerous uses of the proposed Industrial Dynamics methodology, the extensive studies already conducted of project life cycles in other contexts, and the successful application of the approach to major projects proposed in the Susquehanna River Basin study, all suggest the potential effectiveness of the systems methods.

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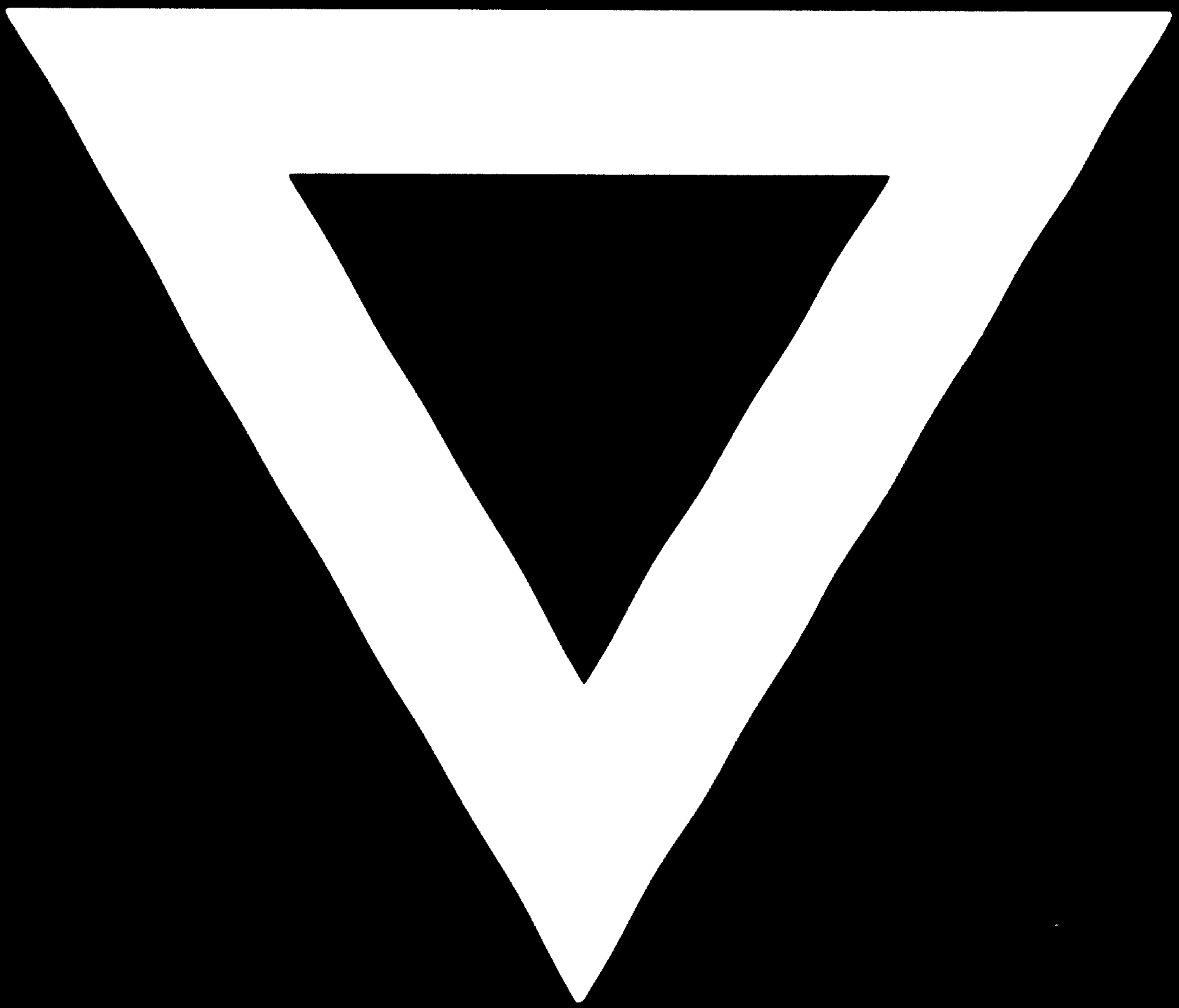

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