FEASIBILITY ANALYSIS FOR PROCESSING SEA URCHIN ROE IN NEW ENGLAND FOR EXPORT

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by

JAMES RICHARD TOWNLEY, JR.

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

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at the

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FEASIBILITY ANALYSIS FOR PROCESSING SEA URCHIN ROE IN NEW ENGLAND FOR EXPORT

by

JAMES RICHARD TOWNLEY, JR.

Submitted to the Department of Ocean Engineering on July 31, 1973, in partial fulfillment of the requirements for the degree of Master of Science in Shipping and Shipbuilding Management.

ABSTRACT

Recent efforts have been made for finding ways to help revitalize the waning New England fisheries industry. One consideration, spurred by such current events as the Balance of Trade Deficit and the recent devaluation of the dollar, has been to evaluate the New England fisheries industry in terms of the potential services it might provide to the export market. One specific alternative has been to look at underutilized marine resources that offer marketing potential abroad.

This thesis tests the feasibility for processing one such underutilized marine resource, the sea urchin, for export. The specific case of processing fresh sea urchin roe in the state of Maine for export to Japan is used for the purpose of conducting the feasibility analysis. A new management decision tool called SMART (Systems Management Analysis and Review Technique) is developed and used in carrying out this analysis.

The thesis concludes with a presentation of the findings of the analysis. In addition, specific recommendations are made and discussed for improving various cost figures that are derived in the analysis, thus increasing the potential profitability of the venture.

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CHAPTER I

INTRODUCTION

Purpose of Thesis

This thesis tests the validity of the following hypothesis:

> The harvesting and processing of sea urchin roe for export is an economically feasible venture for certain fisheries industries in New England.

This hypothesis is tested through utilization of an innovative managerial decision tool that has been given the acronym of SMART for Systems Management Analysis and Review Technique. The hypothesis serves as the vehicle for developing this new decision tool.

Scope and Limitations

It is not possible to test the hypothesis directly. Parameters cannot be varied under controlled conditions to determine the effect alternative patterns of action and reaction would have on overall system performance. Comparative analyses of similar systems in geographically, functionally, or temporally separated areas are also not possible. Therefore, the systems approach is used to model the various subsystems, and tests are conducted on the models to provide information

with which sub-hypotheses can be tested and conclusions drawn. For the purposes of describing this analysis, the specific example of exporting sea urchin roe from Maine to Japan is used.

This presentation and the analyses concentrate on the physical operation and the behavioral, social, economic, and legal influences which occur in the state of Maine. Further, various transportation networks between Maine and Japan are considered and evaluated. Due to lack of sufficient information of the Japanese market and behavior, this aspect is considered superficially. This factor has also necessitated that the scope be limited almost solely to costs. Since very little can be predicted about the potential revenues that should be generated by this venture without actually shipping processed sea urchin roe to Japan for an extended period of time, calculations of expected or potential profits is quite impractical. Therefore, a cost distribution is calculated which states that, given all the factors considered in the SMART model and their interrelationships, the probability of achieving a certain total cost is such and such, with mean so and so. Using the going price of sea urchin roe on the Tokyo market as a bench mark, the distribution of these prices, weighted with some correction factor, can be compared against the cost distribution. From this comparison, the economic feasibility and potential profitability of the venture can be evaluated.

The scope of this thesis has also been limited to the consideration of existing technologies. A breakthrough on

frozen sea urchin roe would have a very definite effect on the feasibility of this venture. The eventual perfection of SST cargo transport would have a similar effect. Yet both have been assumed away for the planning horizon used in this paper.

Lastly, this thesis is limited somewhat by the lack of quantifiable data and statistics. Since sea urchin roe has never been exported from New England, the actual methods that might be used eventually are largely a matter of conjectural hypothesis and qualitative information, (i.e. guess work). This does not mean that the resultant models are inherently inaccurate. To the contrary they are probably quite accurate. What it does mean, however, is that the accuracy and reliability of the models and the information used in the models cannot be tested. Be that as it may, the models do provide a good "first cut" at evaluating market feasibility and at determining the sensitivity of costs to each of the influencing parameters.

Definitions

Aphasia. "the loss or impairment of the power to use words as symbols of ideas that results from a brain lesion."[1]

Blastula. "an early metazoan embryo typically having the form of a hollow fluid-filled rounded cavity bounded by a single layer of cells..."[2]

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[1] "Aphasia," Webster's Third New International Dictionary, unabridged, 1968.

[2] "Blastula," Webster's Third New International Dictionary, op. cit.

Calcareous. "1a: like calcite or calcium carbonate esp. in hardness..."[3]

Coelom. "the body cavity or perivisceral cavity of metazoans..."[4]

Decision. An irrevocable commitment to the allocation of a scarce resource.[5]

Dichotomy. "1a: division into two parts, classes, or groups esp. into two groups mutually exclusive or opposed by contradition..."[6]

Echinoid. "SEA URCHIN"[7]

Environment. "2: the surrounding conditions, influences, or forces that influence or modify: as a: the whole complex of climatic, edaphic, and biotic factors that act upon an organism or an ecological community and ultimately determine its form and survival - compare HABITAT b: the aggregate of social and cultural conditions (as customs, laws, language, religion, and economic and political organization) that influence the life of an individual or community"[8]

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[3] "Calcareous," Webster, op. cit.

[4] "Coelom," Webster, op. cit.

[5] From lecture notes taken in class of Prof. D. A. Love, Graduate School of Business Administration, New York University, November 18, 1971.

[6] "Dichotomy" Webster, op. cit.

[7] "Echinoid," Webster, op. cit.

[8] "Environment," Webster, op. cit.

Epicyclitus. The continual modification of a poor model to conform to a certain system, as opposed to designing a new and better model to replace the original one.

Epithelium. "1: a cellular animal tissue that covers a free surface or lines a tube or cavity, that consists of one or more layers of cells forming a sheet practically unbroken by intercellular substance..."[9]

Feedback. "1: the return to the input of a part of the output of a machine, system, or process..."[10]

GERT. Acronym for Graphical Evaluation and Review Technique.[11]

Goals. An objective expressed in terms of one or more specific dimensions.[12]

Hierarchy. "5a: the arrangement of objects, elements, or values in a graduated series..."[13]

Homeostasis. "3: a tendency toward maintenance of relatively stable social conditions among groups with respect to various factors..."[14]

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[9] "Epithelium," Webster, op. cit.

[10] "Feedback," Webster, op. cit.

[11] A.A.B. Pritsker and W. William Happ, "GERT: Graphical Evaluation and Review Technique Part I, Fundamentals," The Jounal of Industrial Engineering, Vol. XVII, No. 5 (May 1966), p. 268.

[12] Love, loc. cit.

[13] "Hierarchy," Webster, op. cit.

[14] "Homeostasis," Webster, op. cit.

Homeostatic. "related to or characterized by homeostasis"[15]

Interface. "1: a plane or other surface forming a common boundary of two bodies or spaces..."[16]

Madreporite. "a perforated or porous body that is situated at the distal end of the stone canal in echinoderms..."[17]

Management. "...the fundamental integrating and operating mechanism underlying organized effort. Management is defined for conceptual, theoretical, and analytical purposes as that process by which managers create, direct, maintain, and operate purposive organization through systematic, coordinated, cooperative human effort."[18]

Model. An abstract representation of a system.[19]

Oligopoly. "a market situation in which each of a limited number of producers is strong enough to influence the market but not strong enough to disregard the reaction of his competitors..."[20]

Objective. A specific commitment to a desired future situation attained through an organization of certain states or conditions.[21]

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15 "Homeostatic," Webster, op. cit.

16 "Interface," Webster, op. cit.

17 "Madreporite," Webster, op. cit.

18 Dalton E. McFarland, Management Principles and Practices, 3rd ed. (The Macmillan Company, New York, 1971), pp. 4-5.

19 Love, loc. cit.

20 "Oligopoly," Webster, op. cit.

21 Love, loc. cit.

Periproct. "the well-defined area surrounding the anus of various invertebrates (as a sea urchin)..."[22]

Peristome. "2: the region around the mouth in various invertebrates..."[23]

PERT. An acronym for Program Evaluation and Review Technique.[24]

Pluteus. "2...: the free-swimming bilaterally symmetrical larva of a sea urchin..."[25]

Policy. A contingent decision as to what will be done if and when a decision opportunity arises.[26]

Purse Seine. "...a large seine designed to be set by two boats around a school of fish and so arranged that after the ends have been brought together the bottom can be closed,..."[27]

Purse Seiner. "...a usu. power-driven fishing boat equipped or used for fishing with a purse seine..."[28]

Riparian. "...one that lives or has property on the bank of a river"[29]

Roe. "...1...b: the eggs or ovaries of an invertebrate..."[30]

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22 "Periproct," Webster, op. cit.

23 "Peristome," Webster, op. cit.

24 McFarland, op. cit., p. 278.

25 "Pluteus," Webster, op. cit.

26 Love, loc. cit.

27 "Purse Seine," Webster, op. cit.

28 "Purse Seiner," Webster, op. cit.

29 "Riparian," Webster, op. cit.

30 "Roe," Webster, op. cit.

SMART. Acronyn for Systems Management Analysis and Review Technique.

Stochastic. "...skillful in aiming, proceeding by guesswork,..."[31]

System. An ordered set of elements (objects, concepts and/or activities) whose order results from the exchange of materials, energy and/or information.[32]

Taxonomy. "...2: the systematic distinguishing, ordering, and naming of type groups within a subject field: CLASSIFICATION..."[33]

Temporally. "...2: with regard to time"[34]

Test. "...the external shell or other hard or firm covering of many invertebrates..."[35]

Topological. "...2: concerned with relations between objects abstracted from exact quantitative measurement..."[36]

Transmittance. "...Transmission..."[37]

Trematode. "...of or relating to the Trematoda...a flatworm ...of the class Trematoda"[38]

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[31] "Stochastic," _Webster_, op. cit.

[32] Love, loc. cit.

[33] "Taxonomy," _Webster_, op. cit.

[34] "Temporally," _Webster_, op. cit.

[35] "Test," _Webster_, op. cit.

[36] "Topological," _Webster_, op. cit.

[37] "Transmittance," _Webster_, op. cit.

[38] "Trematode," _Webster_, op. cit.

Methodology

This thesis constitutes a preliminary study into the economic feasibility of harvesting and processing sea urchin roe for export and marketing in Japan. This study is unique in that it (1) deals with a stochastic system that does not yet exist and has never existed, and (2) introduces a new and innovative method of testing the economic feasibility of that system.

The completeness and accuracy required in a study of this complexity necessitate certain methodological shifts throughout the development and presentation. This is accomplished in six chapters which are developed in the following manner:

Chapter I is the Introduction and is purely descriptive. It defines the purpose of the thesis. It provides pertinent definitions. It states and discusses the scope and limitations of the paper. It describes the methodology of the presentation.

Chapter II is purely theoretical. It provides a brief summary of systems theory and modeling practices and limitations. It then discusses PERT, DCPM, and GERT, in that order. Each of these techniques represent stepping stones which must be taken in order that SMART be fully understood. The three steps of the SMART approach are then introduced. These are: (1) apply the systems approach; (2) develop models for all subsystems; and (3) construct a GERT network that represents the aggregate system. The chapter concludes with a comparative analysis of SMART and Forrester's Industrial Dynamics. This

analysis serves to bring SMART's explanation into sharper focus.

Chapter III is descriptive. It describes the external and internal characteristics of the sea urchin. It presents the biological and ecological background of the sea urchin concentrating specifically on the urchin's habits and behavior. The characteristics of the species Strongylocentratus drobachiensis, the variety indigenous to Maine's coastal zone, are summarized separately, concentrating on spawning and eating habits.

Chapter IV is descriptive, analytical, and theoretical. Its primary purpose is to provide as much qualitative information as possible relating to the harvesting, processing, transporting , and marketing of fresh, sea urchin roe. Because so little information is available on the Japanese market, its customs and habits, this chapter concentrates on Maine's behavioral environment. The Chapter divides the presentation into legal, economic, and social perspectives then looks at harvesting, processing, and transporting operations from these perspectives. This chapter serves in a secondary role of developing a "feel" for where this proposed sea urchin roe venture fits with respect to other economic areas of pursuit which contribute to the economic and social well being of the state of Maine.

Chapter V is analytical. It represents the actual applcation of SMART to the "sea urchin system." As such, Chapter V is therefore divided into three steps. Step one is the application

of the systems approach. Step two consists of the actual modeling of the various subsystems and sub-subsystems that comprise the aggregate system. Step three is the application of GERT for the final solution of the stochastic network.

Chapter VI presents the conclusions of this thesis. It lists areas requiring further research and offers several recommendations. Alternative courses of action are also considered. Chapter VI concludes with a summary of procedures used, analytical findings, conclusions, and recommendations.

CHAPTER II

SYSTEMS MANAGEMENT ANALYSIS AND REVIEW TECHNIQUE

Discussion

This chapter is derived from theoretical research which is based on the proposition that all variables that influence any predefined system interact and/or interrelate systematically. That is to say, common threads or patterns exist between concepts or variables which comprise various, and possibly diversified, sets of relationships that can be identified, and more importantly "modeled" in some way, after the particular system of interest has been defined.

A general summary of systems theory and modeling practices and limitations is required before the implications of the preceding statement can be fully understood. The first half of this chapter, therefore, is devoted to providing that summary. The second half serves to develop a new and possibly innovative approach to the management, analysis, and review of systems' activities. This approach, for lack of a better acronym, has been termed SMART (Systems Management Analysis and Review Technique). It is important to recognize the dual purpose served by this chapter. It should be recognized that a clear understanding of the second half is based upon full comprehension of the first.

Discussion of Systems Theory

What is systems theory?

> There are indications that general systems theory implies the possibility of the "unity" of all science, for it is found as a new frontier in the biological and physical sciences as well as in the work of psychologists, sociologists, anthropologists, economists, political scientists, and management scientists. The systems model is widely useful in developing theories applicable to physical and social events, and to human relationships in large or small groups.[1]

Thus, systems theory, it would appear, is a relatively new concept that seems to hold forth great potential for the future unification of scientific endeavor.

A system has been defined as, "anything that consists of parts connected together."[2] A second, somewhat more complete definition describes a system as a set of objects with a given set of relationships which connect the objects and their attributes.[3] Bringing the definition into sharper focus, a system has been defined as, "An ordered set of elements (objects, concepts, and/or activities) whose order results from the exchange of materials, energy, and/or information.[4]

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1 Dalton E. McFarland, Management Principles and Practices, 3rd ed. (The Macmillan Company, Collier-Macmillan limited, London; New York, 1970), p. 310.

2 Stafford Beer, Cybernetics and Management (New York: John Wiley & Sons, Inc., 1964), p. 9.

3 Stanford L. Optner, Systems Analysis for Business and Industrial Problem Solving (Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 1965), pp. 26-27.

4 From lecture notes taken in the class of Prof. D. A. Love, Graduate School of Business Administration, New York University, November 15, 1971.

> Systems are identified and described by a number of elements or characteristics. Among these are boundaries, interacting and mutually interdependent parts, feedback and equilibrium.
>
> The boundaries of a system are an important characteristic. A system's boundary may be physical or tangible,..., or it may be abstract and intangible.... The boundary tells us what is inside or outside the system, and can be arbitrarily assigned when we define the system.
>
> The idea of system also implies the interrelationship of its various component parts. The concept of interdependence holds that a change in one element of the system leads to changes in other parts of the system.... The systems concept emphasizes the totality of a set of interrelated parts, conditions or activities.
>
> A system has a tendency to achieve a balance among the various forces operating within and upon it. This balance is called equilibrium or steady state.
>
> Feedback is a central concept in the theory of control, as well as in the theory of systems. ...It is a diagnostic concept for the practitioner in management, for breakdown of the feedback process is evidence of grave difficulty in the operation of an organization or other system. Feedback is a process by which systems gather information about how they are doing, feeding the information back into the system to guide, direct, and control its further operations.[5]

Summarizing what has been presented thus far, a system is a set of elements (e.g. subsystems) that are linked in some ordered pattern by means of purposive interactions. A system is characterized by the interactions and interdependencies of its parts, by indentifiable boundaries, by feedback responses, and by references to some equilibrium or steady state condition.

One, as yet unmentioned, characteristic of systems theory merits consideration. C. West Churchman discussed

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[5] McFarland, op. cit., pp. 311-312.

this aspect of systems theory in the following way:

> The word system has many different meanings in discourse, but all along we are concerned with the design of systems to accomplish a set of purposes. From this point of view, the parts of the system bear special relationship to the whole; namely, in principle it should be possible to evaluate a part in terms of its system effectiveness, that is, in terms of its contribution to the attainment of the system objectives. More precisely, associated with each part we should in principle be able to determine an effectiveness measure; given a fixed state of the rest of the system, the more effective a part becomes (within specified limits) the better will be the whole system. The question of system design is directly concerned with this effectiveness measure.[6]

The preceding discussion serves to emphasize the interdependent relationships of system parts or subsystems. It also hints at the existence of feedback and equilibrium. But most importantly it introduces the system concept of measurement. This concept was best summarized by Dr. D. A. Love when he defined "Love's Law" which states, "If a system does not have an adequate idea of what it's supposed to be doing it cannot have a meaningful performance measurement system. A system with a good performance measurement system, conversely, will have a good idea of what it's supposed to be doing."[7]

Systems theorists have developed systems taxonomies based upon the nature of interrelation and interdependence of these system components, and upon the relative degrees to which each of these components is present in any given system. Figure 2-1

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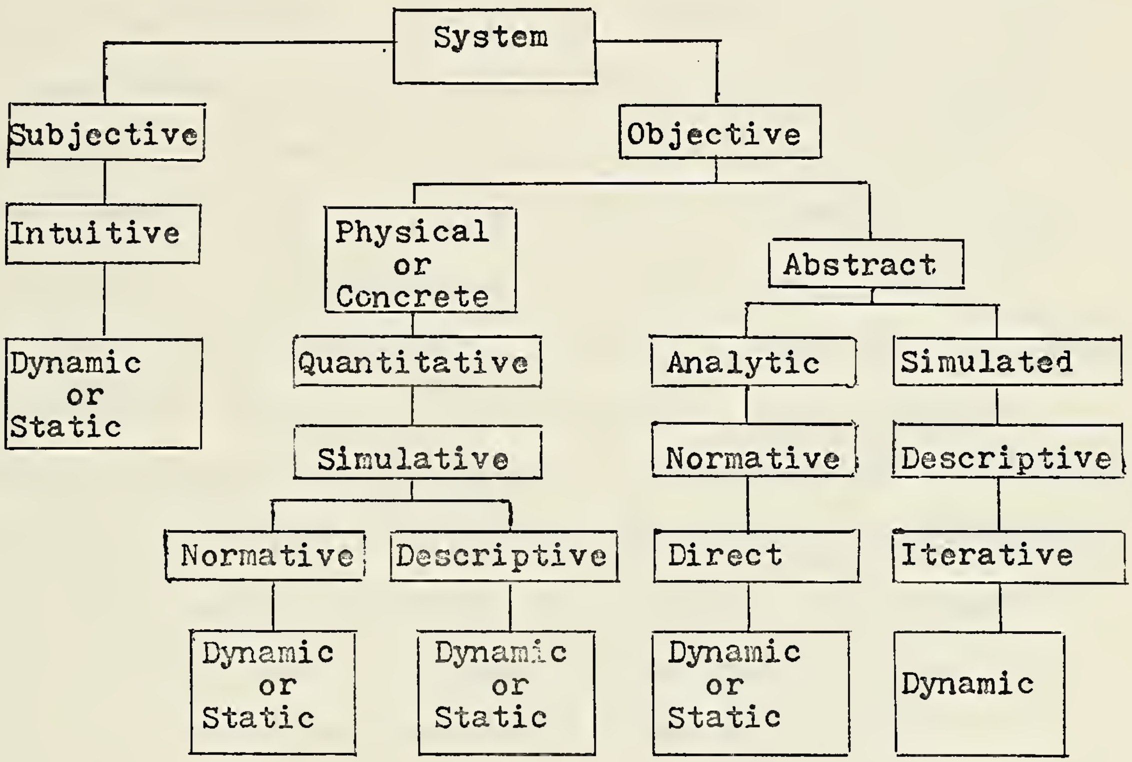
[6] C. West Churchman, A Challenge to Reason (McGraw-Hill Book Company, Inc., New York, 1968), p. 181.

[7] Love, loc. cit.

presents one such taxonomical hierarchy which is based upon the purpose served by various systems. That is, if the systems role is defined as seeking order out of chaos, then in a subjective sense, systems fill individuals' needs to identify and/or for identification. In an objective sense they enable purposive objectives to be pursued (e.g. enabling better systems to be devised: more humane systems, etc.).

Systems Taxonomy



Source: Lecture notes taken in the class of Prof. Norman Martin, Graduate School of Business Administration, New York University, Spring Term 1972.

Figure 2-1

Systems are classified by types. The method of interaction and the interrelationships of the system's parts or subsystems defines the system under consideration as either probabilistic or deterministic. In a deterministic system the parts interact in a predictable manner. In a probabilistic system the outcome or effects of the part's interaction is not predictable.

Depending upon feedback arrangement, a system may be either open or closed. An open system is one that is unaware of its own performance. Conversely, a closed system is aware of its performance and is usually made so aware by feedback. In conducting a systems analysis, one usually moves from open to closed to open to closed systems, in moving from sub-sub-subsystems to sub-subsystems to subsystems to the total system overview and vice-versa. Drawing an analogy: an engine running without control is an open system. Once a speed governor is attached to the engine, the system under consideration becomes closed. Place the engine in an uncontrolled motorboat and the system being considered is now open. Place a boat operator aboard to steer the boat and control its speed in response to wind and wave actions and the system under consideration is once again closed. Let the boat and operator wander aimlessly on the water and the system is open. Give the boat operator a task to perform, like go from pier A to anchorage B, and the system in question is closed, and so on.

The feedback itself can be either positive or negative. Positive feedback affects system inputs in such a way as to

reinforce system output. Negative feedback, on the other hand, affects output in such a way as to diminish output.

A system's relationship to equilibrium determines whether the system is static or dynamic. Quite obviously a system in change is dynamic while one that remains unchanged is static. But equilibrium properties of systems go beyond this rather simplistic definition that is based on change. Some systems are homeostatic and others are not. This means that some systems are placed in a state of disequilibrium from external or internal pressures and seek to return to the same level of equilibrium from which they started. Other systems seek out new levels of equilibrium. Still others exhibit no tendency to equilibrate. Thus, systems may be classified according to the equilibrium properties they exhibit.

System bounds and measurement standards act upon, and are acted upon by the previously discussed characteristics. The arbitrary assignment of bounds, for example, might change an open system to a closed system, or vice-versa. The choice of a measurement standard for systems analysis might determine whether the system being considered is probabilistic or deterministic. The measurement systems utilized in an open system might differ appreciably from that used in a closed system, and so on.

This concludes the rather brief, but vitally necessary summary of systems theory. Modeling practices and limitations are discussed next and should add further dimension to the preceding summary of systems theory.

Modeling Practices and Limitations

Systems theory and modeling practices are inextricably intertwined. A model, by definition, is an abstract representation of a system.[8] Use of systems theory and modeling practices together constitutes what has been termed "the systems approach."

Models serve two classes of role. First, at the objective level, the model facilitates conditional prediction. That is, if such and such is so, then so and so should follow. Second, at the group existential level, the model seeks to eliminate the perceptual differences of group members. This requires some elaboration. Assuming that all important worldly decisions are made by groups, a principle reason for lack of unanimity could be attributed to differences in individual value systems. But even if all members shared the same values, they would still have differing perceptions of reality. In effect, they would hold different models of reality. Therefore, the development and use of an explicit, common model eliminates or helps to eliminate or compensate for this perceptual reason for lack of unanimity.[9]

Models can be dichotomized into systems models or developmental models.[10] Systems models concentrate on system components or parts; boundaries; patterns of interactions;

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8 Idem

9 Idem

10 From lecture notes taken in the class of Prof. D. E. Zand, Graduate School of Business Administration, New York University, Fall term, 1971.

specific operations; transferability of operations; response patterns; feedback effects, loops, purposes; imbalance, tension, stress, conflict; and homeostatic properties. Developmental models are concerned more with change and those factors which induce and/or control change. The developmental model concerns itself with: noticeable differences between system states at different times; sequence of states, orderly processes; growth vs. decay, maturation vs. deterioration, gain vs. loss; direction, goal attainment, process and progress; identifiable states; forms of progression (i.e. monotonically increasing, linear, spiral, oscillatory, cyclical, branching, differentiation, speed up or regression, etc.); forces; structural or behavioral limits of the system; and utility of the developmental model to the practitioner.[11]

The last "utility to the practitioner" feature of the developmental model should not be misinterpreted to mean that this aspect is limited solely to the developmental model. On the contrary, it applies equally to both systems and developmental models. It should be noted that a model's value is measured in terms of its utility and not in its conformance to reality.[12] The only difference is that from the developmental model's perspective, this feature is recognized explicitly.

According to systems approach advocates, "the question is never whether or not to model. It is How much? What kind? and How expensive?"[13] This assertion can be substantiated from

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[11] Idem.

[12] Love, loc. cit.

[13] Idem.

many highly reliable, highly diversified sources. For example:

> Constructing a model helps you put the complexities and possible uncertainties attending a decision making problem into a logical framework amenable to comprehensive analysis. Such a model clarifies the decision alternatives and their anticipated effects, indicates the data that are relevant for analyzing the alternative, and leads to informative conclusions. In short, the model is a vehicle for arriving at a well structured view of reality.[14]

Considering another source:

> ... Building a model of a process enforces more disciplined thought than does mere discussion, just as a written description usually leads to more careful thought than does a conversation. So model building leads to a better considered and more precise statement of the system description. After a model has been formulated, model simulation shows whether or not the agreed component assumptions can lead to the expected behavior.[15]

From yet another source:

> Experimentation is an essential part of science. But large systems...cannot be brought into a laboratory nor can experiments be conducted on them as a whole in their natural environment. Therefore, since experimentation is necessary to gain understanding and control over such systems and experiments cannot be conducted on them, experiments must be conducted on something other than the system under study. Clearly, if such experimentation is to yield knowledge relevant to the system, it must be conducted on something that is like the system under study. Models are representations of systems that serve this purpose.[16]

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14 Harvey M. Wagner, Principles of Operations Research (Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1969), p. 10.

15 Jay W. Forrester, "Industrial Dynamics-After the First Decade," Management Science, Vol. 14, No. 7 (March 1968), p. 414.

16 Russell L. Ackoff, A Concept of Corporate Planning (New York: Wiley-Interscience, Inc., 1970), p. 10.

Despite their many attributes, models also have certain limitations. A clear understanding and awareness of these limitations is of great importance to the study of systems theory and to the ultimate implementation of systems fundamentals. The great importance of modeling limitation's relationship to systems theory application derives from the fact that the modeling practitioner's perception of the actual system (i.e. the "real world") is biased, influenced, and governed by the models he chooses to implement. His perceptions can be no more correct, accurate, precise, etc., than the correctness, accuracy, precision, etc., of the models he implements. One only begins to sense the full impact of this relationship with the realization that the words and phrases with which men communicate are, in actuality, models of feelings and ideas.

The single greatest limitation to modeling practice lies with the practitioners inability to model the total system. He is forced to deal with a system in parts. As a result, the types of models used and the diversity of systems approaches that result are extremely difficult and more usually impossible to integrate into one representative model of the system, or into one representative approach to understanding or controlling the system. Furthermore, optimizing the activities of each of the subsystems usually produces suboptimal behavior at the next higher level of aggregation.

In many cases the optimal solution prescribed for a certain subsystem becomes infeasible or unrealistic when

evaluated in terms of the total system. For example, the optimal production schedule might be developed, by means of a linear programming model, for the production department. Simultaneously, the optimal course of action is dictated, by means of a behavioral model, for the safety department. In this case, faced with the impossible task of integrating two non-integrable models, the decision maker falls back upon some implicit intuitive model of his own to arrive at the actual course that will be pursued by the total system.

Of course, operations research advocates would argue that the constraints imposed by the safety department could be taken into account in the linear programming model for the production department. But this approach has two significant factors going against it. First, because the variables which bear on the safety objective are largely qualitative, the behavioral model would be far superior to a linear programming model for this area of interest. Consequently, any attempt at altering the safety department's objectives to fit as constraints in a linear programming model necessitates the adoption of a clearly inferior model. Such action, in turn, greatly reduces the quality, accuracy, and reliability of attainment of stated safety objectives. Second, the linear programming advocate is faced by the "curse of dimensionality" which maintains that a model's complexity increases exponentially as the number of dimensions considered in the actual system is increased.[17]

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[17] From lecture notes taken in the class of Prof. D. H. Marks, Massachusetts Institute of Technology, Department of Civil Engineering, Fall term 1972.

Thus far only the problems associated with optimizing decision models have been considered. The optimizing model was chosen because of its direct application to engineering methods. The construction of physical models for purposes of simulation and ultimate system optimization are probably the best known of all modeling techniques. Consequently, the optimizing model provides a convenient vehicle for conceptualizing and exemplifying modeling techniques, relationships, and, of course, limitations. But this approach tends to oversimplify the actual problems which face the modeling practitioner. In the real world optimizing models constitute but a small fraction of all the various models used. In decision making, for example, satisficing models prove more useful than the optimizing models used earlier in decision theory development.[18]

In the management field a great diversity of modeling approaches are used. Many diverse facets of a business enterprise are modeled and considered as separate subsystems. Production models, inventory models, marketing and sales forecasting models, physical flow and information flow models, behavioral models, conceptual models, decision models, simulative models, and so on are but a few examples of the various types of models that are used. The task of integrating any two of these, yet alone all, into a representative model of the total firm is quite impossible at present. The great diversity and dimensionality involved constitutes a very significant limitation, therefore, to the model practitioner.

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[18] For a more comprehensive discussion of this aspect of modeling theory see Richard M. Cyert and James G. March, A Behavioral Theory of the Firm (Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1963), pp. 1-127.

The primary limitations to modeling practices, however, rest with the modeling practitioners themselves. These limitations can be characterized in the form of two modeling diseases. These are : epicyclitus and model aphasia.[19]

"Epicyclitus" is a term coined in reference to the Ptolemaic model of the solar system. In his model, Ptolemy placed the earth at the center of the universe with the sun, moon, planets, and stars revolving around it. While the model was functional, it was never completely accurate and required continual modification as new information was discovered, and it required the development of a fairly complex set of relationships to account for relative motion in the system. At the height of its development the Ptolemaic system compensated for the resultant effects of relative motion by modeling epicyclical orbits for all stars and planets as they traveled in their major orbits around the earth. Hence the term "epicyclitus." It should be noted that the Copernican model that replaced it was much simpler in construction, more adaptable to new information inputs, and highly accurate. It is even more interesting to note that the displacement of the highly complex, relatively inefficient Ptolemaic model by the infinitely simpler, highly efficient Copernican model was accomplished by the simple transfer of the sun from a major orbit to the center of the system's model.

Thus, "epicyclitus" can be defined as the continual modification of a poor model as opposed to devising a new

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19 Love, loc. cit.

model, through application of a systems approach, etc., to replace the old one. Eric Von Daniken assailed this facet of modeling theory when he bemoaned the inept formulations that have been derived from archeological research. According to Von Daniken:

> Our historical past is pieced together from indirect knowledge. Excavations, old texts, cave drawings, legends, and so forth were used to construct a working hypothesis. From all this material an impressive and interesting mosaic was made, but it was the product of a preconceived pattern of thought into which the parts could always be fitted, though often with cement that was all too visible. An event must have happened in such and such a way. In that way and no other. And lo and behold - if that's what the scholars really want - it did happen in that way. We are entitled, indeed we ought, to doubt every accepted pattern of thought or working hypothesis, for if existing ideas are not called in question, research is at an end. So our historical past is only relatively true. If new aspects of it turn up, the old working hypothesis, however familiar it may have become, must be replaced by a new one. It seems the moment has come to introduce a new working hypothesis and place it at the very center of our research into the past.[20]

Von Daniken's remarks lead nicely into the discussion of the second modeling disease, "model aphasia." In this context, model builders, having gained proficiency in the use of a certain model or models resort more and more frequently to "their" model's usage. They tend to bend reality to fit their models rather than develop a model that fits reality in such a way as to best serve the potential model user's purpose.

Model aphasia is quite commonly exhibited in the work of linear programming advocates. In operations research

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20 Eric Von Daniken, <u>Chariots of the Gods</u>? (G. P. Putnam & Sons, New York, 1970), p. 13.

circles, this second model disease has been termed "the hammer syndrome," in which every problem in the world can be viewed as a nail, and linear programming as the hammer which drives home the solutions.[21] Similar analogies can undoubtedly be drawn in other areas of modeling endeavor.

Developing a Decision Making Approach

The problem of harvesting sea urchins in the state of Maine and transporting sea urchin roe to Tokyo for marketing in Japan can be approached in many different ways. From a linear programming perspective, for example, the problem is essentially that of a classic transportation linear programming problem.[22] From an economic perspective the problem is largely one of calculating and equating marginal costs and marginal revenues.[23] To the systems analyst or management scientist the problem may be viewed as a network that requires a network scheduling solution.[24]

Conventional practice would dictate that the modeling approach ultimately chosen would reflect the discipline of the practitioner, be that individual a linear programming operator, an economists, or a management scientist. But are any of these

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[21] Marks, loc. cit.

[22] Wagner, op. cit., pp. 166-186, 213-224, 387-392.

[23] Paul A. Samuelson, Economics, 8th ed., (McGraw-Hill Book Company, New York, 1970), pp. 468-474, 523-524, 532; Ingo Walter, International Economics, Theory and Policy, (The Ronald Press Company, New York, 1968), pp. 59-115, 221-303.

[24] Richard W. Conway, William L. Maxwell, Louis W. Miller, Theory of Scheduling (Addison-Wesley Publishing Company, Reading, Massachusetts, 1967), passim.

approaches clearly superior to any of the others? Would the results or conclusions of any of these approaches approximate the results of any of the other approaches? How reliable would the results be, given that the chosen approach limits its considerations to a rather select set of subsystems to the exclusion of any others?

Quite obviously a single model of the total system is very much preferred. But won't the diversity of model types and their dimensions prohibit the design of a single representative model? Past experience has proven that there are exceptions to this generalized trend that usually accompanies the development of integrated models. It should be remembered that the Copernican model was far more accurate and infinitely simpler than the model it replaced. Further:

> ... The physical size or scope of a system has but little to do with the complexity of the model necessary to represent that system adequately. The bigger the system, the greater can be the degree of aggregation. A model of an economy need not contain all component companies. A model of a company does not represent each person. A model of human behavior would not reach to the individual cell. A model of dynamics of a cell would aggregate to a much higher level than individual atoms and most molecules. In fact, the models needed in each of these systems would probably be of about the same complexity.[25]

Enumerating the subsystems that make up the aggregate system produces the following breakdown of operations: harvesting, processing, ground transport, sea or air transport, and marketing in Japan. The ideal types of models required for each of these subsystems are quite diversified.

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25 Forrester, op. cit., p. 413.

The obstacles presented in designing a systems model to integrate the diversity of subsystem models appear almost insurmountable. Behavioral model parameters do not offer any identifiable links with transportation network variables. Methods of delineating system bounds and of establishing subsystem interfaces are not readily apparent. Common standards of measurement are nonexistent. The homeostatic properties and dynamic characteristics of the various models are too diversified. The methods and types of subsystem interactions are not clearly understood.

A cursory examination of an approach utilizing developmental models produces significantly different results. Shifting problem emphasis to concentrate on change and those parameters which influence and/or control change yields a conceptual framework that is quite different from those that would evolve from systems model usage. This resultant framework presents a radical departure from the more conventional modeling methods and represents the essence of SMART. Its acceptance in this particular instance is based upon the following hypothesis:

> The development of Maine's underutilized resources, in this case being sea urchin roe, is completely a management problem. The transshipment of the roe, and its eventual marketing in Japan are also completely management problems.

The eventual impact of this hypothesis pivots upon the definition of the word, "management." This term, therefore,

is defined as follows:

> ... Management is defined for conceptual, theoretical, and analytical purposes as that process by which managers create, direct, maintain, and operate purposive organizations through systematic, coordinated, cooperative human effort.[26]

In this case, managers are taken to be any individual or individuals whose actions or inactions can influence the eventual success or failure of this particular venture. The organization referred to is the system by which Maine sea urchins are harvested, processed, transported, and marketed in Japan. The sum of these considerations leads to the development of a decision making approach. The need for this development is dictated by what has been described as "the management process."[27]

The importance of the decision making facet of the managerial process cannot be overemphasized. It is intricately interwoven with the entire management function. This point is easily missed if decision making is viewed only as the final choice among a set of alternatives. Focusing only on the final moment of choice leads to a false concept of decision and according to Simon, "ignores the whole lengthy, complex process of alerting, exploring, and analyzing that precedes that final moment."[28]

Decision making should be viewed as an on-going process where many decisions generate other decisions, passing through

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26 McFarland, op. cit., pp. 4-5.

27 Peter F. Drucker, The Practice of Management (New York: Harper and Row, Publishers, Inc., 1954), passim.

28 Herbert A. Simon, The New Science of Management Decision (New York: Harper and Row, Publishers, Inc., 1960), p. 1.

a sequence of steps, leading to the "final" decision. It is this process character of decision making that has accorded this facet of the management process a central role in the revisionist's theories of management. To them, decision making and managing are synonymous.[29]

Emphasis can also be placed on the after-the-moment-of-choice side of the decision process. According to Ackoff, "Making a decision is only one aspect of what might be called a decision cycle. Such a cycle has...four steps...decision making, implementation, evaluation, and recommendation."[30] Ackoff further stresses that, "It should be apparent that control, decision, and management-information systems are strongly interrelated and are merely subsystems of what might be called the management system."[31]

It is therefore concluded that management and decision making go hand in hand for, according to Drucker, "Whatever a manager does he does through making decisions."[32] But even more importantly, the preceding discussion establishes the concept of a decision flow. Within this framework, a manager becomes one who controls system activities by exerting an influence on a decision stream. This concept of a "decision stream" becomes quite important in the comparative discussion

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[29] Ibid., pp. 1-4.

[30] Ackoff, op. cit., p 99.

[31] Ibid., p. 112.

[32] Drucker, op. cit., p. 351.

of SMART and Jay Forrester's Industrial Dynamics approach conducted in the next to the last section of this chapter.

PERT and DCPM

PERT is the acronym for Program Evaluation and Review Technique, and is sometimes referred to as the Critical Path Method (CPM). It is a network approach to planning and scheduling work projects in a system. Developed jointly by the Navy Special-Projects Office and Booz-Allen-Hamilton management consultants, in conjunction with the Fleet Ballistic Missile Program, it was successfully used in producing the Polaris missile.[33] Since that time it has been increasingly used in industry.[34]

> PERT is a system of planning and control involving (1) the identification of all key activities in a project, (2) devising the sequence of activities and arranging a flow diagram, and (3) assigning duration times for the performance of each phase of the work. The sum of the estimated durations along the most lengthy sequence of activities gives the estimated total time span for the entire project. PERT uses time as a common denominator to reflect three basic factors in work projects: time, use of resources, and performance specifications. PERT appears to represent an advance over former systems of planning and scheduling, such as Gantt charts, by the addition of mathematical concepts and the use of computers. ...
>
> The critical path of a program is the longest possible time span along the system flow plan. The critical path is obtained by organizing the events in sequence, beginning with the final event in the total network. ... Observation of the network plan and the critical path makes possible the comparison of progress in each part of the project with the target dates of completion.[35]

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33 McFarland, op. cit., p. 278.

34 Daniel D. Roman, "The PERT System: An appraisal of Program Evaluation Review Technique," Journal of the Academy of Management, 5 (April 1962), p. 57.

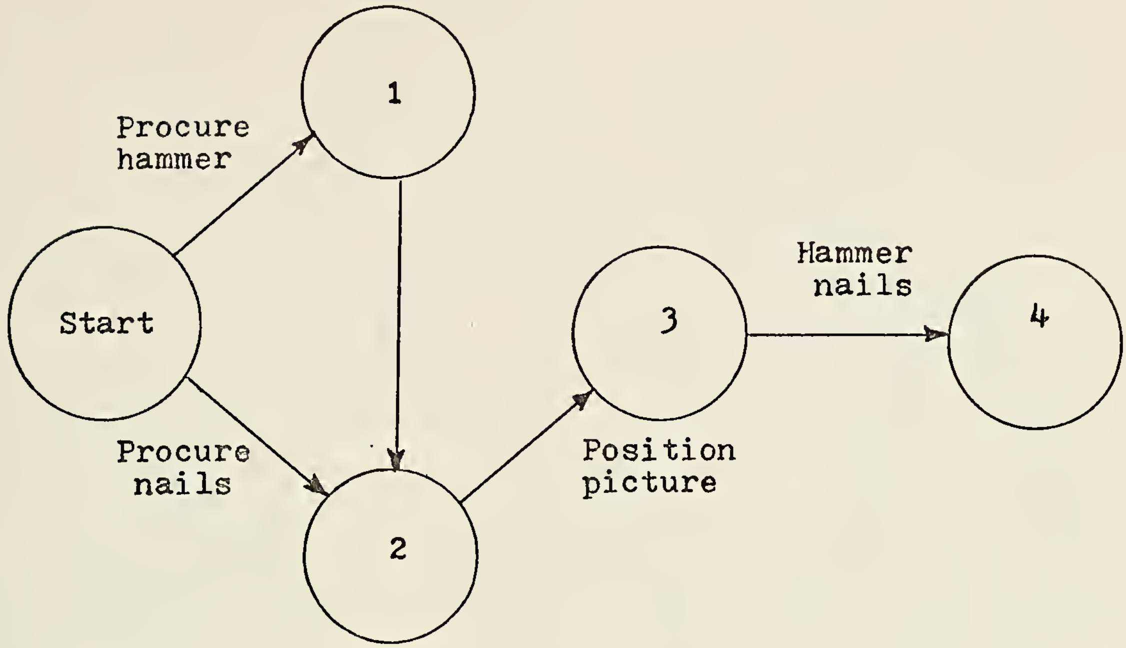
35 McFarland, loc. cit.

Figure 2-2 shows two examples of PERT flow diagrams. Circles show the key events while arrows represent the priority relationships between the events. The numerical symbols beside the arrows indicate the costs or times associated with the attainment or the respective events. The measurement standard most frequently used is time, measured in units of seconds, minutes, hours, days, weeks, months, etc.

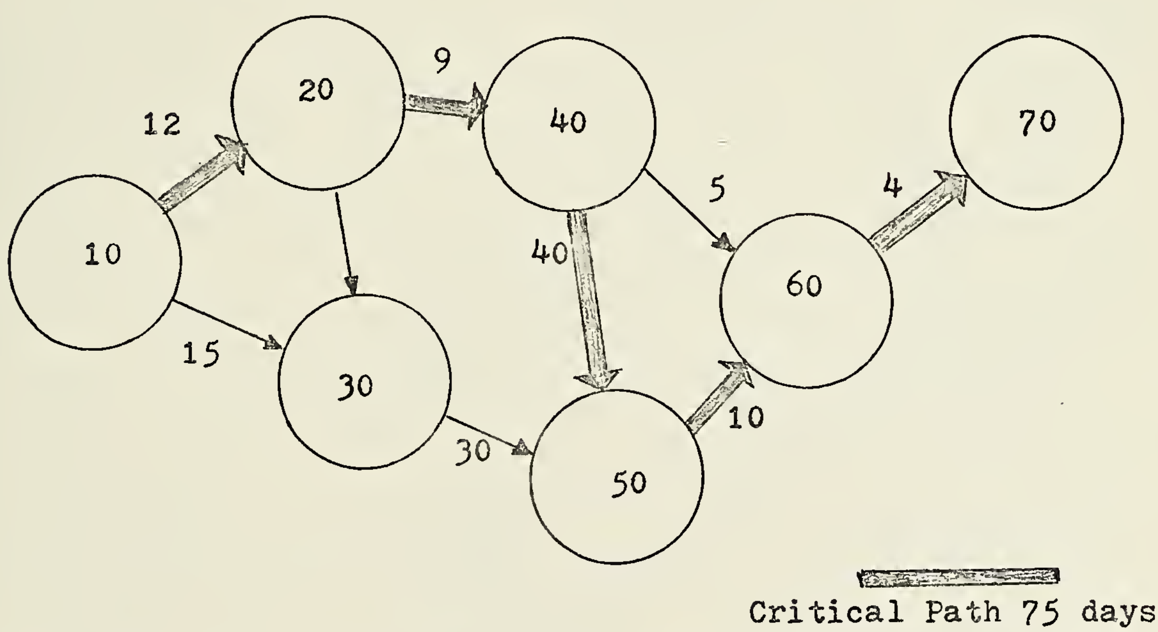
DCPM is the acronym for Decision Critical Path Method. It represents an extension of PERT that provides for the introduction of activity interdependence and alternatives which are required to effect integrated planning, scheduling, and control. By using DCPM, projects can be scheduled in a system where alternative methods exist for accomplishing the same purpose. DCPM diagrams, as in PERT diagrams, depict activities as circular nodes. Triangles are introduced, however, to represent mutually exclusive alternatives of an activity set. If the set consists of non-mutually exclusive activities, it is denoted by a triangle whose base is enclosed by a semi-circle.

Figure 2-3 shows a DCPM network where two activities, 2 and 5, can be performed in two different mutually exclusive ways, which are defined by 51,52, and 21, 22. Figure 2-4 enumerates the alternative paths which are represented in Figure 2-3. This method of enumeration shows that it is a fairly simple matter to solve this DCPM by hand, by simply choosing the least costly alternative. This task, however, becomes increasingly more difficult as the number of nodes and alternatives is increased.

Examples of PERT Flow Diagrams



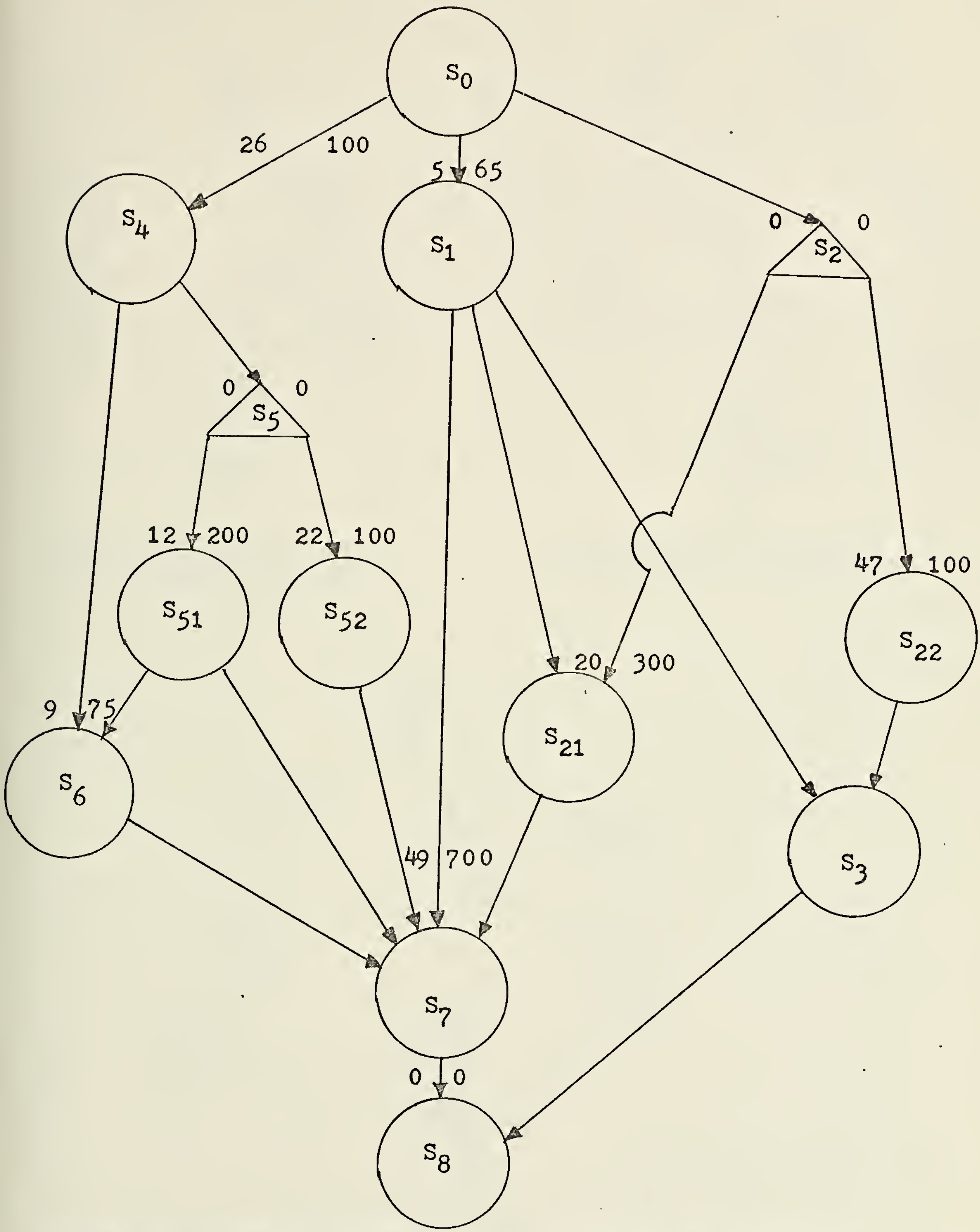
Source: Jerome Kanter, Management Guide to Computer System Selection and Use (Prentice-Hall, Englewood Cliffs, New Jersey, 1970), p. 26.



Source: Daniel D. Roman, "The PERT System: An Appraisal of Program Evaluation Review Technique," Journal of the Academy of Management, 5 (April 1962), p. 58.

Figure 2-2

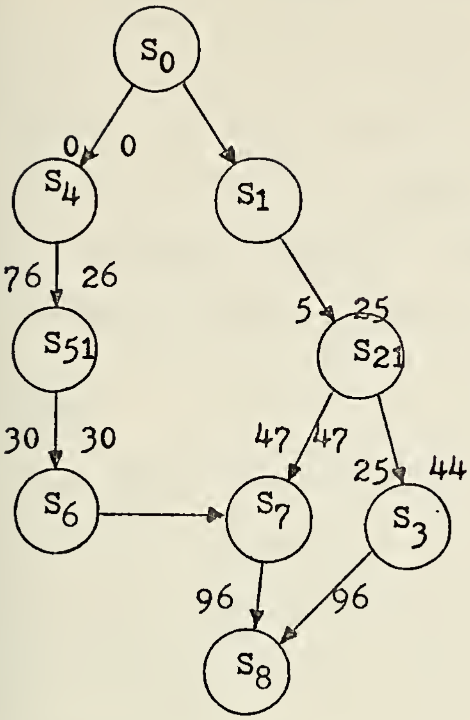
Example of DCPM Network



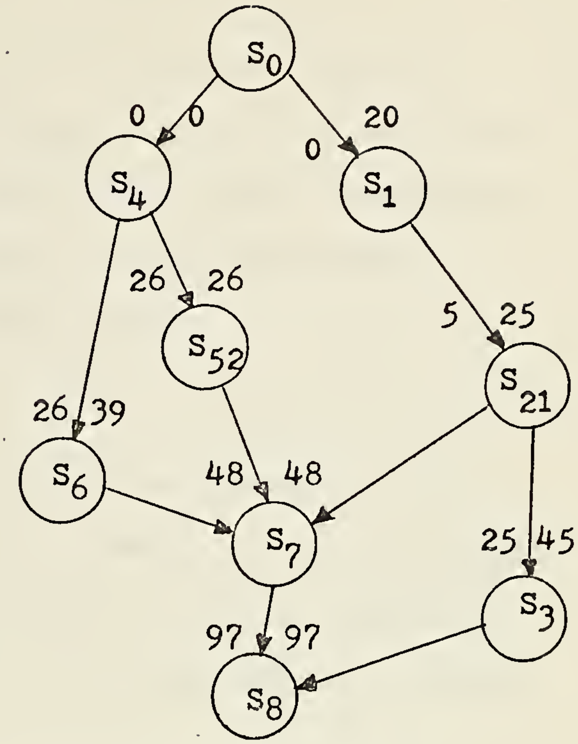
Source: Lecture notes distributed in the class of Prof. E.G. Frankel, Department of Ocean Engineering, Mass. Institute of Technology, Spring term, 1973.

Figure 2-3

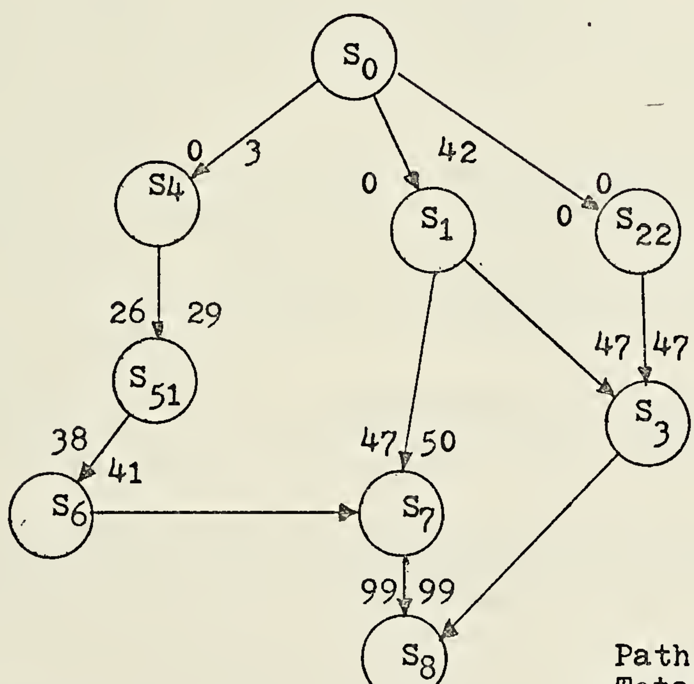
Enumeration of DCPM Alternatives



Path Alternative 51,21
Total Costs = 1600



Path Alternative 21,51
Total Costs = 1500



Path Alternative 22, 51
Total Costs = 1395

Source: Frankel, loc. cit.

Figure 2-4

PERT and DCPM form the basis from which SMART is derived. But the explainatory transition cannot yet be made. The most important intermediate step in the transition has yet to be mentioned. This "intermediate step" represents a further extension of PERT and DCPM. It is called GERT (Graphical Evaluation and Review Technique).

GERT

GERT was developed jointly be the U. S. Air Force and the RAND Corporation to assist the Air Force in the development of a more comprehensive inventory control program. GERT was used extensively and successfully in the Apollo Space Program by NASA.[36]

> Gert is a technique for the analysis of stochastic networks. Stochastic networks have the following characteristics:
>
> 1. Each network consists of nodes denoting logical operations and directed branches.
> 2. A branch has associated with it a probability that the activity represented by the network will be performed.
> 3. Other parameters describe the activities which the branches represent. These parameters may be additive such as time or multiplicative such as reliability. Time will be used in the generic sense to represent a variable which is additive. ...
> 4. A realization of a network is a particular set of branches and nodes which describes the network for one experiment.
> 5. If the time associated with a branch is a random variable, then a realization also implies that a fixed time has been selected for each branch.
>
> GERT will derive both the probability that a node is realized and the conditional moment generating function (M.G.F.) of the elapsed time required to travel between

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36 From lecture notes taken in the class of Prof. E. G. Frankel, Department of Ocean Engineering, Massachusetts Institute of Technology, Spring term, 1973.

any two nodes.

The GERT approach to problem solving utilizes the following steps:

1. Convert a qualitative description of a system or problem to a model in stochastic network form.
2. Collect the necessary data to describe the branches of the network.
3. Determine the equivalent function or functions of the network.
4. Convert the equivalent function into the following two performance measures of the network:
The probability that a specific node is realized.
The moment generating function of the time associated with an equivalent network.
5. Make inferences concerning the system under study from the information obtained in 4 above.

The approach combines concepts of PERT type networks with flowgraph concepts. From PERT the concepts are taken that a branch can be used to represent an activity and that the time to perform the activity is a parameter of the branch. From flowgraph theory, the analysis procedure incorporating a topological equation is utilized.[37]

A node in a stochastic network is comprised of an input function and an output function. Table 2-1 depicts six types of nodes which result from consideration of three possible input relations and two possible output relations. Figure 2-5 shows a GERT network which uses this GERT notation. Note the similarity between the GERT network and electrical circuitry networks. This relationship constitutes one of the primary advantages of GERT. It enables the modeling practitioner to implement a vast array of electrical engineering models, tools, and concepts during the formulation and solution of GERT model types.

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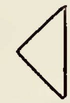
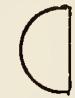
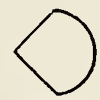
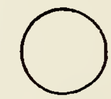
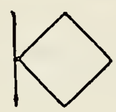
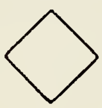
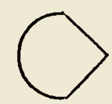
37 A. Alan B. Pritsker and W. William Happ, "GERT: Graphical Evaluation and Review Technique Part I, Fundamentals," The Journal of Industrial Engineering, Vol. XVII, No. 5 (May 1966), pp. 267-268.

GERT Node Characteristics and Symbols

Output \ Input	Exclusive-or 	Inclusive-or 	and 
Deterministic, 			
Probabilistic, 			

Exclusive-or - The realization of any branch leading into the node causes the node to be realized; however, one and only one of the branches leading into this node can be realized at a given time.

Inclusive-or - The realization of any branch leading into the node causes the node to be realized. The time of realization is the smallest of the completion times of the activities leading into the Inclusive-or node.

and - The node will be realized only if all the branches leading into the node are realized. The time of realization is the largest of the completion times of the activities leading into the and node.

Deterministic - All branches emanating from the node are taken if the node is realized, that is, all branches emanating from this node have a p-parameter equal to one.

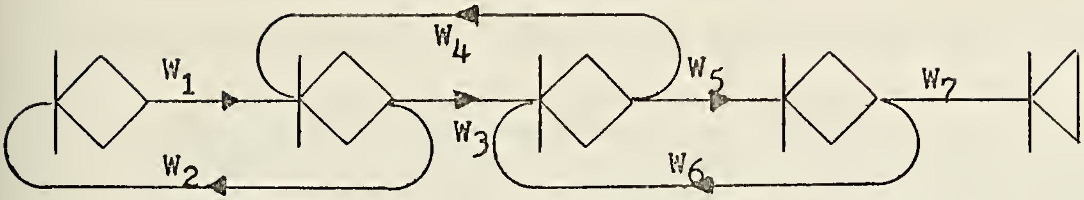
Probabilistic - At most one branch emanating from the node is taken if the node is realized.

Source: A. Alan B. Pritsker and W. William Happ, "GERT: Graphical Evaluation and Review Technique Part I, Fundamentals," The Journal of Industrial Engineering, Vol. XVII, No. 5 (May 1966), p. 268.

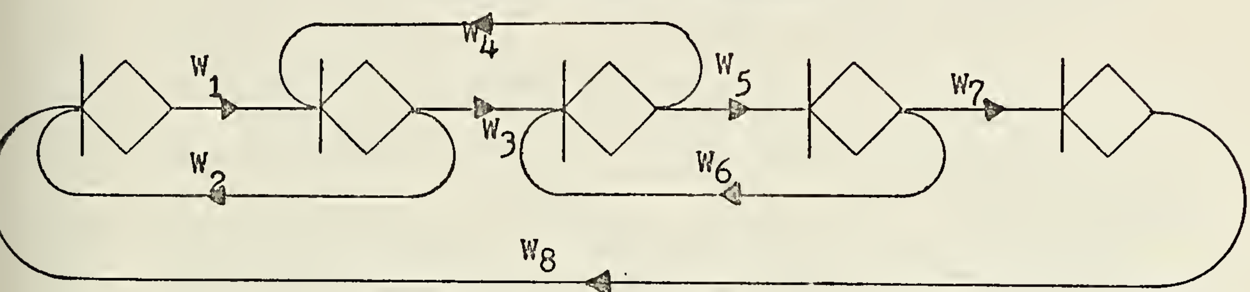
TABLE 2-1

GERT Networks

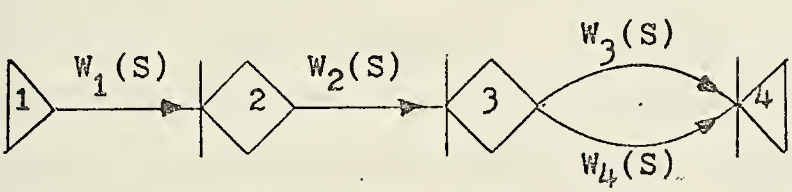
Open System Example



Closed System Example



Electrical Network Flow Graph of a Series Parallel Network



(GERT notation is used at nodes. Flow Graph network does not make such distinctions)

Source: Adapted from A. Alan B. Pritsker and W. William Happ, "GERT: Graphical Evaluation and Review Technique Part I, Fundamentals," The Journal of Industrial Engineering, Vol. XVII, No. 5 (may 1966), pp. 270-271.

Figure 2-5

One of the most flexible tools available to the electrical engineer is the flow graph. Flow graphs are used extensively in the solution of network and control problems. Flow graphs differ from CPM and other additive networks in that they represent a sequence of multiplicative operations.

> Flow graphs can be used to replace additive networks and vice versa by the assumption of a transform representation of activity or transform value. In this case, the value, in the form of an exponent, is added to others when the transforms are multiplied.
>
> Flow graphs have several advantages over other network approaches by their ability to represent feedback as well as feedforward relationships which are of major use in representing or simulating iterative situations.
>
> Similarly, solution methods for flow graph models permit effective sensitivity testing for each activity or transmittance in the network without modifying the overall structure or computational content of the model. This characteristic permits the introduction of a large number of alternatives into complex model structures without reworking the model.[38]

All the advantages of flow graph methods are manifest in GERT. Use of a transform allows multiplicative parameters, like probabilities, to be carried as transform coefficients that are multiplied together as various system alternatives are traced through the network from start to finish. Simultaneously, additive parameters, like time, are carried as transform exponents that are added together as various system alternatives are traced through the network from start to finish. The end result is a transform value with probability of realization coefficient and a mean expected time of completion exponent.

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[38] Frankel, loc. cit.

Industrial Dynamics and SMART Comparative Analysis

SMART is GERT modified for management usage. It represents a blending of systems theory, modeling practices and GERT techniques. Its major departure from GERT, in modeling the system for harvesting, processing, transporting, and marketing sea urchin roe, centers around the substitution of a cost parameter in place of the time parameter which usually accompanies the formulation of a GERT network.

While SMART has been derived independently of other modeling and systems analysis techniques, it shares many common characteristics with Jay Forrester's Industrial Dynamics (ID) approach. These similarities are significant and form the basis of this analysis.

Industrial Dynamics and SMART both concentrate on change. Both utilize developmental models primarily, for representing actual systems. In both approaches, these developmental models are used in a simulative capacity, representing changes that are experienced in the actual systems. Both deal extensively with qualitative activities such as the social and behavioral facets of organizations and systems.[39]

Both ID and SMART use a systems approach and emphasize the importance of analyzing the total system.[40] Both concentrate on developing a simulative model of the qualitative activities of a system (i.e. behavioral interactions, peer group pressures, norms, social values, etc.) and both stress

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[39] Jay W. Forrester,"Industrial Dynamics-A Response to Ansoff and Slevin," Management Science, Vol. 14, No. 9 (May 1968), pp. 608-609.

[40] Ibid., pp. 601-608.

the point that quantitative performance data be used in the qualitatively structured model.[41] (In this context, qualitative means that statistical and empirical data are used in model formulation but are supplemented where ever possible with the intangible factors).

The most important relationship between ID and SMART is the emphasis placed on the decision making processes and the concept of a decision stream. In Forrester's words:

> ... The word "decision" is used here to mean the control of an action stream. Such an action stream may be the time devoted to sleeping in response to one's physical state, the effort to improve products in response to market information about product acceptance, the change in interest rates in response to money supply, the change of prices in response to a world-wide commodity shortage, or the rate of consumption of rabbits as a response to the size of the coyote population. As in these and all other decision streams, the action resulting from the decision stream affects the state of the system to which the decision stream itself is responding.[42]

Similarly, SMART maintains that "decisions" are both the cause and result of actions and/or change in a system. In SMART, the term "action stream" and "decision stream" are synonymous.

While these and other comparisons can be drawn relating ID and SMART, significant dissimilarities exist which differentiate the two. These differences fall under one of three headings. These are structure, feedback, and other minor differences.

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41 H. Igor Ansoff and Dennis P. Slevin, "An Appreciation of Industrial Dynamics," Management Science, Vol 14, No. 7 (March 1968), pp. 384-385.

42 Forrester, "Industrial Dynamics-After the First Decade," op. cit., p. 402.

Industrial Dynamics stresses the importance of structure and feedback. The entire ID theory pivots around the concept of feedback in decision processes and in systems. ID therefore limits itself to closed systems.[43] According to Forrester:

> The feedback loop is seen as the basic structural element of systems. It is the context within which every decision is made. Every decision is responsive to the existing condition of the system and influences that condition. This is a statement equally true for the forces that control the flow of electricity into a capacitor, for the conscious decisions of the individual or the manager, and for the selective decisions of nature that fit species to the environment by the processes of evolution.[44]

In similar fashion, ID theory derives much of its impetus from structure and theory of structure:

> Industrial dynamics is a philosophy of structure in systems. It is also gradually becoming a body of principles that relate structure to behavior. The structure which is codified in industrial dynamics has its counterpart in other fields and other bodies of literature. It is in industrial dynamics, however, that the structure has probably been given its sharpest definition and its most rigorous application.
>
> Structure is seen as having four significant hierarchies:
>
> - The Closed Boundary
>   - The Feedback Loop as the Basic System Component
>   - Levels (the integrations, or accumulations, or states of a system)
>   - Rates (the policy statements, or activity variables, or flows)
>   - Goals
>   - Observed Conditions
>   - Discrepancy between Goal and Observed Conditions
>   - Desired Action[45]

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[43] Forrester, "Industrial Dynamics-After the First Decade," op. cit., p. 406.

[44] Ibid., p. 408.

[45] Ibid., p. 406.

SMART favors neither open nor closed systems. While ID actively seeks ways to draw arbitrary boundaries around systems in question so as to ensure inclusion of all interacting feedback loops and thereby close the system, SMART does not. SMART concentrates on defining the arbitrary system bounds subject to the single constraint that the resultant model best serve the stated purpose for its construction. This represents a "let the Chips fall where they may" approach which is completely indifferent to whether the resultant model is open or closed. It is assumed that every system is a subsystem of some larger system and, therefore, could be closed but that, from the perspective of what ever purpose the model is to serve, the modeling effort required to close the system might be unduly excessive.

SMART has no particular obsession with structure. It acknowledges that structure is very important but is to be considered as one necessary step taken in applying the systems approach. This is conceptually clearer if SMART is viewed as a three step process. Structure becomes a vitally important consideration in the first stage which is applying the systems approach. The second step is to develop models for each of the subsystems using whatever technique best serves the purposes of the respective subsystems. The third step is to utilize GERT techniques to link all the submodels into one representative model of the entire system.

At this stage in its development GERT is not able to be employed to solve all subsystem models simultaneously. Optimization solutions are derived independently, for example, to determine

break points in bulk shipment rates, etc. These results become inputs in the overall GERT model. Simultaneous solution thus far is only possible if all submodels are transformed into a GERT network prior to solution. Otherwise GERT serves as a conceptual shorthand for keeping track of a vast array of interacting factors only. SMART has a long way to go before approaching the sophistication of ID but is offered here, none-the-less, as an effective way of approaching a rather complex problem and as a method which holds forth a great deal of promise for future development.

Summary

This chapter has presented a logical development of the factors required to provide insight and an understanding for SMART. Systems theory and modeling practice where summarized first since the systems approach constitutes the first step of the SMART technique. A discussion of PERT and DCPM was conducted next since these methods form the foundation upon which SMART is based and from which it was eventually derived.

GERT was considered in greater detail because it represents the focal point of the SMART method. This was made readily apparent in the statement that SMART is GERT adapted for management usage.

The comparison of SMART and ID was then conducted to sharpen the focus and impact of the explaination. SMART was described as a potentially effective tool, lacking ID's sophistication, whose true value can only be realized through actual application to many real world problems over time.

CHAPTER III

SEA URCHINS AND SEA URCHIN ROE

General Background

The sea urchin is an echinoderm of the class Echinoidea. Echinoderms are any animals that belong to the phylum Echinodermata, familiar examples of which include the starfish, sand dollar, and sea urchin.

> The echinoderms are divided into five classes: the asteroids (Asteroidea), or sea stars, in which the arms are broadly attached to the disk; the ophiuroids (Ophiuroidea), or serpent stars, in which the arms are narrow, slender, and highly flexible; the echinoids (Echinoidea), including the sea urchins, heart urchins, and sand dollars, having no arms but possessing a globular, oval, or disklike shell; the holothurians (Holothuroidea), or sea cucumbers, having elongate, leathery bodies and a circle of branched tentacles around the mouth; and the crinoids (Crinoidea), including the sea lilies and feather stars, having slender, branched arms bearing side branches or pinnules. The crinoids have few living members; they are remnants of a large fossil assemblage, which included three additional classes now totally extinct.[1]

Echinoderms are characterized by a five-rayed structure, a system of locomotion operated by water pressure, and an internal skelton of calcareous material that supports external spines or tubercles.[2] These can be divided into two general

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[1] "Echinoderm," Collier's Encyclopedia, Vol. 8, 1971, p. 507.

[2] Idem.

types. In the one type, the body consists of a central disk, from which radiate five or some multiple of five arms. This type is represented by the starfish, star serpent, and the crinoids. In the other type, the body is globular, oval, disklike, or cucumber shaped, showing equally spaced radiating structures which are usually five in number. This type is represented by sea urchins and sea cucumbers.[3]

The term Echinodermata is derived from the Greek "echino," meaning spiny, and "derma," meaning skin. The term appears to have originated with Jacob Klein in 1734 in his treatise, _Naturalis dispositio echinodermatium_.[4] While Klein applied the term solely to echinoids, the term evolved in its usage to encompass all the animals possessing the characteristics previously listed. The echinoids, however, form the focal point of this discussion since they include marine animals commonly known as sea urchins, heart urchins, and sand dollars.

Including both fossil and living forms, about 250 genera and 4000 species are known.[5] A count in Mortensen's monograph reveals that there are about 750 described existing echinoids.[6]

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3 Idem.

4 Libbie Henrietta Hyman, _The Invertebrates: Echinodermata, The Coelomate Bilateria_, Vol. IV (McGraw-Hill Book Company, New York, 1955), pp. 1-3.

5 "Sea Urchin," _Encyclopedia Americana_, Vol 24, 1970, p. 477.

6 T. Mortensen, _Monograph of the Echinoidea_ (15 Volumes, published from 1928 to 1951) in L. H. Hyman, _The Invertebrates_, op. cit., pp. 414-415.

Sea urchins are found in all seas and at all depths. They are particularly numerous in warm waters, however, and generally live in shallow waters along the coast. Very few species of sea urchins are found in the shallow waters of the Atlantic Coast. A very common species found along the rocky shores of New England is the green sea urchin (Strongylocentratus drobachiensis). Another North American sea urchin is the purple or deep brown Arbacia punctulata which is found from Cape Cod to the Gulf of Mexico.[7]

Diadema and Toxopneustes are found only in the South Atlantic states while the flat or cake urchins (Clypeasteroidea), the sand dollars (Echinarachinus parma and Mellita testudinata) are North American examples.[8] On the Pacific coast, in the shallow waters of California, the red urchin (Strongylocentrotus franciscanus) and purple urchin (Strongylocentratus purpuratus), are the most common.[9] The species of greatest interest to this discussion is the green sea urchin, Strongylocentratus drobachiensis, which is assumed to predominate the Maine shallow water coastal areas.[10]

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7 Encyclopedia Americana, loc. cit

8 Idem.

9 Susumu Kato, "Sea Urchins: A New Fishery Develops in California," Marine Fisheries Review, in Reggie Bouchard, Potential Markets for Maine Seafoods in Japan (Maine Department of Sea & Shore Fisheries, Augusta Maine, n.d.), white pages.

10 Ibid., "Japanese Report Supplement," p. 7.

External Characteristics

Echinoids (i.e. sea urchins) present differentiated oral and aboral surfaces. They move upon the oral surface, which is consequently flattened or even concave. The aboral surface, on the other hand, is moderately or highly arched.

The most conspicuous external feature of the sea urchin is its bristling armature of thickly placed spines. These spines are usually longer around the urchin's periphery than at the oral or aboral areas. The spines are usually differentiated into two main sizes, the larger, or primary spines (also called radioles) and the smaller, or secondary spines.[11] The primary spines are arranged in meridional rows which extend from the top of the aboral surface to the bottom center of the oral surface (periproct to peristome). The secondary spines are also arranged in similar fashion but are not quite as well ordered as the primary. These patterns are best seen by examining the skeletal plates of the denuded urchin.

Figure 3-1 depicts the sea urchin (Strongylocentratus drobachiensis) from top, bottom, and isometric views. Figure 3-2 depicts the denuded urchin, or "test" which shows the patterns of arrangement for the primary and secondary spines. Of particular interest are the plates, themselves, into which the primary and secondary spines are set. These plates reflect the pentamerous symmetry previously described.

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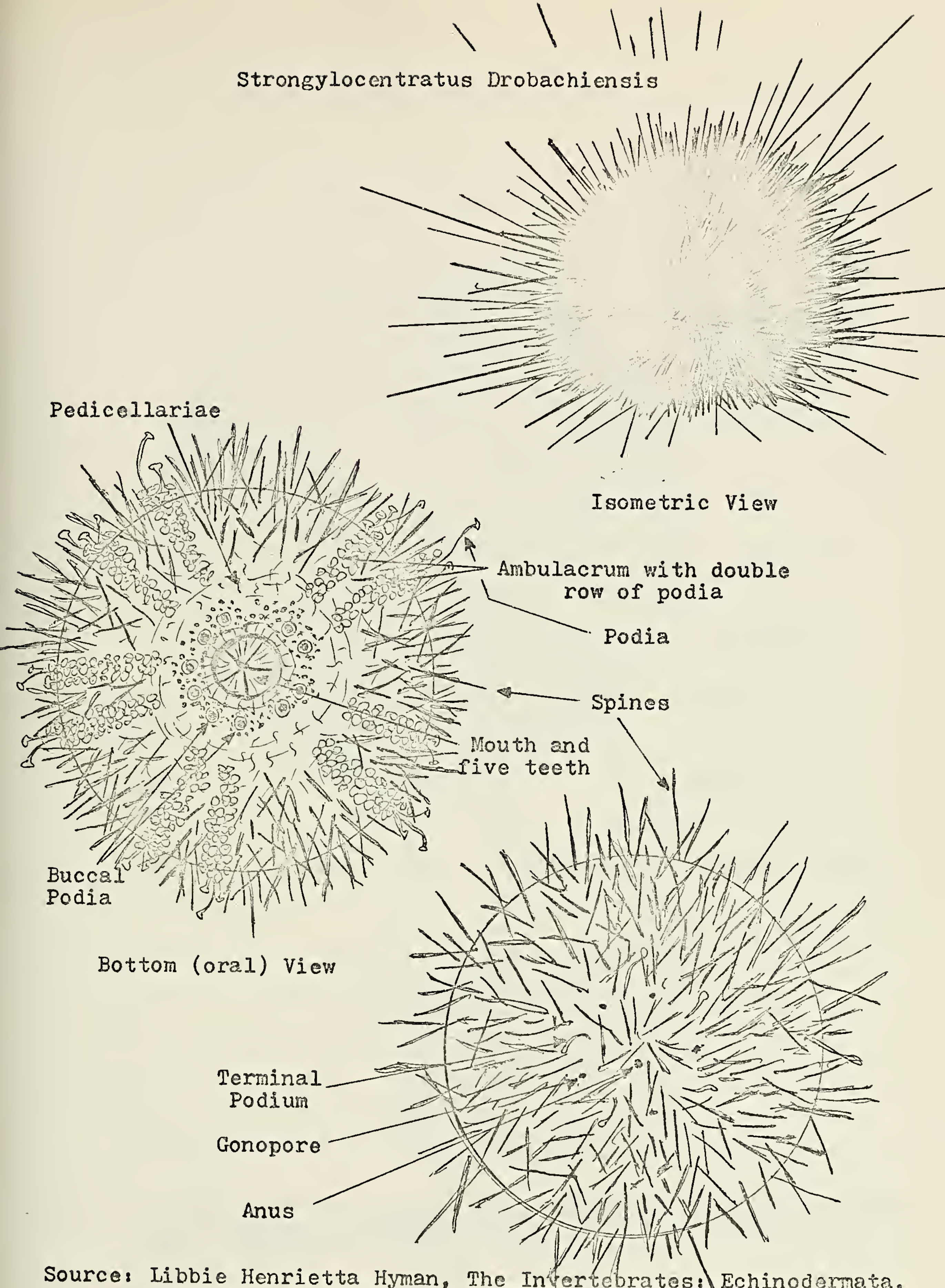
[11] Hyman, op. cit., p. 424.

Strongylocentratus Drobachiensis

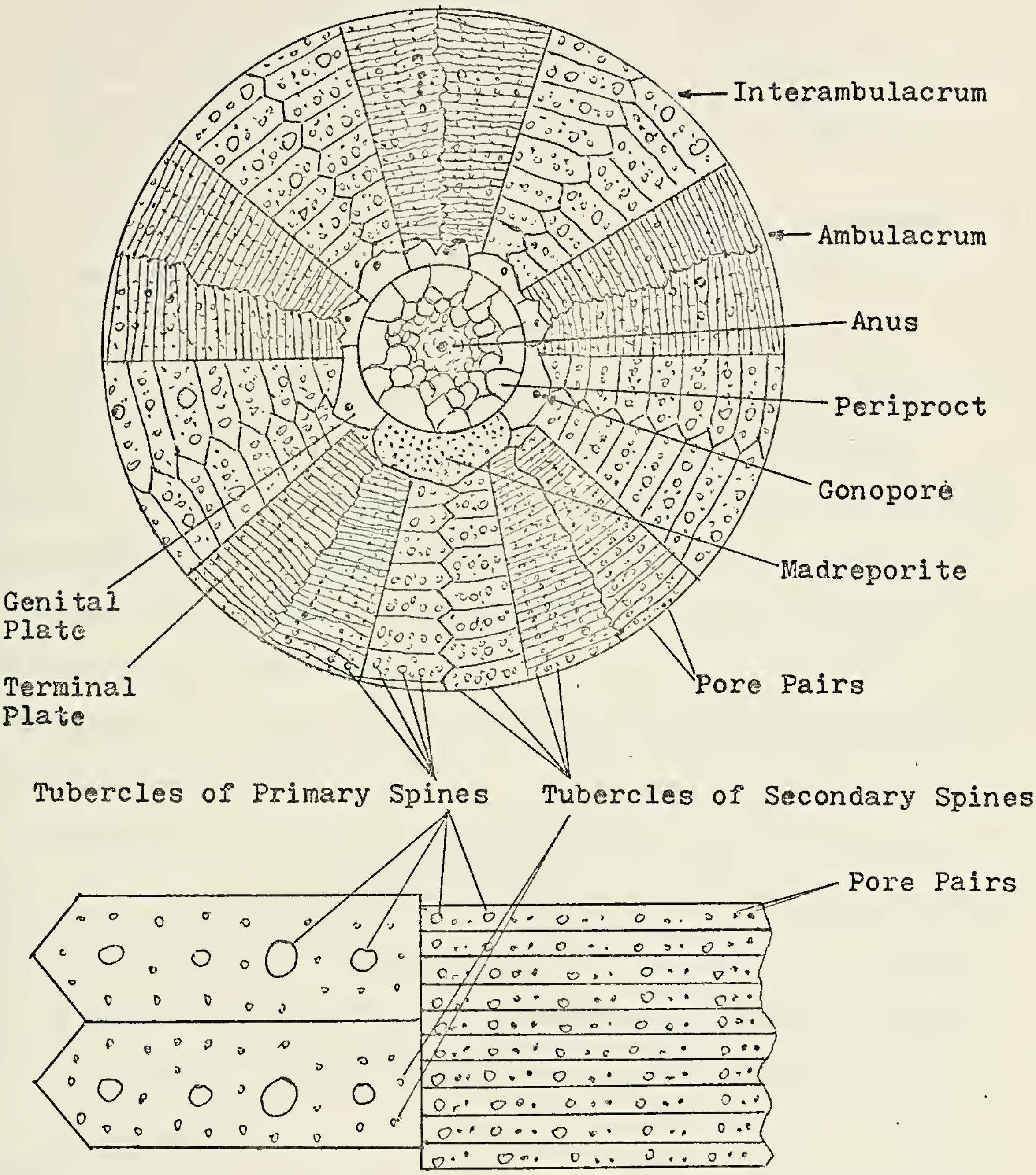


Source: Libbie Henrietta Hyman, The Invertebrates: Echinodermata, The Coelomate Bilateria, Vol. IV (McGraw-Hill Book, Co., Inc., New York, 1955), pp. 416, 450.

Figure 3-1

Denuded Test of the Sea Urchin

(Aboral View)



Source: Libbie Henrietta Hyman, The Invertebrates: Echinodermata, The Coelomate Bilateria, Vol IV (McGraw-Hill Book, Co., Inc., New York, 1955), p. 450.

Figure 3-2

These plates are usually largest at the periphery and decrease in size toward the poles. According to Hyman:

> ...They are elongated horizontally and are five-sided with more or less straight horizontal edges. ...The plates of the two rows of each double row alternate, and as their inner edges along which they meet are shaped like an arrow head, the plates dovetail and present a zigzag line of meeting. ... the outer edges are more or less straight. All the plates are rigidly and immovably fitted closely together by ligamentous material....[12]

On the aboral side of the urchin, a special system of plates surrounds the periproct. This consists of five larger "genital" plates, each of which is pierced by a genopore, and five smaller "terminal" plates, each pierced with a single hole through which terminal podiums emerge. Further, "One of the genital plates is larger than the others and is peppered with numerous pores, thus revealing itself as the madreporic plate or madreporite."[13] These are shown in the aboral view of Figure 3-2.

Between the spines on the aboral and oral sides of the sea urchin, and on the peristome, though only sparingly on the periproct, are minute appendages called pedicellariae. These consist of a head composed of three movable jaws mounted on flexible stalks of varing lengths. The jaws are moveable and are provided with sharp serrated edges or teeth. There are four types of pedicellariae, each of which occurs in

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[12] Ibid., p. 445

[13] Idem.

numerous shapes and sizes. One type, however, the "glandular," is of particular interest in that its teeth are serviced by glandular sacs which secrete a toxic venom.

The pedicellariae serve three apparent purposes. First, they provide a defense mechanism which enables the sea urchin to bite and hold antagonists. Second, they allow the urchin to capture animals that come within reach and in some cases stun the animal, or paralyze it with its venom , so that it can be moved to the peristome region and eaten. Third, they enable the sea urchin to move away unwanted foreign matter that may collect on its plates and spines.

Around the sea urchin's periphery, in the ambulacra region, are "podia," or tube feet. These are usually arranged in five double rows on the ambulacra, extending in symmetrical patterns from peristome to periproct. They are usually long and slender and in most cases have a terminal disk or suction cup at the outer tip. These are used primarily for locomotion while podia without the disks or suckers, which terminate at a blunt or rounded end, serve in a sensory capacity.[14]

Internal Characteristics

Figure 3-3 shows the internal arrangement of a sea urchin that has been split horizontally. At the center of the oral surface is the mouth which is provided with five hard teeth belonging to the chewing apparatus called "lantern of Aristotle." These teeth, which continually grow, are worn away as the urchin

[14] Ibid., p. 436.

chews the food collected by the podia.

The chewing apparatus is highly complex, consisting of too many inter-connected and inter-related parts to describe here. Suffice it to say that it is attached to a pentagonal pharynx by membranes, which emerges from the top of the lantern of Aristotle and passes immediately into the esophagus. The intestine is usually arranged in festoons fastened to the inner surface of the sea urchin's test by mesenteries. The intestine winds around to the rectum which passes up to the periproctal surface to the anus.

Figure 3-3 also shows the internal arrangement of the sea urchin's reproductive system which consists of five gonads. These gonads are sometimes fused and are not necessarily spaced as evenly in the pentamerous symmetry as depicted. The gonads are suspended by mesenterial strands along the inner surface of the interambulacra.[15] "At its aboral end each gonad narrows to a short gonoduct that exits by the gonopore in the corresponding genital plate of the apical system."[16] Further, "The gonads consist of an outer coelomic epithelium, a middle layer of muscle fibers and connective tissue, and a lining of germinal epithelium."[17]

The digestive and reproductive systems make up the interior of the test, or body, of the sea urchin, which has been described as a spacious coelom, or body cavity. This coelom is filled

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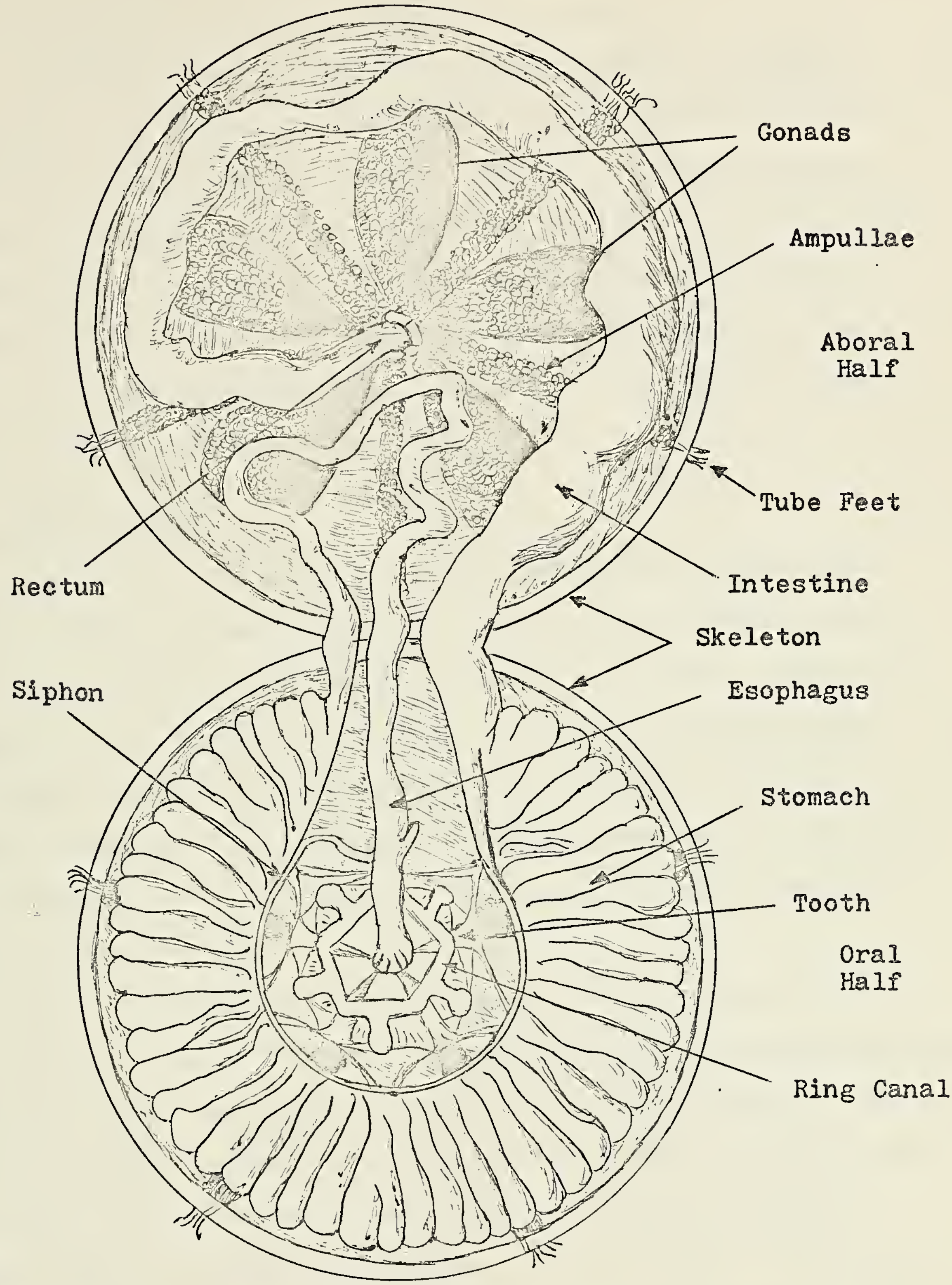
15 Ibid., pp. 477-478.

16 Ibid., p. 478.

17 Idem.

Internal Arrangement of an Echinoid, or Sea Urchin



Source: T. I. Storer and R. L. Usinger, <u>General Zoology</u> (McGraw-Hill Book Co., In, New York, 1957).

Figure 3-3

with a fluid that is very similar to sea water. It floats freely throughout the body tissues and organs.

In addition to the digestive and reproductive systems described, the sea urchin possesses a fairly advanced nervous system and water-vascular system. Neither is really critical to this discussion. While the nervous system will be discussed somewhat further under the section on "Sea Urchin Biology," consideration of the water-vascular system is dropped at this point. It serves in the joint capacity of a respiratory and circulatory system to the sea urchin.

Sea Urchin Biology

Sea urchins are usually colored in uniform, plain, dark shades. They are most commonly found in green, brown, purple, and black, though a few are red or even pale white. They are usually of two genders, either male or female, although some have been discovered possessing some combination of male and female gonads in the same body.[18] For all intents and purposes it is impossible to distinguish the sex of an urchin from an external examination.

Sea urchins have a fairly complex nervous system but do not possess a central brain. Besides actuating and coordinating body functions, the system serves in a sensory capacity. Inputs from the spines, podia, and pedicellaria enable the sea urchin to search for and capture food, move from place to place, right itself if turned upside down, and coordinate its efforts by moving itself, its spines, or both toward or away from any

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[18] G. Gadd, Ein fall von Hermaphroditisms bei Strongylocentratus drobachiensis (Zool. Anz. 31, 1907), passim.

source of stimulation.

Reproduction occurs through the simultaneous discharge of eggs and sperm into sea water. Fertilization and development ensue immediately. Cells divide very rapidly and at the eight cell level two separate poles of the developing organism can be readily identified. One pole is defined as the vegital pole, and the other as the animal pole.

> .... After fertilization, the resulting Zygote embarks on a series of cleavage divisions which occur very rapidly ($\frac{1}{2}$ - 1 hour per cell cycle) and without intervening growth...
>
> Subsequent cleavage divisions occur in all parts of the embryo eventually giving rise to a hollow ball of cells; the blastula.... The period of cleave lasts 8 - 18 hours depending on species and temperature. At the end of this time the embryo secretes an enzyme, hatching enzyme, which digests the fertilization membrane and the embryo emerges as a swimming blastula.[19]

Figure 3-4 shows the progress of the developing sea urchin from fertilization through the first four months. As can be seen in this figure, the vegetal pole of the blastula flattens, and the developing cells begin to withdraw to the interior. This commences the gastrula stage which lasts from 1 to 2 days. The gastrula alters into a larva type, the pluteus. After 4 to 6 weeks of development in the pluteus stage, the pluteus undergoes metamorphosis into a young urchin. This final stage of sea urchin development is shown in Figure 3-5. The event usually occurs in less than an hour. The outer wall ruptures and shrinks back

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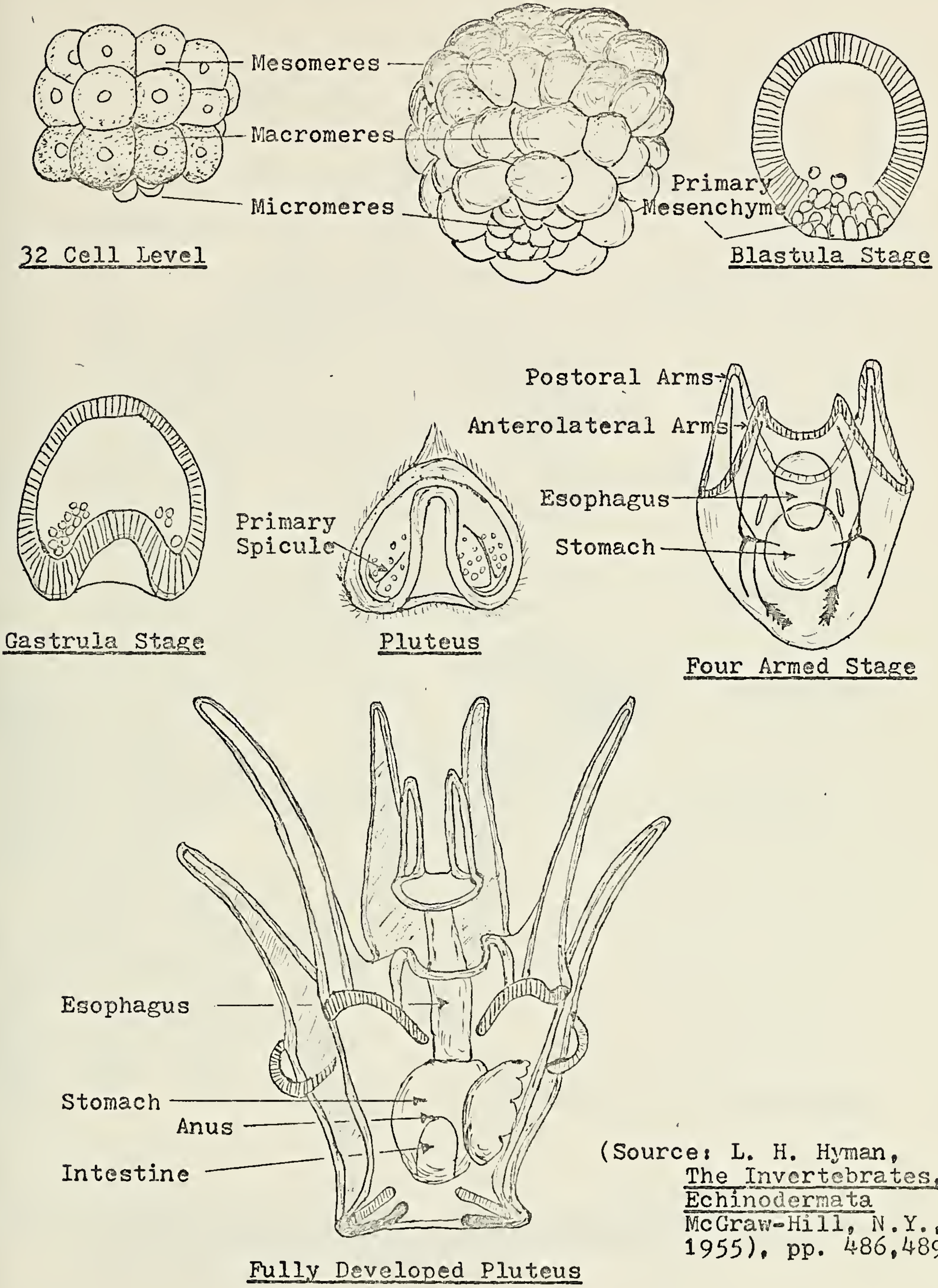
19 Richard Olding Hynes, Regulation of Gene Expression During Early Cleavage in Sea Urchin Embryos (PhD Thesis, Mass. Institute of Tech., Dept. of Biology, August 1971), pp. 11-12.

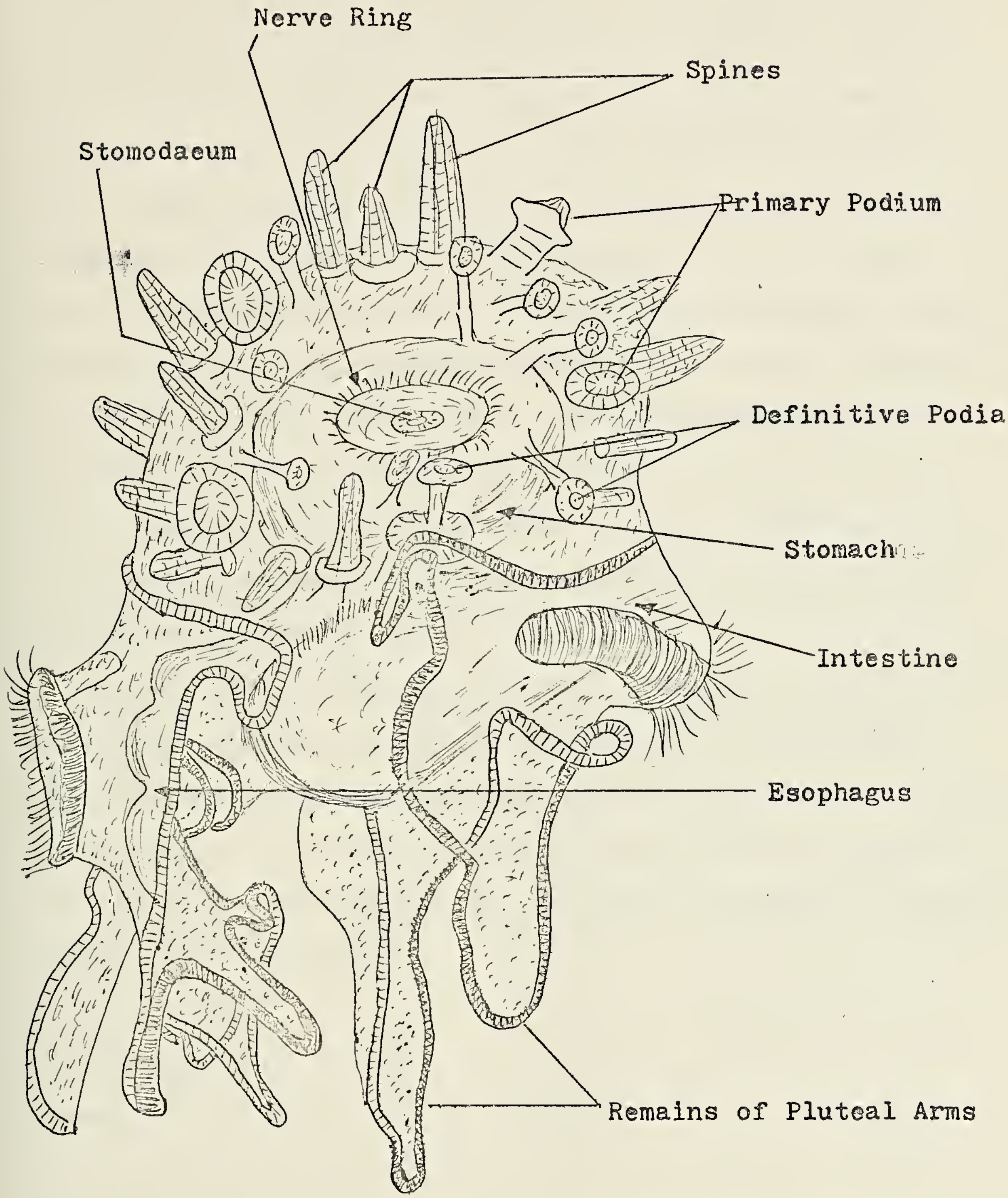
Sea Urhins: The First Four Weeks



(Source: L. H. Hyman, The Invertebrates, Echinodermata McGraw-Hill, N.Y., 1955), pp. 486,489).

Figure 3-4

Metamorphosis of the Young Sea Urchin



Source: Libbie Henrietta Hyman, The Invertebrates: Echinodermata, The Coelomate Bilateria, Vol IV (McGraw-Hill Book, Co., Inc., New York, 1955), p. 499.

Figure 3-5

allowing primary podia, spines and any additional podia that have developed to emerge to the exterior. The urchin continues to develop after metamorphosis and grows with size as a function of species, temperature, and the food supply. The urchin grows from a body diameter of 1 mm to 10 mm in 8 months, and 20 mm at 1 year. Under laboratory conditions it was found that sea urchins grew to approximately 26.2 mm in diameter at 2 years, 29.2 at 3 years, 30.3 at 4 years, 37 at 5 years, and 38.7 mm at 6 years.[20] It was also found that specimens of Strongylocentratus drobachiensis collected off the Norway coast measured 0.5 mm at metamorphosis, growing to 5 to 6 mm in diameter a 1 year, 15 mm at 2 years, 24 at 3 years, 40 at 4 years, 50 at 5 years, and 60 at 6 years.[21] The largest specimen, 78 mm in diameter, were assumed to be approximately 8 years old.[22]

It can be seen that growth rates are quite erractic in this phylum although it can be concluded that the species under consideration, Strongylocentratus drobachiensis, develops more rapidly. It is also concluded that urchins live for up to 6 years, on the average, and are usually capable of spawning after their first year.[23]

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20 Hyman, op. cit., p. 588.

21 Idem.

22 Idem.

23 Mortensen, loc. cit.

Ecology: Habits and Behavior

Echinoids are exclusively marine benthonic animals and all their activities and adaptations occur on the ocean bottom. The oral surface always stays in contact with the bottom as the urchin moves about in search of food. If overturned, the coordinated action of spines and podia serve to return the urchin to its normal position.

Sea urchins generally move over top of food, holding it with spines and podia, and chewing it with the lantern of Aristotle. If food comes in contact with the aboral surface, it is pushed toward the mouth by the coordinated action of spines and podia. Food is detected at distances which average up to 18 inches, at which time the urchin moves in a round about fashion, until it is approximately 12 inches from the food, then in a straight line, over obstacles etc., to the food.

Food for sea urchins appears to consist of almost anything, but some tend to be carnivorous, others herbivorous, and in the absence of preferred items, they ingest bottom material and act as general scavengers.[24] Urchins with carnivorous tastes subsist on sissile and encrusting organisms such as hydroids, bryozoans, barnacles, sponges, dead fish, fish eggs, snails, snail eggs, crustacean legs, etc. Those with herbivorous preferences feed on plankton, kelp and seaweed, sometimes remaining in one spot for the 2 to 3 weeks required to chew and digest a bunch of seaweeds.

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[24] Hyman, op. cit., pp. 553-554.

Sea urchins usually inhabit rocky or partially rocky bottom, or other types of hard bottom, although some may be found on sand. Coral reefs seem to constitute a very favorable habitat for large numbers and kinds or sea urchins. In such suitable spots it has happened that urchins collect in such large numbers as to completely blanket a particular bottom area.

One noteworthy capability of the creature is its boring capacity. Sea urchins dig burrows into hard rock and coral, apparently as a protective measure against waves. In some cases the urchins dig so deep and grow so large that they are unable to get out of the entrance to the hole which they made when younger and smaller. In these cases the urchin must depend on food washed up to it by tidal and wave action. All doubt as to the boring capability of the sea urchin was laid to rest by a study of the boring activities of Strongylocentratus purpuratus, which had caused extensive damage to steel piers on the coast of California by boring deep burrows into the steel pilings in which the urchins were found.[25]

Sea urchins tend to shy away from light, preferring shaded areas and the darkness offered by crevices in coral reefs or by their own burrows. Urchins sometimes cover their aboral surface with plants, shells, etc., holding the debris in place with their podia, in effort to shade themselves

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25 Margaret Irwin, "Sea Urchins Damage Steel Piling," Science, Vol. 118 (1953), passim.

from light. In addition to this aversion to strong light, sudden increases and decreases in illumination cause a very definite reflex reaction of a defensive nature. The spines erect themselves and point to the source in the same manner that they would if mechanical stimulation had been applied.

Despite their armature of spines and poisonous pedicellariae, sea urchins fall prey to other animals such as crabs, sea stars, large fish, mammals, and birds. "The gonads when ripe are highly nutritious and are eaten, either raw or after roasting in the half shell, by man in various parts of the world."[26]

Sea urchins serve as hosts to a variety of parasitic animals, internally and externally. The spines being devoid of living tissue can become encrusted with a variety of sissile organisms such as barnacles, algae, sponges, anemones, hydroids, bryozoans, etc. Internally the intestinal tract is often infested with great numbers and varieties of ciliates. Mortensen records that the Japanese Mespilia globulus "is very generally infected with a trematode living in its genital organs and destroying these more or less completely."[27]

Snails feed upon the surface tissues of sea urchins, fastening their egg masses to the test. This is particularly common with Strongylocentratus drobachiensis, which is

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[26] Hyman, op. cit., p. 581.

[27] T. Mortensen, Echinoderms of New Zealand and the Auckland-Campbell Islands, in Hyman, loc. cit.

primarily herbivorous.

Summary: Strongylocentratus drobachiensis

The Strongylocentratus drobachiensis is geographically distributed throughout the north European and North American coasts. It is a circumpolar species which inhabits both the North Atlantic and North Pacific, reaching as far north as Discovery Bay, north of Greenland, at 81° north latitude.[28] It is also found in the Bering Strait, north of Russia and Siberia. It is the most common species, if not the only one, off the coast of Maine, and therefore is of greatest importance to this discussion.

Strongylocentratus drobachiensis is primarily herbivorous.

> ...The food habits of S. drobachiensis seem to vary with locality: in Puget Sound it eats mostly seaweeds and resorts to animal material only when plant material is not available (Weese, 1916); also on the eastern Canadian coast this species eats mainly seaweeds and similar material scraped from rocks plus fish refuse from adjacent canneries (Dawson, 1868); but Eichelbaum's specimens from the Baltic contained chiefly diatoms, tube worms, and hydroids, with smaller quantities of other animals.[29]

Its embrological and larval development are the same as that previously described. It was noted earlier that its growth rate is more rapid than that of other species, increasing in size at about 10 mm diameter every year after the first year. It was also noted that it was capable of spawning after its first year.

Spawning usually occurs in late spring or early summer.

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28 Hyman, op. cit., pp. 575, 581.

29 Ibid., p 554.

Spawning usually occurs earlier the more southern the latitude. It is therefore assumed that the Strongylocentratus drobachiensis is entering its spawning season in April or May. In actuality very little is now known about the reproductive aspect of the sea urchin from a macro perspective. There is need for further research in this area to determine number of eggs spawned each cycle, larval survival rate, young urchin survival rate, sensitivity of urchin population to such factors as sea urchin density in any given area, water temperature, quantity of food available, etc. There is a need for more information on where and how the urchin fits into the ecological cycle of the Maine coastal zone. Calculation of a maximum sustainable yield is dependent upon quantifiable information on the sea urchin's reproduction capabilities, behavior, and habits. The harvesting of the Strongylocentratus drobachiensis should not be undertaken until more is known about its own reproductive capacities and its relationship with the ecological cycle.

CHAPTER IV

THE BEHAVIORAL ENVIRONMENT

Introduction

SMART requires vast amounts of qualitative information in the formulation of its developmental models. Such information shapes the design and final conceptual structure of the various networks and the aggregate system. Qualitative inputs also serve to temper the probabilities that would be derived from purely quantitative and statistical data. For these reasons, this chapter discusses and presents as much qualitative information as possible relating to the potential development of Maine's underutilized sea urchin resource.

Before proceeding further, therefore, it becomes increasingly desirable to consider the many facets that comprise the behavioral environment of the state of Maine. For purposes of this analysis, these facets have been divided into legal, economic, and social perspectives. Consideration of each of these in turn provides the necessary insight for building a qualitative data base.

Developing an information base

The Legal Component. The laws of a state frequently reflect the attitudes and values of its citizenry. Maine is certainly no exception. Its laws and court decisions reflect conservatism, individualism, and a high regard for the rights

of its individual citizens. The clearest example of these attitudes is provided by the adjudicative proceedings which have served to shape Maine's concepts of a riparian land owner's water rights. Maine's concepts of riparian rights differ significantly from those that have evolved in the other Atlantic coastal states.

The early Maine case of Blanchard v. Baker[1] held that any diversion of water which was not returned was actionable even though there were no actual damages. This interpretation was based on the riparian owners right to the water undiminished in quality or quantity. The difference in this opinion was that in most other states some form of damage had to be shown before diversion of water which was not returned could be considered actionable.

In the Lawrence v. Lockwood case, the Maine Supreme Judicial Court weighed a dispute between two riparian owners. In this case, Lockwood, a downstream riparian textile owner, attempted to enjoin Lawrence, an upstream and chronologically earlier saw mill operator, from discharging sawdust edgings, shavings and other material into the river which hindered the textile mill's operations.[2] The court did not grant the injunction on the grounds that the lumber mill provided a greater economic service to the community.

The results of these two cases had a profound impact on the decisions rendered in many cases that followed. These decisions, in turn, continued to shape Maine's concepts of

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[1] 8 Me. 253, 1832.

[2] 77 Me. 297, 1885.

riparian rights.

In Kennebec Water District v. Maine Turnpike Authority, the water district sought remuneration for damages to its ability and right to take water from a brook and distribute it for public use.[3] The district claimed that the Turnpike Authority had constructed a bridge over the brook, mudding the waters, making it unfit for distribution. The court referred to the Lockwood case and interpreted the phrase, "the rights of the owners are not absolute but qualified, and each party must exercise his own reasonable use with just regard to the like reasonable use by all others who may be affected by the acts."[4] In this case, however, it was held that reasonable use pertained to reasonable "riparian" use. Therefore, because the water district was not a "riparian" user, no remuneration for damages was granted.

In the Stanton v. Trustees of St. Joseph's College case, the courts continued to develop the reasoning laid down in the Blanchard v. Baker and Kennebec Water District cases.

> ...The private college, located at some distance from a non-navigable brook, proposed to build a new dormitory which would necessitate the emission of 50,000 gallons of liquid residue per day. The college acquired a small parcel of land adjacent to the brook as well as easements permitting it to lay sewer pipes from the dormitory site to the riparian parcel, to discharge into the brook. The effluent was to be treated so as to leave the quality of the water virtually unchanged while only slightly increasing its quantity. The proposed discharge of effluent had been licensed by the Environmental Improvement Commission.
>
> The court held that the plaintiffs, downstream riparian proprietors, had a right to have the waters

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[3] 145 Me. 35, 71 A. 2d 520 (1950); 147 Me. 147, 84 A. 2d 433 (1951).

[4] Ibid., p. 44.

> of the stream unchanged in quantity or quality except by reasonable riparian uses of other riparian owners; that riparian uses are only those uses of water which benefit adjacent land; that the waste disposal use contemplated by the college, not being for the benefit of the small riparian parcel, was not a riparian use, and thus was unreasonable as a matter of law. The Court took notice of the license issued by the Environmental Improvement Commission, but held that the agency was incompetent to rule on rights as between private individuals....
>
> The decision in the St. Joseph's case is an unfortunate one. By giving the riparian owner injunctive relief when there was no actual harm to the quality of the water and only a slight augmentation of the quantity, the Court placed technical private rights above the public interest in sewage disposal.[5]

The most important point brought out by these cases, is the emphasis placed upon private riparian rights. Maine apparently places a very high value on the private rights of its citizenry to the point where private rights are to be maintained even to the detriment of the public good.

The Economic Component. The primary interest of this study centers upon Maine's coastal fisheries. It is useful, therefore, to develop a feel for how and where Maine's fishing industry fits economically into the rest of Maine's economic coastal environment. In January of 1970, for example, Maine's Department of Sea and Shore Fisheries estimated that Maine's fishing resources accounted for an annual landed value of $26 million.[6] Assuming these figures remain fairly constant from year to year, where does Maine's fishing industry fit in relation to its other coastal industries?

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5 Regulation of the Coast: Land and Water Uses (Maine Law Affecting Marine Resources, Volume Three, School of Law of the University of Maine, NSF Office of Sea Grant Programs, 1970), pp. 461-462.

6 Portland Press Herald, Financial and Industrial Edition, January 31, 1970.

Recreation is Maine's second largest industry.[7] Since timber and forest products constitute Maine's largest industry, recreation could be identified as its largest coastal zone industry. It has been estimated that tourism brought $348 million to Maine in 1967 and $400 million in 1968.[8] This represents a significant competing use for Maine's coastal resources since the great majority of out of state vacationers congregate in the coastal towns and along the shore. A very significant factor is that only 34 miles of Maine's 2,162 miles of shoreline with recreational potential is now in public ownership.[9]

Maine's mineral industry brought in revenues of $17 million in 1968. Sand and Gravel accounted for $6 million of this figure.[10] Maine's activities in the mining area in the past have included quarrying for building rock for export, limestone, copper, lead, zinc, gold, silver, molybdenite, mica, serpentine, and grinding pebbles. While quarrying and other mining activities are fairly dormant today, copper and zinc mining in Penobscot Bay are still quite active.[11]

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7 Regional and National Demands on the Maine Coastal Zone (New England River Basins Commission, Boston, Mass., 1971). p. 37.

8 R. Elliot, "Vacation Trend Promotion in 1967," 1967 Maine Department of Economic Development Annual Report, p. 14; and R. Elliot, "Vacation Trend Promotion in 1968," 1968 Maine Department of Economic Development Annual Report, p. 16.

9 Regulation of the Coasts, op. cit., p. 507.

10 Maine Pocket Book (Maine Department of Economic Development, Augusta, Maine, August 1969).

11 Bostwick H. Ketchum, The Water's Edge, Critical Problems of the Coastal Zone (The MIT Press, Cambridge, Mass, 1972), p. 77.

Maine's coastal areas, like that of most of the coastal states, have suffered from developmental pressures. Real property valuations in coastal towns rose 57% from 1960 to 1970 representing a total market value of $3.2 billion. The estimated median value of year-round homes in coastal towns rose 63% over this period. The number of homes used as permanent residences in coastal areas increased from 137,000 units to 146,000 units over this period leaving 23,000 or 39% of the states total seasonal homes in the coastal area.[12]

The economic implications for power generation and use in the state of Maine are quite profound. Projected demands for electric power nationally, in New England, and in Maine, are staggering. At the national level, it has been estimated that with little or no increase in population, power requirements over the next 30 years will grow to 2½ times present consumption levels.[13] In New England, where the growth rate has been a traditional 7%, projected demands are expected to quadruple in the next 20 years.[14]

It has been estimated that 70% of the power produced in New England by 1990 will be by nuclear power plants.[15] These plants will require approximately 1 million tons of cooling water per day per megawatt generated.[16] Maine's coast,

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[12] Maine Coastal Resources Renewal (State Planning Office Executive Department, Augusta Maine, July 1972), p. 106.

[13] Ketchum, op. cit., p. 114.

[14] Regional and National Demands, op. cit., p. 59.

[15] A Study of the Electric Power Situation in New England, 1970-1990, New England Regional Commission, September 1970).

[16] Regional and National Demands, loc. cit.

with its year-round cold waters offers an ideal location for the siting of power plants. The temperature of Maine's water is 60 degrees F or lower during the summer. Presently, only one nuclear power plant is in operation in Maine, in Wiscasset. This facility is expected to serve as a pilot project to test the feasibility for siting other nuclear plants in Maine's coastal zone.

It is interesting to note that approximately 65% of Maine's electric power is generated from fossil fuel sources, the remaining 35% being attributed to water power.[17] It is also interesting to note that Maine's cost of electricity is as much as 30% higher than the national average. This seems quite illogical at first when it is realized that the value of petroleum products crossing Maine's borders each year is estimated at $541,000,000.[18] Portland Harbor is the largest crude oil handling port in New England, and the second largest in the nation. The reason for the higher costs becomes evident when it is realized that 80% of Portland's imported crude is transshipped to Montreal and the 20% that is left is generally marketed for refining purposes. Ninety to 95% of Maine's energy requirements are then imported from outside sources.[19] It should also be noted, however, that this oil transhipment industry accounts for approximately $27 million in revenues annually.[20]

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17 Maine Coastal Resources Renewal, op. cit., p. 84.

18 Ibid., p. 52.

19 Idem.

20 Portland Press Herald, loc. cit.

The Social Component. Social factors will play the dominant role in determining the ultimate success or failure of the sea urchin processing and marketing venture. The Japanese social values and norms will affect the sale and marketing of the processed or bulk roe. The social values and norms of Maine's citizens, however, will shape the ultimate processing, harvesting, domestic and international transport network. Both are important. Unfortunately, little information is currently available about the socio-cultural norms of the Japanese and/or the buying habits of the Japanese housewife. Consequently this section is limited to consideration of Maine's social characteristics only.

That same single characteristic that was exemplified in the discussion of the legal component stands out just as noticeably in the social perspective. The Maine citizen seems best typified under the general category of "staunch individualism." A discussion of the attempt to introduce aquacultural enterprise into the state of Maine best serves as the vehicle for developing this point. According to a recent study on the subject:

> A formidable obstacle inhibiting the development of an aquaculture industry in Maine is the individualism of Maine's coastal inhabitants. Although the independent manner of these taciturn citizens enthralls tourists, it has also dislodged many attempts to gain a foothold for even minimal aquaculture development on the Maine coast.
>
> Efforts to introduce aquaculture have often failed because aquaculture requires the cooperation of large numbers of people...Although ignored by public relations men, the individual's preference for self-reliance is usually tightly interwoven with a keen distrust for organization. The changes in laws, traditions and personal hierarchies requisite for

aquaculture do not come easily in this environment. Many coastal organization failures can be attributed to this problem, and each failure increases the individual's conviction that he is wise to labor alone.[21]

Of course, aquaculture is not the only industry to suffer from this social constraint. According to Ivan W. Fly, President of Seafoods U.S.A. of Damariscotta, "We cannot indefinitely continue to operate in the 1970's as we did in the 1930's. Petty jealousies and a lack of willingness to help anyone but yourself is what is killing the infant marine industries of Maine."[22] It stands to reason that the social and cultural elements of the Maine coastal industries must be thoroughly considered when formulating any overall plan for harvesting, processing, transporting, and marketing sea urchin roe.

The Maine Fishing Community

General Background. U.S. domestic fisheries have maintained an annual production level of 5 billion pounds despite increasing national needs. Per capita consumption has increased steadily over the last 25 years while total landings of fish and shell fish has steadily declined. Looking at Maine's fishing history provides insight into how and why this trend has developed in Maine and in all the New England coastal states.

The Gulf of Maine is bounded by the Maine coast, Nova Scotia, Cape Cod, and Georges Bank. This relatively shallow basin of water is continually stirred by the warm Gulf stream

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21 Maine Coastal Resources Renewal, op. cit., p. 39.

22 Idem.

making it one of the most fertile and rich fishing areas in the world. Since the beginning of colonization of the New World, fishing industries have flourished along the Maine Coast. In the early 1800's an extensive mackerel fishery sprang up in Eastport and herring catches continued to grow until the turn of the century, when over two hundred smoke houses operated along the Maine coast.[23]

> As smoked herring faded in popularity, a process was devised to package sardines in hermetically sealed containers, giving birth to the sardine industry. By the early 1900's fourty-five sardine canneries packed herring caught in the Gulf of Maine. Until only recently, when the industry has been forced to import sardines from Nova Scotia, the production of the sardine industry was greater than any other Maine fishery.
>
> Technological innovations in canning and shipping methods greatly expanded markets accessible to the fishing industry. The processing and sale of several species such as menhaden flourished and then failed. The menhaden fishery, after growing to a multi-million dollar industry in fifteen short years, crumbled suddenly when the fish disappeared from coastal water in 1878.[24]

After the collapse of the menhaden industry, fishing emphasis shifted to the lobster which grew from a half million dollar industry in 1880 to a 16 million dollar industry in 1969.[25] Northern shrimp fishing was the most recent industry to develop in Maine where heavy catches from 1965 through 1969 prompted heavy capital investment in boats, gear, and processing plants. In 1970 the catch of both shrimp and lobster failed leaving both industries heavily

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23 Ibid., p. 4.

24 Idem.

25 Idem.

overextended in capital and labor.

This brief summary of Maine's history in the fishing enterprise serves to identify two trends which account for the current lack of success of the New England fishing fleets. First, while total landings of fish and shell fish have continually declined, the levels that have been sustained have resulted from shifts from one fishing resource to another. Second, any success encountered in a particular fishing resource has resulted in a flood of capital and labor intensive investments, resulting in over-fishing of the resource, producing poor catches in the following years, leaving many failing industries struggling for their very existence. The ultimate result of this unfortunate sequence is the extreme hesitation that is expressed by members of the fishing community to explore and enter new areas of endeavor. This precludes such activities as researching species to be harvested, coordinating efforts among competitors, planning, innovating, etc. This, in turn, carries some grave implications for the potential management and development of any new coastal resource.

Future Promise for Maine Fisheries? In an industry plagued with uncertainty and unpredictability, one innovative solution has been singled out as being the most likely method for salvaging the Maine fisheries industry. This method has been termed aquaculture and involves the growing, harvesting,

[26] Ibid., p. 5.

and processing of seafoods under controlled conditions. Thus aquaculture would introduce a great deal of certainty and predictability into the fishing industry. This topic has a very decided impact on the topic at hand. The aquacultural development of sea urchins, as can be seen with reference to the model and problem solution offered in Chapter V, could greatly reduce the overall costs of the venture.

As has been mentioned earlier, the development of aquaculture enterprise in the state of Maine would not be without difficulty. Despite the promise offered by this fisheries innovation, obstacles to the development of aquaculture in the state of Maine are quite formidable. An enterprise of this type would require legal protection in the form of some type of regulating mechanism that would provide short or long term leasing arrangements, zoning laws to prohibit encroachment and deleterious effects of domestic or industrial activity, permission to conduct experimentation in polluted areas, etc. Unfortunately these activities touch upon areas already covered in Maine fisheries laws which were developed around conventional fishing philosophies and technologies of a by-gone era. These existing laws are quite inflexible to the interpretations that aquacultural enterprise would require. In addition, the sanctions that might be required go against the interpretation of riparian rights as it has developed in the state of Maine. Existing state health requirements, residency requirements, zoning requirements, etc. all pose problems that would have to be overcome for any aquaculture enterprise to be developed in the state of Maine.

This has not been to say that aquaculture is an impossibility in Maine, nor that laws do not exist which make provisions for aquacultural activities in the state. There are indeed provisions in Maine law for the aquaculture of clams, quahogs, and mussels.[27] These laws, administered by municipalities provide for one fourth of the total area of all flats and tidal creeks to be leased for periods of from five to ten years. In unorganized towns this responsibility falls upon the Department of Sea and Shore Fisheries.[28] Provisions have also been made for the aquaculture of oysters. These provisions do not rely upon the Department of Sea and Shore Fisheries or Municipalities since the legal arrangements for the aquaculture of oysters predates the Department of Sea and Shore Fisheries. The right to use waters for these purposes is subject to the assent of adjacent riparian owners.[29]

National demand for lobster, oysters, clams, shrimp and other seafoods certainly justifies the required research needed for establishing domestic aquacultural enterprise on an economic basis. According to Dr. Robert Dow, Director of Research for the Maine Department of Sea and Shore Fisheries, "There is no valid reason why the production of food and

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27 State, Public, and Private Rights, Privileges, and Powers (Maine Law Affecting Marine Resources, Volume two, School of Law of the University of Maine, National Science Found. Office of Sea Grant Programs, 1970), pp. 343, 349-350.

28 Resources from the Sea and Federal Limitation on State Control (Maine Law Affecting Marine Resources, Volume four, School of Law of the University of Maine, National Science Found. Office of Sea Grant Programs, 1970), pp. 673-674.

29 Ibid., p. 674.

pharmacologicals from the sea cannot become Maine's primary industry, employing more personnel at higher salaries than any other industrial activity."[30]

The uniqueness of Maine's coast, situated near, and fed by the Gulf Stream, with its meandering shoreline and indentations of bays, coves, and estuaries, with its bottom conformation, tidal range, and general water circulation system, make it, "...one of the outstanding places in the world for the development of aquaculture."[31]

> The development of an aquacultural industry, even at a level which would produce raw materials valued at $20 billion a year, would not be incompatible with many other coastal activities, nor would it interfere with the continued use of the wild resource for recreational and subsistence fishing, nor even for limited commercial fishing as, for example, the resource is used at the present time. An aquacultural industry in effect simply develops a viable food, pharmaceutical, and light industrial complex based on the use of naturally occurring resources which are then increased in yield through such means as selective breeding and modified or controlled environment. It is in effect divorcing the coastal food industry from the concept of welfarism, the public domain, and primitive hunting practices.[32]

New England Fisheries-The "Real World"

If it seems incredible that the "staunch individualism" of the Maine native could be responsible for the failures and calamities experienced by the Maine fisheries industry, consider the following account from a highly reliable source.

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30 Robert L. Dow, Renewable Marine Resource Industry Potential in Maine (State of Maine, Department of Sea & Shore Fisheries, Augusta, Maine, November 1970).

31 Resources from the Sea, op. cit., p. 771.

32 Ibid., p. 784.

"The fisheries business in Maine is probably the most competitive business in the world.... It is more than competitive...competitor's actions are vindictive.... A man will go to work every morning knowing that he's going to lose two dollars...just to keep a competitor from making money."[33]

Ralph Stevens of Stinson Canning Company, Bath, Maine stated it this way: "My father used to say that a man will throw away the whole loaf just to be sure that no one else would get a slice."[34] It is within this framework of reality that the sea urchin roe harvesting, processing, and transporting must function.

In the actual operation various combinations of fishing vessels and techniques would be employed. The harvesting operation would be carried on by independent operators. Each fisherman would make a determination every morning of every day as to whether or not to go for sea urchins or for some other catch which is more profitable. His decision will usually be based upon the per pound value offered for the respective catches. For example if the going price for sea urchins is $1.00 and shrimp is $1.20, per pound, the fisherman will go out after shrimp in most instances. This means that the processor faces an highly probabilistic input of the raw product and/or an highly probabilistic cost for the material.

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33 Statement of an executive of a Maine processing company, personal interview, May 1973.

34 Statement of Mr. Ralph Stevens, Stinson Canning Co., Inc., Bath, Maine, personal interview, 6 July, 1973.

Maine processors are very much aware of this fact. They also realize that the fisherman are, in most if not all instances, completely unaware of the interdependent nature of their respective activities. Fishermen do not seem to realize that their livelihood is dependent upon the processor as well as vice versa. The combination of these two factors necessitates that the processor travel to various drop points along the Maine coast each day to negotiate for the bulk product. The processor is also aware of the fact that the going price for sea urchins, which is currently fluctuating between $4 to $5 per bushel will go up to at least $6 per bushel if the enterprise is successful and starts to generate any volume[35]

The factors to consider in the processing plant itself are also quite significant. One Maine processor, drawing upon experience gained from previous endeavors in processing new marine products, estimated that his company could reasonably expect a proficiency gain of 2.5 on the processing of sea urchin roe. This means that if the plant personnel manage to process 100 lbs of roe during the initial test runs, an expected yield of 250 lbs of roe should result during the same period of time once the processing operation was fully established.

It was also anticipated that the current wage rate of $1.80/ hr would be increased in the near future to $2.20/hr. Using the $2.20 figure as the evaluation base, it was fully expected that all initial sea urchin roe processing would be

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[35] This information, and the information that follows represents a condensation of material provided by several Maine processing companies through personal interviews conducted during May, June and July of 1973.

initially costed at the hourly rate. It was speculated that if the venture turned out to be profitable, the processing companies would most probably shift to piece work rates. This would result in a wage increase of up to $3.00 to $3.40/hr with at least a doubling of production. Therefore, the processing cost per pound would be reduced. The cost of supervision would be increased, however, since piece work usually generates sloppy production. This realization is quite important however in view of the fact that the workers realize that the per unit cost figures, which determine the wage they receive once the shift is made to piece work rates, are based upon production results at the hourly rates. It is therefore anticipated that plant personnel will deliberately "drag their feet" during the hourly wage rate phase.

Shifting attention to the marketing aspect, one might question the Japanese interest in Maine seafoods. The interest is apparently quite real and based upon several factors. First, the Japanese consumer is becoming more sophisticated and much wealthier. The market for such delicacies as sea urchin roe, therefore, is expanding. Second, U.S. Government officials have made it clear to the Japanese that new ways must be found for reducing the trade deficit between these two countries. The Japanese Government, therefore, has stimulated its large trading companies to search for and help develop American products which could qualify for sale in the Japanese market. Third, the revaluation of the yen has made American products appear less expensive to the Japanese consumer, and therefore, appear more attractive. Fourth, the Japanese, who rely heavily

upon seafoods for one of the country's principal source of protein have witnessed a serious scarcity of preferred seafoods.[36] The sea urchin falls into this category.

The Japanese sea urchin roe market is subject to wide price fluctuations each day. It is also a very seasonal market. The market price for sea urchin roe is lowest in the summer, picking up in September and reaching its peak in December and January. By early March the price begins to drop rapidly, returning to the summer low. These prices can fluctuate from $2.00 to $10.00 per pound in a season.[37]

Maine sea urchins begin to ripen in October, hitting their peak in January and February. By March and April they are ready to spawn and their value at that time begins to decrease. It is very much to Maine's advantage that their sea urchins ripen conincident with Japan's peak seasonal demand. One further advantage accrues to Maine's sardine processors specifically. Sardines are also seasonal and their availability reaches its peak during the summer, tapering off to practically nothing by late fall. Processing facilities then lie dormant during most of the winter, switching over to shrimp processing in late winter or early spring, then back to sardines in late March or April. Obviously the sea urchin roe venture is an attractive countercyclical enterprise that would enable the sardine processor to utilize his facilities and provide employment for his workers during what would otherwise be a slack time.

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36 Reggie Bouchard, Potential Markets for Maine Seafoods in Japan (Maine Department of Sea and Shore Fisheries, Augusta, Maine, n.d.), p. 9.

37 "Japanese Report Supplement," in Bouchard, op. cit., p. 3.

Looking to the international transport problem, one finds three airlines Pan Am, TWA, and Japan Airlines with the facilities to service the New York to Japan market. of the three Japan Airlines offers the best scheduling and handling package. Surprizingly, however, Japan airlines, or any of the other airlines for that matter, would not be overly excited at the prospect of handling and shipping sea urchin roe. As it turns out, the winter season is the airlines busiest time of year. It is also the time of year when the airlines recieve their greatest quantity of high dollar density, "hard" non perishable items. Perishable items, and particularly highly perishable items like sea urchin roe require more careful handling, much closer observation, and generate larger amounts of paper work than their non perishable counterparts. As a result, the airlines would much rather be handling something else. To further complicate matters, the airlines are plagued at this time of year for vacation requests from their employees which means that they are somewhat under-staffed at this particular time of year, not to mention over-time expenses, etc. which they encounter during their winter months of operation.

This concludes the "real world" presentation of behavioral factors that directly or indirectly affect the sea urchin roe venture. It is now time to commence structuring a model of the system based upon these behavioral factors, statistical data, and available cost information. Once this is done, the overall feasibility of the venture can be evaluated.

CHAPTER V

CONSTRUCTING THE MODEL

Step One: The Systems Approach

Establishment of Boundaries. The system must encompass all the factors that influence the eventual success or failure of this particular investment opportunity (i.e. to develop Maine's underutilized sea urchin resource). This includes all five stages of the potential operation, harvesting, processing, domestic transport, international transport, and marketing. Therefore, the system's boundaries are established as follows:

The legal geographic borders of the state of Maine and the coastal waters which extend from Maine's shore to the designated outer limits of the contiguous zone bounds the harvesting and processing stages of the system. This boundary also includes all the labor, capital, and other monies subject to the direct control of Maine's local, regional, and/or state governments, agencies, organizations, or businesses. More specifically, all people who reside or derive all or any part of their income from the state of Maine within these designated bounds, including their socio-cultural norms and values, habits, and any other characteristics which make up the behavioral aspect of the state's activities are included in these bounds.

The domestic transport stage consists of several transportation branches, each of which is bounded by the physical path covered by the transport vehicles. This includes all major and minor roadways, railways, sea lanes, and/or air corridors outside of the state of Maine, extending from Maine's boundaries to Boston and/or New York. This further includes the property boundaries of all scheduled road/rail/sea/or air service agencies, storage, and transshipment facilities. Also included are all personnel outside the state of Maine who transport, load or unload, or inspect the transported commodity, including the transport vehicles, and all behavioral factors which typify or are characteristic of each of the respective transporting industries. Not included within system bounds are the transport companies, their owners and operators, other commodities carried on the respective transport vehicles, state and federal regulating industries and agencies, and any other activities not directly involved with sea urchin or sea urchin roe movement.

The international transport stage consists of several transportation branches, each of which is bounded by the physical path covered by the transport vehicles. This includes all sea lanes from Portland, Boston, and New York harbors to Tokyo harbor in Japan, and all major airways from Kennedy International Airport in New York to Tokyo and Osaka airports in Japan. These boundaries include all scheduled airport stops, all scheduled seaport stops and the Panama Canal, all transport vehicles and their crews, and the

behavioral characteristics of the transportation companies and their crews. These boundaries also include U.S. and Japanese Customs Agencies.

The marketing stage is limited to the personnel that make up the Japanese trading companies, the trading companies, and the transportation companies, vehicles, and personnel that distribute the product to the consumer in the market place. Unfortunately too little data is available about this facet of the operation to permit an in-depth analysis of the factors which contribute to the marketing of fresh or frozen roe in the Japanese markets.

Establishing System Taxonomy. The system has been conceptually divided into the five stages of: harvesting, processing, domestic transportation, international transportation, and marketing. System interfaces, therefore, are located between harvesting and processing, processing and domestic transportation, domestic transportation and international transportation, international transportation and marketing. This taxonomy is both functional and logical.

It should be noted that the system could be divided in several other ways. For example, the system could have been divided into the three functional categories of sales, transportation, and production. Or it could have been divided according to the firms involved, i.e. each individual trading company, airline, ship operator, trucking company, sea food processor, and fishing groups. Or it could be left as it is and not be divided at all. In this case each cost could be considered as an individual expense, each alternative could

then be totaled, and the least costly route through the system at any one time could be chosen. But none of these methods exhibit any characteristics that are inherently superior to the five stage method that has been selected. In fact, the five stage method is more flexible in that it will enable a very diversified set of parameters (i.e. costs, social values, work habits, cultural norms, etc.) to be integrated into the problem solution.

Statement of Purpose. The purpose of the system is to develop one of Maine's underutilized resources, the sea urchin. The purpose of the model is to structure all the parameters that influence the eventual outcome of the system, to impart understanding as to how these factors interrelate, to determine the costs associated with their interrelations, to assess the potential return on investment that could be expected from the venture, to predict the ultimate success or failure of the system.

Enumeration of Alternatives. To simplify the presentation, alternatives are listed as they occur in each of the five subsystems (i.e. harvesting, processing, domestic transport, international transport, and marketing). The various subsystem combinations that can be structured in the aggregate system, are then considered in the final model.

In the harvesting subsystem there appear to be five possible alternatives. These are: (1) Use small boats, scuba divers and boat tenders, (2) Use a relatively larger boat, suction pumps, and possibly one diver to guide the suction outlet on the ocean bottom and/or to scout for sea urchin

clusters, (3) Drag the bottom using an intermediate size boat with a scallop type dredge, (4) Use a skiff and scoop the sea urchins up from the bottom with a long handled net device, (5) Use no boats and wade for them, picking up the sea urchins by hand, or any combination of the five.

The processing subsystem is faced with three alternatives. (1) Don't process the urchin but ship it in bulk instead, (2) Process the urchin and ship the fresh roe, or (3) Process the urchin, freeze the roe, and ship frozen roe. If alternative one is chosen, the processor is faced with the two sub-alternatives of shipping bulk to Japan or developing and shipping to domestic markets. If alternatives two or three are chosen, the processor is faced with four sets of sub-alternatives. These are: Set 1, (1) Ship to Japan, or (2) Develop and ship to domestic markets; set 2, (1) Use conventional labor intensive processes or, (2) Concentrate on developing some technological innovation that will permit automation of the process in whole or in part; set 3, (1) Use an assembly line processing approach or, (2) Organize small task oriented work units; set 4, (1) Use an hourly wage rate or, (2) use a piece work wage rate.

Both the domestic and international subsystems are faced with the same sets of alternatives. Further, they are both somewhat dependent upon the alternative selections made in the processing subsystem. The only exception to this general statement is the obvious exclusion of truck transport from the international subsystem. If the processor chooses to ship

sea urchins in bulk, or to ship fresh roe, he is limited to truck and/or air transport in the domestic subsystem, and to air transport in the international transport subsystem. Frozen roe, on the other hand, could be shipped by land, sea, or air domestically, and by sea or air internationally. Quite obviously the frozen roe processing alternative is the most flexible from the processor's point of view and, as it turns out, the least risky. The technological feasibility of this alternative remains to be proven, however.

Unfortunately very little is known about the available alternatives in the Japanese markets. There appear to be two which are: (1) Sell to Japanese trading companies, or (2) Sell to small independent merchants. This applies to both bulk and processed shipments. It should be noted, however, that the second alternative has a very low probability of attainment since the Japanese trading companies represent huge oligopolies which market most, if not all, of Japans imports.[1]

Much better information is available on the domestic markets but none has yet been collected in quantifiable form. The possible alternatives appear to be as follows: (1) Ship in bulk to the various ethnic markets that exist in major east coast cities, or (2) ship processed, fresh roe to restaurants and restaurant chains in the major east coast cities. Interest has been expressed in Maine sea urchin roe by representatives from Japanese restaurants in New York City.[2]

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1 Reggie Bouchard, Potential Markets for Maine Seafoods in Japan (Maine Department Sea & Shore Fisheries, Augusta, Maine, n.d.), pp. 4-5.

2 Bouchard, "Japanese Report Supplement (November 22, 1972)," ibid, p. 2.

Assumptions

Operations.

1. Maine sea urchin roe is comparable to the Japanese product (Some Japanese sources claim that it is slightly inferior to theirs but of "good" quality, while other Japanese food experts have stated that Maine's sea urchin roe is of "superior" quality[3]).

2. Maine sea urchin roe is comparable to or of higher quality than that of California, Mexico, or Canada, Maine's potential market competitors.

3. Harvesting season will start in November, reach its peak in December and January, and end in March.

4. Because sea urchins' potential harvest yield is closely related to kelp's five year cycle, a good planning horizon is assumed to be five years.[4]

5. Traffic from Maine to Tokyo during the first five years will not be sufficient to justify a commodity rate.

6. Technological and/or marketing break throughs for frozen roe will not occur during the five year planning horizon.

7. Domestic transport rates, salaries, wages, and other costs, are assumed to be in accordance with Table 5-2.

8. All probability distributions are normal distributions, except where noted.

9. Initial harvesting operations will not approach the maximum sustainable yield.

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[3] Ibid., passim.

[4] Ibid., p. 10.

10. Fishermen will follow traditional work patterns and schedules.

11. Processing plants will operate 8 hours per day, 5 days per week.

12. Pan Am, TWA and Japan airlines will remain the only feasible carriers to serve from Maine to Japan and will not significantly vary their flight schedules or rates from those shown in Tables 5-3 and 5-1, respectively.

Decision Making. Neo-classical theories of decision making and decision behavior usually assume:

(1) Men are rational and as such will follow their rational self interest once this is revealed to them.[5]

(2) Organizations are autonomous extensions of man, pursuing goals, acting rationally, making decisions just as an individual man would do.[6]

(3) Organizations operate with perfect knowledge.[7]

(4) Organizations consider all possible alternatives when making decisions.[8]

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[5] Robert Chin, Kenneth D. Benne, "General Strategies for Effecting Changes in Human Systems," in Warren G. Bennis, Kenneth D. Benne, Robert Chin, The Planning of Change, 2nd ed., (Holt, Rinehart and Winston, Inc., New York, 1968), p. 34.

[6] Richard M. Cyert & James G. March, A Behavioral Theory of the Firm (Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1963), pp. 4-8.

[7] Ibid., p. 10.

[8] Ibid., pp. 44-82.

These assumptions are gross at best. Yet most of the models currently in use in American society are based upon these presuppositions. To state these decision behavior assumptions and attempt to develop a model in the next section of this chapter that accurately portrays the decision process as it relates to the organization (i.e. system) that is to develop Maine's underutilized sea urchin resource would be counterproductive. Therefore, the model developed in this chapter is based upon the following assumptions:

13. Men are not always rational and will not always follow their rational self interest once this is revealed to them.

14. Individuals have goals but collectivities of individuals do not.[9]

15. Organizations operate with imperfect knowledge.

16. Organizations actively search for information.[10]

17. Organizations consider only a limited number of decision alternatives.[11]

18. Variations in short run decision making will cause the system to behave probabilistically in the long run.

19. Decision rules implemented in the first two years of operations will remain in effect during the last three years of the planning horizon.

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9 Ibid., pp. 26-44.

10 Herbert A. Simon, "A Behavioral Model of Rational Choice," Quarterly Journal of Economics, 69 (1955), pp. 99-118.

11 Cyert and March, op. cit., p. 83.

Thus, the decision model used in SMART is representative of an adaptively rational system rather than an omnisciently rational system.[12]

Standards of Measurement. Essentially there are only two measurement standards used. The first is probabilistic and represents the percentage of times a particular activity occurs as compared to the percentage of times some alternative activity occurs. Probabilities are either based upon statistical data, or more qualitative forecasting techniques which could include: Delphi method, Historical analysis of comparable systems, Priority pattern analysis, Input-Output analysis, and/or Panel consensus.[13] The second measurement standard is completely quantitative and represents activity costs measured in dollars. A greater depth of understanding can be realized through digression to a general discussion of GERT.

In GERT there are two parameters associated with any branch: (1) the probability that a branch is taken, p_a, given that the node from which it emanated is realized; and (2) a time, t_a, required to accomplish the activity which the branch represents.[14] In this thesis the time parameter, t_a, is replaced

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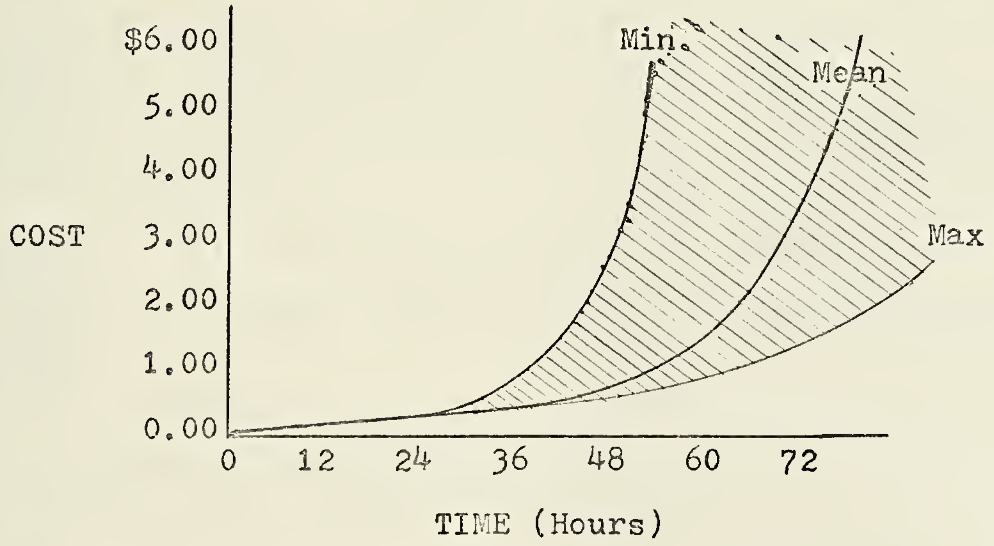
[12] Herbert A. Simon, Models of Man (New York: Wiley-Interscience, Inc., division of John Wiley & Sons, 1957), passim; see also Herbert A. Simon, Administrative Behavior (The Macmillan Company, New York, N.Y., 1956), passim. The distinction between "adaptively" and "omnisciently" rational decision systems is treated in these texts.

[13] John C. Chambers, Satinder K. Mullick, and Donald D. Smith, "How to Choose the Right Forecasting Technique," Harvard Business Review (July-August, 1972).

[14] A.A.B. Pritsker, GERT: Graphical Evaluation And Review Technique (National Aeronautics and Space Administration, Rand Corporation, Santa Monica, California, 1966), p. 5.

with a cost parameter, c_a. This cost parameter varies with time in accordance with Figure 5-1 shown below. Time and cost are analogous, therefore, but this conversion increases the model's flexibility. The costs of independent activities can now be introduced as step functions anywhere within the decision network. Probabilistic data can be evaluated directly as it relates to overall system profitability. Hence, an action taken by a Maine fisherman as a result of traditionalism, habit, personal preferences, peer pressures, economic factors, etc., can be evaluated in terms of its incremental cost or benefit (profit) to the entire system. Figure 5-1 is derived from the assumption that any decrease in wholesale value of the roe due to freshness loss over time, can be treated as an increase in costs seen by the system that supplies the roe.

Cost/Time Relationship for Fresh Processed Roe



Source: Adapted from information supplied in Reggie Bouchard, Potential Markets for Maine Seafoods in Japan (Maine Department Sea & Shore Fisheries, n.d.), and from personal interview with Mr. W. Watson Taylor, Japan Airlines, Boston Office, 9 July 1973.

Figure 5-1

Air Cargo Rates For All International Carriers		
Type	Weight	Rate
General Cargo	100 lbs or less	$2.15 per pound
	100 - 220	$1.60 per pound
	221 - 440	$1.51 per pound
	441 - 660	$1.35 per pound
	661 - 880	$1.24 per pound
	881 -1100	$1.10 per pound
	1100 lbs or more	$0.97 per pound
Type 3 Pallet (125"x88" x86")	2300 Kilos or less	$3780
	2301 Kilos and up	$ 164/100 Kilos
Type 4 Pallet (108"x88" x86")	1900 Kilos or less	$3145
	1901 Kilos and up	$ 164/100 Kilos
Type 5 Pallet (125"x88" x64"	1900 Kilos or less	$3145
	1901 Kilos and up	$ 164/100 Kilos
Type 8 or 9 Pallet (62"x92" x64")	900 Kilos or less	$1595
	901 Kilos and up	$ 177/100 Kilos
Insurance Rate: 30¢ per $100 valuation		

Table 5-1

Source: Pan American Airlines, Cargo Information, Boston, Massachusetts.

Domestic Transport Costs, Wage Rates, and Other Expenses		
Item	Specific Description	Rate
Common Carrier	Truck from Pick-up Point to the Fulton Fish Market in New York	$0.04 per pound
Common Carrier	Truck from Portland to the Fulton Fish Market in New York	$0.03 per pound
Common Carrier	Delta Airlines flights from Portland or Bangor to Kennedy	$0.06 per pound
Handling Fees	Fulton Fish Market extra handling charge	$0.25 per package
Driver Rate	Private Vehicle Operator	$2.50 per hour
Crackers	Person who cracks open the shell	$2.20 per hour
Cleaners	People who separate roe from the shell and other internals	$2.20 per hour
Graders	People who separate roe by grade	$2.20 per hour
Packers	People who soak roe and package the final product	$2.20 per hour
Cedar Boxes	Boxes required for Japan's market	$0.20 a piece

Table 5-2

International Transport Flight Schedules				
Carrier	Flt. No.	Dep.	Arr.	Frequency
J A L	041	0400	0845	Wednesday, Friday, and Sunday
J A L	031	0540	1445	Tuesday, Thursday, and Saturday
T W A		0055		Wednesday and Friday
T W A		1415		Wednesday, Thursday, and Saturday
Pan Am	Same Flight Schedule as TWA.			

All three also offer service on passenger flights but these flights are subject to seasonal rescheduling, etc.

Table 5-3

Step two: Modeling the System

Each of the five subsystems are modeled separately. Each subsystem alternative is considered independently. The GERT structure remains unchanged for each of the alternatives because the activities and their relations to each other do not change. What does change, however, is the parametric value for each of the network branches. That is, the costs and probabilities associated with each activity change as attention shifts from one alternative in a subsystem, to the next. For this reason, GERT networks are structured for each subsystem, and each subsystem activity is labeled W_{ab}, where W represents the "transmittance" or cost and probability parameters for each activity, and ab represents the node from which the activity emanates and to which the activity leads respectively.

Harvesting Subsystem. Figure 5-2 depicts harvesting activities and their relationships.

HARVESTING

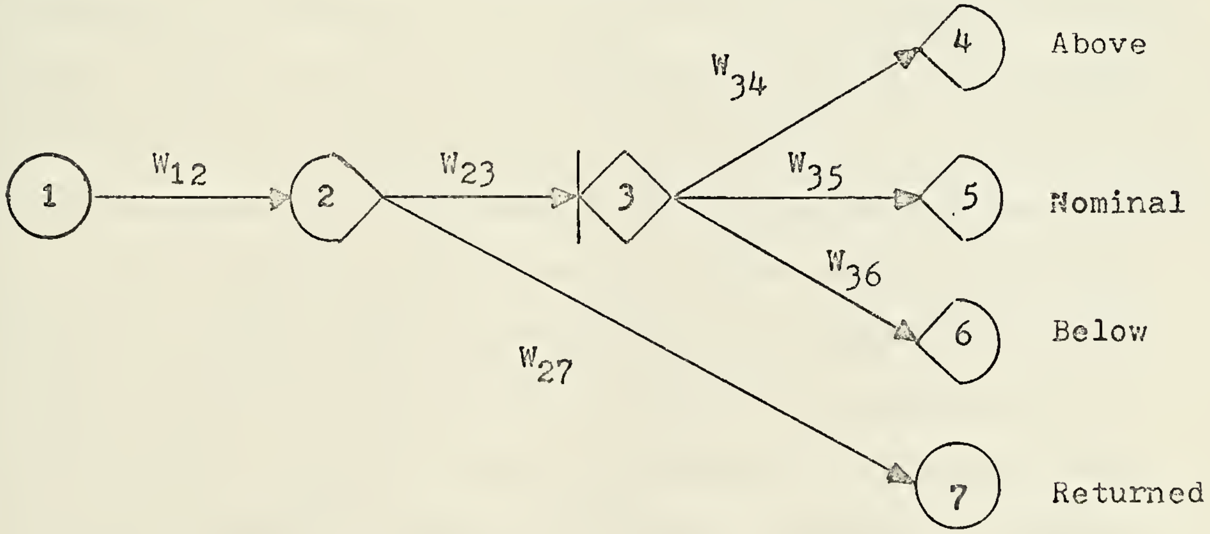


Figure 5-2

W_{12} is the transmittance representing the costs associated with the particular alternative or mix of alternatives used in harvesting the sea urchins. The costs associated with a one man skiff operation are quite different from those associated with a 70 to 90 foot vessel outfitted with a purse seiner rig. The parametric value of W_{12}, therefore, is calculated from the total operating costs of all the various vessels that might be involved over the five year planning horizon. Obviously, actual operating data should be used that is gathered from actual experience with the harvesting operation to revise the values assigned to W_{12}.

The probability associated with W_{12} is always 1. It is assumed that the harvesting operation must be undertaken before any costs are incurred in the rest of the system. Overhead is not a consideration in this case because the sea urchin venture is being evaluated as a potential method for utilizing seasonally underutilized capital and equipment. Since the overhead expenses of the various firms involved would be incurred, regardless of whether or not the sea urchin venture was undertaken, these costs are not considered as long as they remain less than those that would normally be experienced. Any costs above the norm, however, would have to be treated as overhead expenses.

W_{23} represents the percentage of sea urchins that are brought to shore while W_{27} represents the percentage of sea urchins that are returned for one reason or another (i.e. undersized). W_{34}, W_{35}, and W_{36} represent daily yields which are above expected, nominal, and below expected or normal amounts, where nominal refers to the mean or average amount.

<u>Processing Subsystem</u>. Figure 5-3 represents the transshipment network which relates the various costs incurred by the processor in picking up the bulk sea urchins at the various drop points along the Maine coast and in delivering them to the processing plant. $W_{48'}$, W_{58}, and $W_{68''}$ represent the costs associated with transshipping yields which are above expected or normal, nominal, or below expected or normal amounts, respectively.

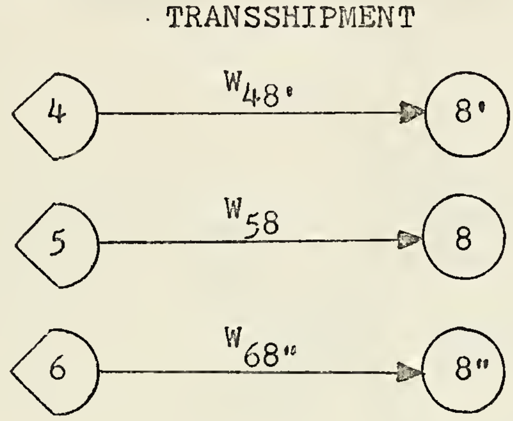


Figure 5-3

Figure 5-4 shows the decision alternatives which the processor faces at plant delivery.

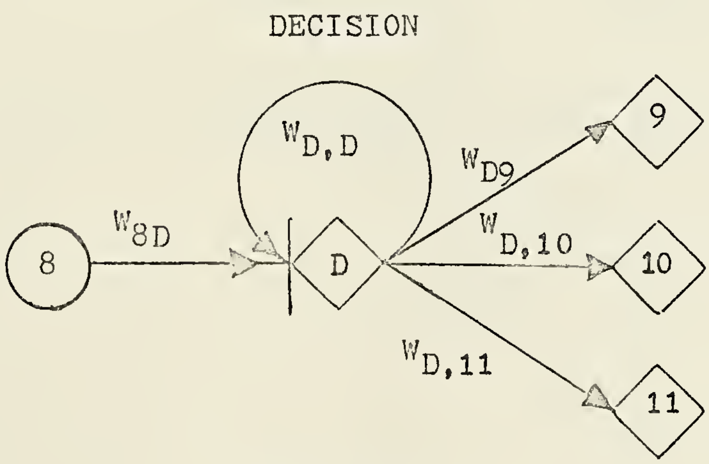


Figure 5-4

Figure 5-4 is a highly simplistic decision model wherein $W_{D,D}$ represents the decision to hold one day's catch of sea urchins over for the next day, assuming that facilities are available for keeping the urchins alive for that period. W_{D9}, $W_{D,10}$, and $W_{D,11}$ represent the decisions to package the sea urchins in bulk, to process the urchins, or to discard the urchins, respectively. In actuality, however, the relationships between alternatives are quite complex as shown in Figure 5-5.

PROCESSOR DECISION MODEL

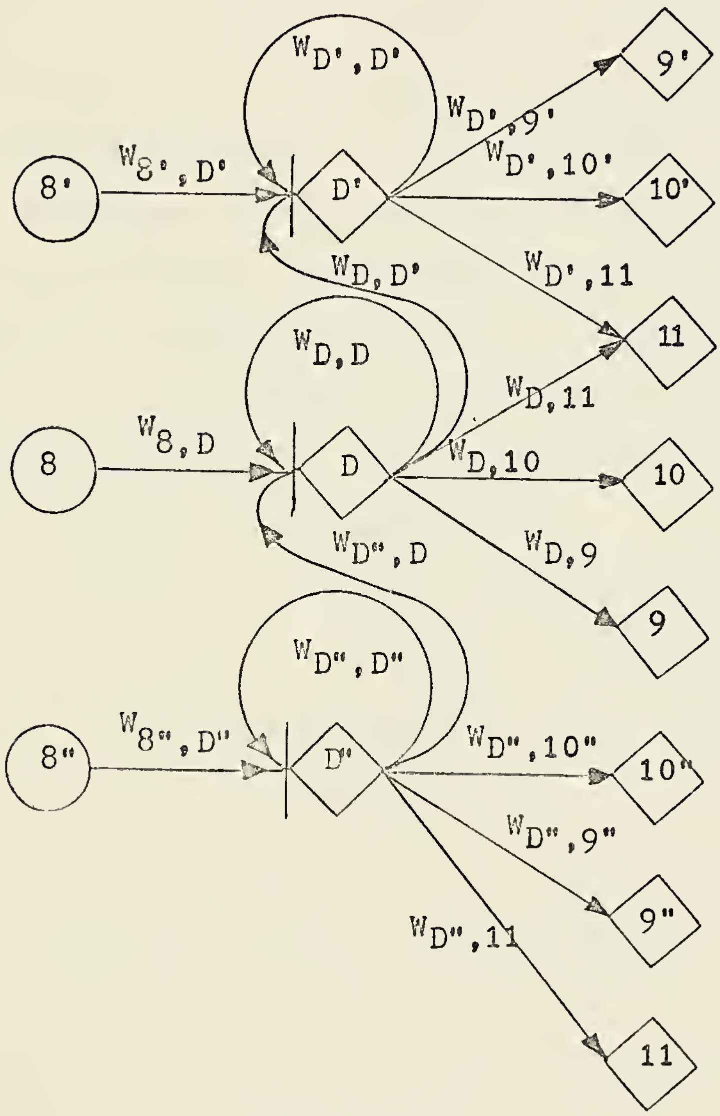


Figure 5-5

The transmittances for Figure 5-5 are as follows: All single prime superscripts refer to decisions made with respect to a daily yield that is above the normal or expected amount. All transmittances without superscripts represent decisions made with respect to the normal or nominal daily yield. All double prime superscripts refer to decisions made with respect to a daily yield that is below the normal or expected amount. The decision to hold in the nominal or below expected yield categories produces two possible results. Either the quantity of urchins held over does not sufficiently augment the next day's yield to enable the processor to take advantage of any economies of scale that exist in the next higher processing and shipping category, or the hold over decision does boost the supply over the necessary "break point" to enable the processor to take advantage of economies of scale. Transmittances $W_{D',D'}$, $W_{D,D'}$ and $W_{D'',D''}$ are examples of the former while $W_{D,D'}$, and $W_{D'',D'}$ represent the latter. All other transmittances are the same as those described for Figure 5-4.

Figure 5-7 shows the packing in bulk alternative for the nominal case. The network is the same for the above and below nominal cases. Only the transmittance values change.

PACKING

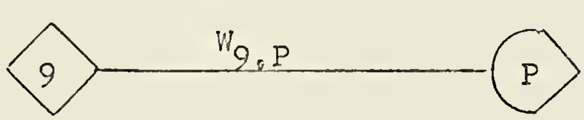


Figure 5-7

Figure 5-8 depicts the processing alternative. Once again only the nominal category is considered. Both the above expected and below expected yield categories are the same. Transmittance values constitute the only differences.

PROCESSING

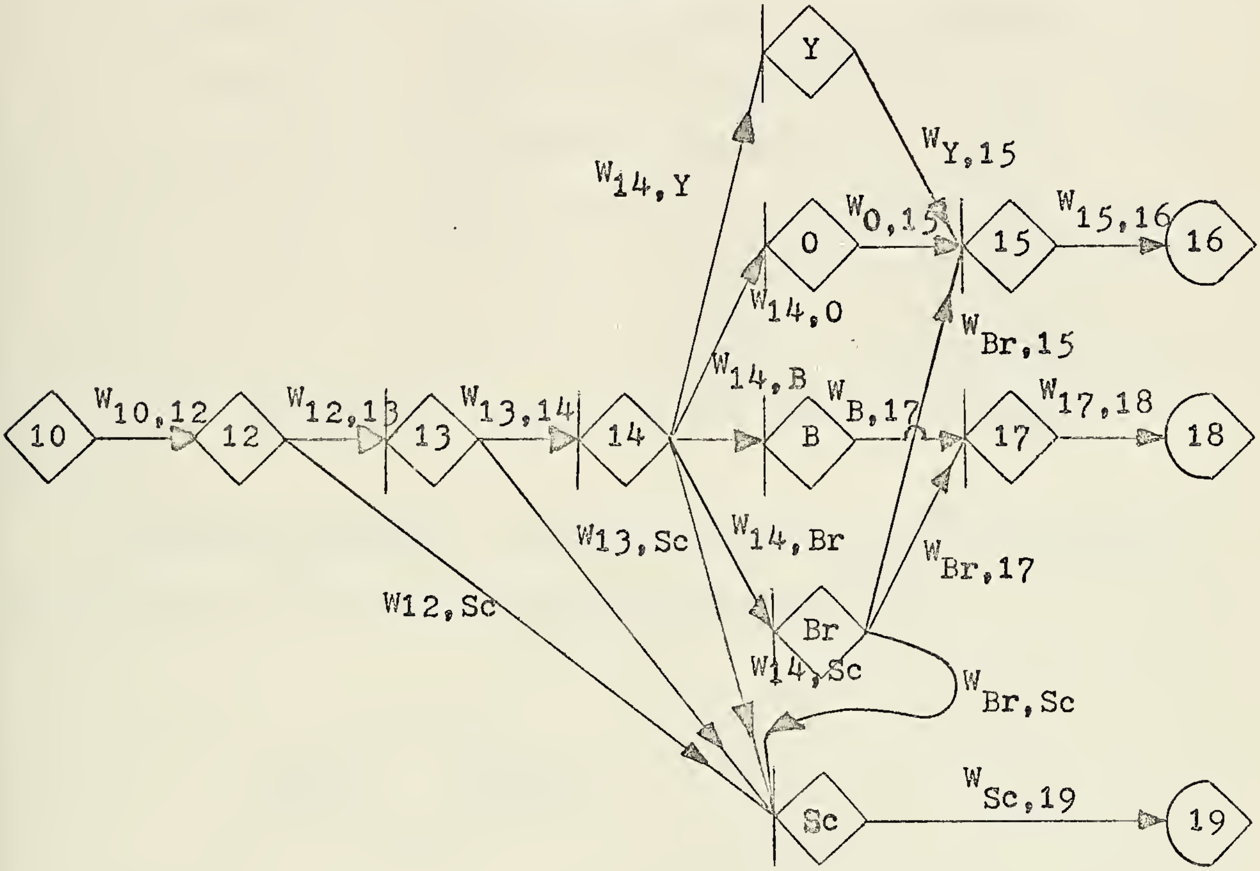


Figure 5-8

Transmittances represent the following activities:

$W_{10,12}$ represents cracking the shell. $W_{12,13}$ represents extracting the roe, washing it in sea water of same or comparable salinity, and placing the roe in an alum solution for a minimum of 20 minutes. $W_{12,Sc}$ represents the spines, shell, and other body parts that make up the sea urchin. $W_{13,14}$ represents the finished product after soaking while $W_{13,Sc}$ accounts for any

roe that was damaged during the extraction or soaking phase of the processing operation. $W_{14,Y}$, $W_{14,O}$, $W_{14,B}$, $W_{14,Br}$, and $W_{14,Sc}$ represent the grading operation where Y is Yellow or highest quality, O is Orange or pink and of average quality, B is broken roe, and Br is Brown and of poor quality, and Sc is scrap, respectively. $W_{Y,15}$, $W_{O,15}$, and $W_{Br,15}$ represent roe that is packed into wooden trays for shipment to Japan. $W_{B,17}$ and $W_{Br,17}$ represent roe that is intended for domestic shipment for use in other foodstuffs, fertilizers, etc. $W_{15,16}$ is the packing or wooden trays into nests and nests into insulated boxes. $W_{17,18}$, is the packing of jumbled roe into appropriate containers. $W_{Sc,19}$ is the disposal of waste material.

Domestic Transport. Figure 5-9 shows domestic transport alternatives and possible consequences for each.

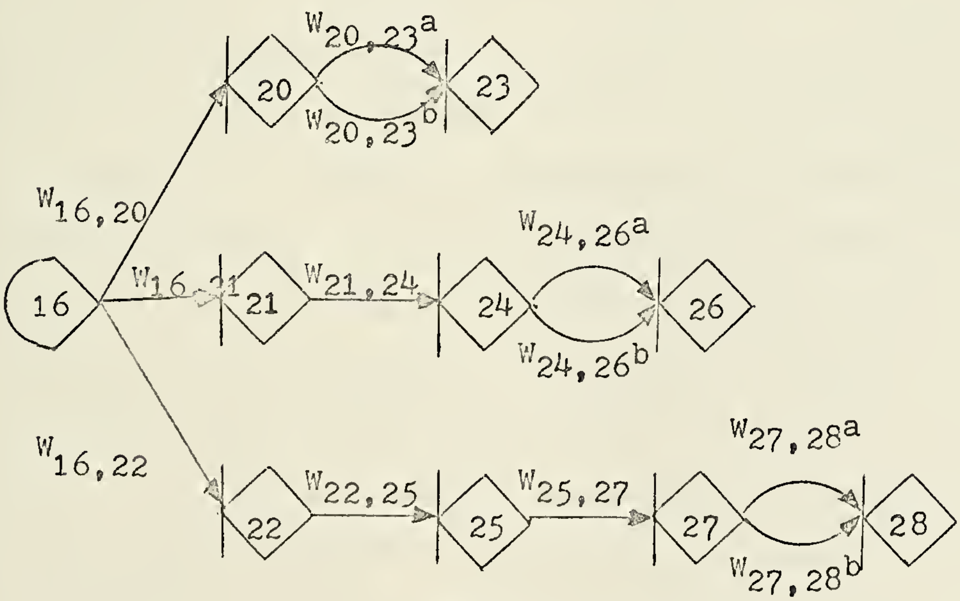
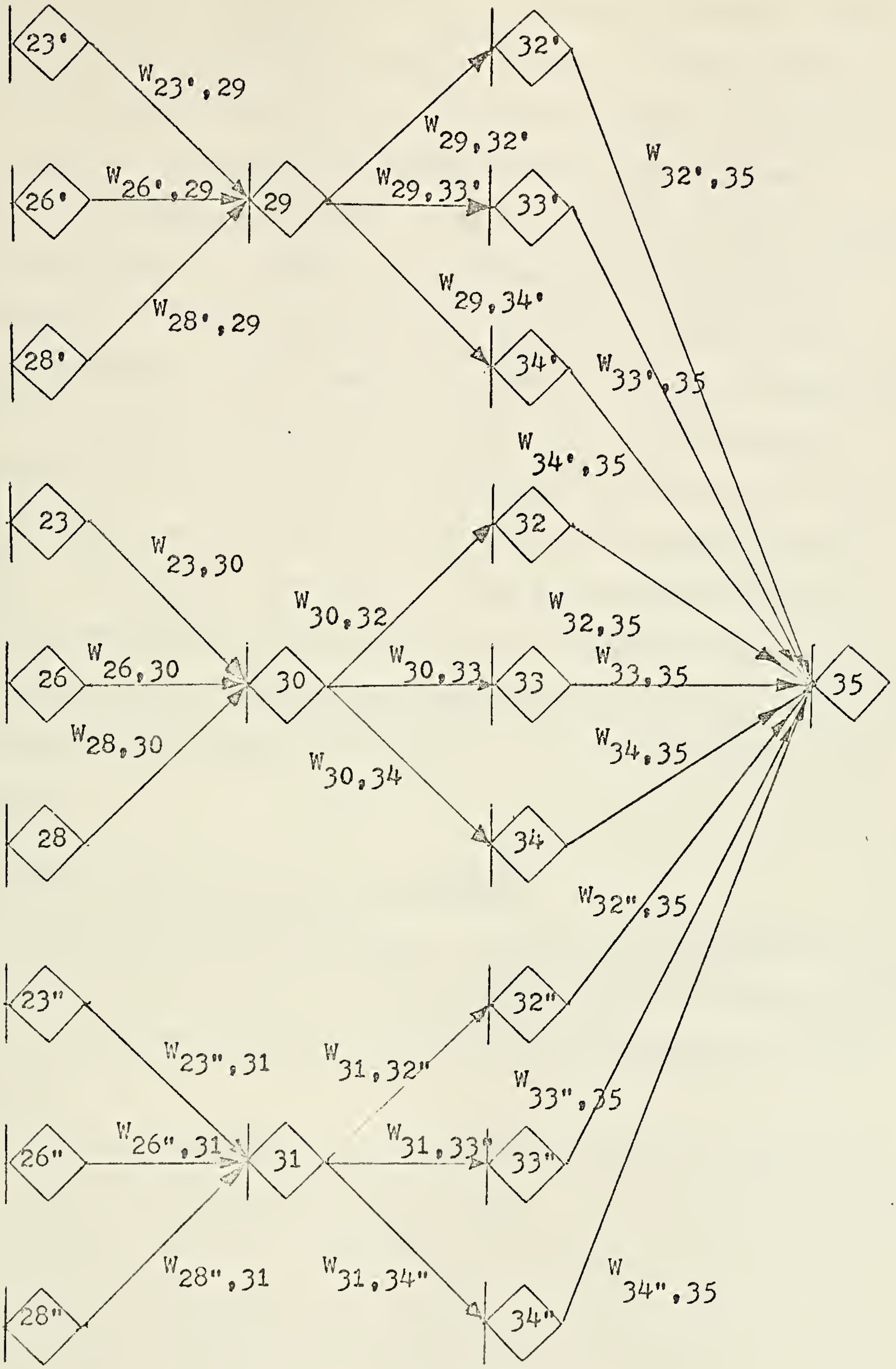


Figure 5-9

Transmittances for Figure 5-9 are as follows: $W_{16,20}$, $W_{16,21}$, and $W_{16,22}$ represent the processor using his own vehicle or vehicles for shipping the fresh roe to Kennedy International Airport in New York, to Portland Airport in Maine, or to a trucking pick-up point or points in Maine which are located near the processing facility or facilities processing the sea urchin roe. $W_{21,24}$ represents Delta Airline flights from Portland to Kennedy International Airport in New York. $W_{22,25}$ and $W_{25,27}$ represent truck shipment from the pick-up point to Fulton Fish Market in New York and transshipment to Kennedy Airport, respectively. Fulton Fish Market serves as a collection point for all commercial carriers trucking fish produce into the New York City area.

$W_{20,23a}$, $W_{20,23b}$, $W_{24,26a}$, $W_{24,26b}$, $W_{27,28a}$, and $W_{27,28b}$ represent the various arrival conditions for each of the domestic shipment alternatives. The "a" and "b" differentiate cargo into the categories of that which arrives undamaged and that which arrives damaged or impaired in quality in some manner during domestic transport handling and/or transporting operations.

Figure 5-10 shows the international transport alternatives that could occur. Unlike the preceding figures, Figure 5-10 depicts the above expected and below expected yield alternatives in addition to the nominal alternative. Because the network structure remains the same for each of the three alternatives, only the nominal alternative is considered in explaining transmittance meanings. Transmittances for the nominal alternative of Figure 5-10 are as follows: $W_{23,30}$, $W_{26,10}$, and $W_{28,30}$ represent freshness losses associated with each transport


23'
W23',29
26'
W26',29
28'
W28',29
29
W29,32'
W29,33'
W29,34'
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31
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W31,34"
32"
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W33",35
W34",35

Figure 5-10

method. $W_{30,32}$, $W_{30,33}$, and $W_{30,34}$ represent higher, nominal, and lower rate levels that might be charged by the airline in accordance with the weight of the shipment that is received.

The last stage of the system, the marketing stage cannot be considered further in this analysis, either domestically or foreign, due to a lack of quantitative and qualitative information. For purposes of this analysis, transmittance $W_{16,20}$ in Figure 5-9 is used to represent the costs associated with the shipment of the fresh roe to the domestic market. It should be noted that these projected costs overstate the actual costs that would be incurred in the processing subsystem. Packaging costs could be reduced significantly for domestic shipments of sea urchin roe. The wooden trays that are required for the Japanese markets could in all probability be replaced with plastic trays, etc. at a considerable cost savings.

Step Three: Utilizing GERT Techniques

Assigning Parametric values. Behind every assigned value there is a certain amount of facts and there are some assumptions. Both are enumerated explicitly during the discussion of each parameter.

The first parameter W_{12} represents the costs associated with operating a fleet of mixed vessels. It is anticipated that approximately 50% of the season's catch would be contributed by by one man skiffs producing 7 bushels per day (current range is from 5 to 11 bushels per day per one man skiff) at a price

of from \$4.50 to \$5.50 per bushel. Approximately 40% of the seasonal catch is anticipated to be produced by two man draggers which range from 35 to 40 feet in length and operate at a total cost of from \$150 to \$200 per day. These figures represent the low end of the operating range so it is estimated that a sea urchin harvesting operation would result in a cost of approximately \$6.50 per bushel on a seasonal average. Finally, it is anticipated that 10% of the seasonal catch would be brought in by 70 to 80 foot purse seining vessels which operate with three or four man crews at a total average cost of from \$250 to \$300 dollars a day (again, estimates are in the low range). Because of the high operating costs of the purse seining vessel, it is assumed that it would only be used in conjunction with a suction apparatus when deep areas of ocean bottom are discovered to be densely carpeted with sea urchins. In this case it is assumed that sea urchins could be harvested at about \$4.00 per bushel. Therefore, the estimated seasonal cost of producing sea urchin yields is: $.5x\ \$5 + .4x\ \$6.50 + .1x\ \$4 = \$5.50$ per bushel. However, since this data is based upon low cost estimates the cost per bushel is assumed to be \$6.00.

Since 1 bushel yields approximately 40 sea urchins and 40 sea urchins yield approximately 4 pounds of roe, the cost of harvesting the roe is \$1.50 per pound. This is represented in the GERT network as: $1e^{1.5s}$. The s is a mathematical notation that indicates that the calculations are being conducted in the "s" domain. A probability coefficient of "1" is used because it is assumed that some fishing has to be done for the urchins before any can be harvested. In other words, the urchins will

not mysteriously appear at the processing plant. At least one fisherman must go out after urchins before the rest of the operations which make up the system can be realized.

All other costs in the harvesting subsystem are considered to be zero since the \$1.50 figure was based upon the total cost of the harvesting operation. The probabilities assigned to the remaining harvesting transmittances are based upon a consensus of opinions of individual's who have harvested and/or eaten sea urchins. These probabilities can be, and should be, refined through actual tests that should be undertaken to determine what the percentages are for harvesting the Maine sea urchin, using regional techniques and regional personnel. Thus, the remaining transmittances for the harvesting operation are: $W_{23} = 0.95$, $W_{27} = 0.05$, $W_{34} = 0.10$, $W_{35} = 0.75$, $W_{36} = 0.15$.

In the processing subsystem a 450 pound per day processing level of production is assumed for the first five years of operation. Transshipment costs are based upon a 12¢ per mile rate and a \$2.15 per hour rate for the vehicle driver. Assuming that an above expected yield would be nominally represented by a 650 pound yield and a below expected yield would be nominally represented by a 250 pound yield, $W_{48'} = 162.5$ bu., $W_{58} = 112.5$ bu., and $W_{68''} = 62.5$ bu.

$W_{8',D'}$, $W_{8,D}$, and $W_{8'',D''}$ are represented by: $1e^{0s}$ which merely designates the fact that the decisions which follow are realized when node 8', 8, or 8" are realized. Other decision transmittances are: $W_{D',D'} = 0.01$, $W_{D',9'} = 0.01$, $W_{D',10'} = 0.97$, and $W_{D',11'} = 0.01$; $W_{D,D} = 0.04$, $W_{D,D'} = 0.02$, $W_{D,11} = 0.01$,

$W_{D,10} = 0.90$, $W_{D,9} = 0.03$; $W_{D'',D''} = 0.15$, $W_{D'',D} = 0.45$, $W_{D'',10''} = 0.30$, $W_{D'',9''} = 0.15$, $W_{D'',11} = 0.05$.

Packaging costs, represented by transmittance $W_{9,P}$ are approximately 11¢ per pound of bulk sea urchins. This is based upon a packaging cost figure of $3.75 for bushel (including insulation material, cartons, and handling), and 40 pounds of urchins per bushel.

In the processing operation, $W_{10,12}$ =$0.07 per pound based upon past experience where 1 man cracking open the shell can process 250 pounds of urchins in one 8 hour day. His salary, in accordance with Table 5-2, is assumed to be $2.20 per hour. $W_{12,13} = 0.1\ e^{0.35s}$. The 35¢ cost figure is derived from having five workers process 250 pounds in an eight hour shift at the $2.20 hourly rate. Comparing $W_{12,13}$ with $W_{12,Sc}$ which equals $0.9\ e^{0s}$, the 0.1 probability indicates that only 10% of the bulk urchin is roe, 90% is everything left over. Consequently, the cost of processing the 0.9 scrap is zero.

The costs of the grading operation are based on one worker grading 250 pounds of urchins in two hours. At an hourly rate of $2.20 the cost equals 2¢ per pound. The percentage of grades shown are purely hypothetical. Only data gained through actual tests and operations can be used to refine or replace the figures used.

Transmittances $W_{Y,15}$, $W_{O,15}$, and $W_{Br,15}$ have a cost of 53¢ per pound based on a cost of 20¢ per cedar tray, 250 pounds of roe being packed by one person in four hours at $2.20 per hour, and that 2.5 cedar trays hold one pound of fresh processed roe.

$W_{15,16}$ = 0.01 based on projected packing time of 1½ hours by one man at the $2.20 rate for 250 pounds of processed roe. $W_{17,18}$ = 0, based on a packing time of ½ hour. $W_{B,17}$, $W_{Br,17}$, and $W_{Br,Sc}$ = 3¢ per pound.

For the above and below nominal yield transmittances, the hourly wage rates remain unchanged, the size of the work groups remains the same, and the sequence of operations remains the same. The only change assumed is that an above nominal yield operation would result in a 285 pounds per hour basis as opposed to the 250 pound figure used in the nominal operation, and a 200 pound per hour basis would best represent the below nominal level. Utilizing these figures, the following transmittances are derived: $W_{10',12'} = 1\ e^{.06s}$, $W_{12',13'} = 0.1\ e^{.31s}$, $W_{13',14'} = 0.95\ e^{.01s}$, $W_{13',Sc'} = 0.05\ e^{.01s}$, $W_{Y',15'}$, $W_{O',15'}$, and $W_{Br',15'}$ retain their costs of 53¢ per pound, $W_{15',16'}$ = \$0.01, $W_{17',18'}$ remains zero, and $W_{B',17'}$, $W_{Br',17'}$, and $W_{Br',Sc'}$ = 3¢ per pound. Continuing, for the below nominal yield, the costs incurred would be: $W_{10'',12''} = 1\ e^{.09s}$, $W_{12'',13''} = 0.1\ e^{.44s}$, $W_{13'',14''} = 0.95\ e^{.02s}$, $W_{13'',Sc''} = 0.05\ e^{.01s}$; $W_{Y'',15''}$, $W_{O'',15''}$, and $W_{Br'',15''}$ become 54¢ per pound, $W_{15'',16''}$ = \$0.01, $W_{17'',18''}$ remains zero, and $W_{B'',17''}$, $W_{Br'',17''}$, and $W_{Br'',Sc''}$ = 4¢ per pound.

In the Domestic Transport subsystem, anticipating a 600 mile round trip and 16 hours of driving time, $W_{16,20} = 0.9\ e^{.25}$. $W_{16,21} = 0.08\ e^{.02s}$ and $W_{16,22} = 0.02\ e^{.00s}$. These values were calculated as follows: $W_{16,20}$ = 600 mi. x 12¢ per mi. + 16 hr. x 2.50 per hour = \$112 for 450 pounds of roe, or 24.8888¢/pound.

For $W_{16,21}$, 40 mi. (to Portland) x 12¢ per mi. + $2.50 per hour x 2 hr. = $9.80 for a 450 pound shipment or, 2.1777¢ per pound. For $W_{16,22}$, 5 mi. (to drop Point) x 12¢ per mi. = $2.50 per hour x 0.25 hr. = 0.27222¢ per pound.

For above and below nominal yields the rates remain the same with only the total shipping weight changing to 650 pounds for above nominal and 250 pounds for below nominal. The resultant transmittances are: $W_{16',20'}$ = 0.172318, $W_{16',21'}$ = 0.015077, and $W_{16',22'}$ = 0; $W_{16'',20''}$ = 0.448, $W_{16'',21''}$ = 0.0392, and $W_{16'',22''}$ = 0.0049.

$W_{21,24}$, $W_{21',24'}$, and $W_{21'',24''}$ carry the same transmittance values since the airlines charges on a per pound basis. It should be noted that the shipping weight has been increased by a factor of 1.5 in the calculations which follow for all airlines involved and for domestic trucking commercial carriers. This is because each package of sea urchin roe weighs 60 pounds of which 24 pounds is roe and 36 pounds is packaging. Each cedar tray weighs approximately 1.6 oz and these trays are stacked 10 high and the top tray is covered with a dry cedar top. The total weight of these 10 high stacks or nests is approximately 18.5 oz. without roe and 82.5 oz with the roe, or the weight of roe per 10 trays is 4 pounds. The ten tray nests are then packaged in groups of 6 or 8 into insulated boxes. This increased shipping weight due to packaging produces the following per pound calculations: At Delta's rate of 6¢ per pound, a nominal yield of roe would weigh 450 x (36/24 = 1.5) = 675 pounds. Above nominal would weigh 975, and below 375. Therefore, the transport cost would be: 975 x .06/650 = 9¢ per pound in

the above, nominal and below nominal cases. Similarly, trucking costs for transmittance $W_{22,25}$ are calculated as: 675 x .04/ 450 = 6¢ per pound. This applies for all three cases. $W_{25,27}$ entails shipment from Fulton Fish Market where a 25¢ to 30¢ per package handling cost is incurred, to Kennedy International Airport. Because various alternatives are available for the transhipment, the total cost involved is assumed to be approximately 3¢ per pound.

In the "a" differentiated transmittances the values reflect the percentage of roe shipments which arrive at the airport unharmed with a cost incurred due to freshness loss during transit time. Once again, these freshness loss costs are merely estimates that should be refined or replaced with actual test data. The "b" differentiated transmittances represent the values which reflect the percentage of roe shipments which arrive at the airport damaged or impaired in quality. The cost figures associated with this branch, therefore, account for the freshness loss incurred during transit, plus the value loss in product due to quality decrease. The transmittance values are as follows: $W_{20,23}a = 0.95\ e^{.10s}$, $W_{20,23}b = 0.05\ e^{.65s}$, $W_{24,26}a = 0.65\ e^{.04s}$, $W_{24,26}b = 0.35\ e^{.5s}$ (note that it is assumed that the airline route will be used only when seasonal schedules changes permit an easy transfer of cargo from domestic to international carrier with lay-over not to exceed 6 hours. One reason for the low probability associated with taking this particular shipment branch is the fact that this "ideal" state does not occur very often). These values do not change for above nominal, nominal, and below nominal cases.

$W_{27,28}a = 0.75\ e^{.25s}$ (the 25¢ cost due to freshness loss in this case is due to a 12 hour lay-over encountered in the Fulton Fish Market). $W_{27,28}b = 0.25\ e^{.65s}$.

In the International Transport subsystem, transmittance values are based upon (1) a flight time of 19 hours with a 1½ hour delay period tagged on each end, (2) the flight rates depicted in Table 5-1, or (3) a freshness loss incurred in the Tokyo Wholesale Market due to an 18 to 24 hour operating delay. The transmittances, therefore, are as follows: $W_{23',29} = 1\ e^{.3s}$, $W_{26',29} = 1\ e^{.25s}$, $W_{28',29} = 1\ e^{.4s}$. The values for the nominal, and below nominal cases are the same.

$W_{29,32'} = 0.2\ e^{1.65s}$ (Calculation of $1.65 figure: Shipping approximately 700 pounds of processed roe results in a total package weight of 700 x 1.5 = 1050 pounds. This puts the shipment in the $1.10 per pound rate bracket. Therefore, 1050 x $1.10 = $1155 for 700 pounds of roe, or $1155/700 lbs = $1.65 per pound), $W_{29,33'} = 0.6\ e^{1.65}$, $W_{29,34'} = 0.2\ e^{1.86}$, $W_{30,32} = 0.1\ e^{1.86}$, $W_{30,33} = 0.8\ e^{1.86}$, $W_{30,34} = 0.1\ e^{2.02}$, $W_{31,32''} = 0.2\ e^{2.03}$, $W_{31,33''} = 0.7\ e^{2.26}$, $W_{31,34''} = 0.1\ e^{2.37}$.

Because so little information is available with respect to the Japanese market and since the information that is available suggests that there is a 24 hour delay in the normal operating procedures of this market, reference is made to Figure 5-1 and an arbitrary value is chosen. Assuming that the mean time spent in transit from Maine to Tokyo is 30 hours for the average time in transit for the sum of the three domestic transport methods, adding 24 hours brings the total to 54 hours. The Mean of Figure 5-1 assigns a freshness loss of approximately

$1.00 to this time interval. Since the method used thus far has represented an ad valorem increase in costs for each stage, the amounts already allocated to freshness losses in the domestic transport subsystem must be subtracted from the $1.00 amount. The 30 hour cost is approximately 40¢ according to Figure 5-1. Therefore, the ad valorem cost is $1.00 - $0.40 = $0.60. Thus the value for all remaining transmittances is $1\ e^{.6s}$.

<u>Problem Solution</u>. A very handy tool used by the electrical engineer and subsequently used quite frequently in GERT analyses, is presented at this point. This tool is called Mason's Reduction. It is not necessary to understand why Mason's Reduction works. It is only necessary to accept the fact that it does and to understand how it is used.

Basically, Mason's Reduction states that if L_i are the transmittances of the i loops (closed paths) in the system and G_j are the transmittances of the j paths (open paths) in the system which connect the two nodes (i.e. input and output) whose relationship is to be found, then the graph determinant is defined as:

$$\Delta = \left[1 - \sum L_i + \sum L_i L_j - \sum L_i L_j L_k + \ldots\right]$$

Where $\sum L_i$ = sum of all loop transmittances

$\sum L_i L_j$ = sum of products of transmittances of all pairs of NON-TOUCHING loops

$\sum L_i L_j L_k$ = sum of products of all triplets of NON-TOUCHING loops

Further, a path factor Δ_j (cofactor), is defined as the graph determinant in which the transmittance of any loop

touching path G_j is made equal to zero. Therefore,[15]

$$\frac{\text{Output}}{\text{Input}} = \frac{G_j \Delta_j}{\Delta} \qquad \frac{\text{path x path factor}}{\text{graph determinant}}$$

Identifying Loops:

$L_1 = W_{D',D'}$

$L_2 = W_{D,D}$

$L_3 = W_{D'',D''}$

Calculating the Graph Determinant:

$\sum L_i = L_1+L_2+L_3 = 0.01e^{0s}+0.04e^{0s}+0.15e^{0s} = 0.2e^{0s}$

$\sum L_i L_j = L_1L_2+L_1L_3+L_2L_3 = (0.01)(0.04)+(0.01)(0.15)+(0.04)(0.15)$

$= 0.0004+0.0015+0.006 = 0.0079e^{0s}$

$\sum L_i L_j L_k = L_1L_2L_3 = (0.01)(0.04)(0.15) = 0.00006e^{0s}$

$\Delta = 1-0.2+0.0079-0.00006$

$\Delta = \boxed{0.80784}$

Categorizing Transmittances:

Transmittance	Path	G_j
$W_{1D'}$	1-2-3-4-8'-D'	$(1e^{1.5s})(0.95)(0.1)(1e^{0s})$
W_{1D}	1-2-3-5-8-D	$(1e^{1.5s})(0.95)(0.75)(1e^{0s})$
$W_{1D''}$	1-2-3-6-8"-D"	$(1e^{1.5s})(0.95)(0.15)(1e^{0s})$
$W_{D'D'}$	D'-D'	$0.01e^{0s}$
$W_{D''D''}$	D"-D"	$0.15e^{0s}$
W_{DD}	D-D	$0.04e^{0s}$
$W_{DD'}$	D-D'	$0.02e^{0s}$
$W_{D''D}$	D"-D	$0.45e^{0s}$
$W_{D'Y'}$	D'-10'-12'-13'-14'-Y'	$(0.97)(1e^{.06s})(0.1e^{.31s})(0.95e^{.01s})$ $x(0.2e^{0s})$

$W_{D'O'}$	D'-10'-12'-13'-14'-O'	$(0.97)(1e^{.06s})(0.1e^{.31s})(0.95e^{.01s}) \times (0.28e^{0s})$
$W_{D'Br'}$	D'-10'-12'-13'-14'-Br'	$(0.97)(1e^{.06s})(0.1e^{.31s})(0.95e^{.01s}) \times (0.16e^{0s})$
W_{DY}	D-10-12-13-14-Y	$(0.90)(1e^{.07s})(0.1e^{.35s})(0.95e^{.01s}) \times (0.2e^{0s})$
W_{DO}	D-10-12-13-14-O	$(0.90)(1e^{.07s})(0.1e^{.35s})(0.95e^{.01s}) \times (0.28e^{0s})$
W_{DBr}	D-10-12-13-14-Br	$(0.90)(1e^{.07s})(0.1e^{.35s})(0.95e^{.01s}) \times (0.16e^{0s})$
$W_{D''Y''}$	D"-10"-12"-13"-14"-Y"	$(0.30)(1e^{.09s})(0.1e^{.44s})(0.95e^{.02s}) \times (0.2e^{0s})$
$W_{D''O''}$	D"-10"-12"-13"-14"-O"	$(0.30)(1e^{.09s})(0.1e^{.44s})(0.95e^{.02s}) \times (0.28e^{0s})$
$W_{D''Br''}$	D"-10"-12"-13"-14"-Br"	$(0.30)(1e^{.09s})(0.1e^{.44s})(0.95e^{.02s}) \times (0.16e^{0s})$
$W_{Y'16'}$	Y'-15'-16'	$(1e^{.53s})(1e^{.01s})$
$W_{O'16'}$	O'-15'-16'	$(1e^{.53s})(1e^{.01s})$
$W_{Br'16'}$	Br'-15'-16'	$(1e^{.53s})(1e^{.01s})$
W_{Y16}	Y-15-16	$(1e^{.53s})(1e^{.01s})$
W_{O16}	O-15-16	$(1e^{.53s})(1e^{.01s})$
W_{Br16}	Br-15-16	$(1e^{.53s})(1e^{.01s})$
$W_{Y''16''}$	Y"-15"-16"	$(1e^{.54s})(1e^{.01s})$
$W_{O''16''}$	O"-15"-16"	$(1e^{.54s})(1e^{.01s})$
$W_{Br''16''}$	Br"-15"-16"	$(1e^{.54s})(1e^{.01s})$
$W_{16'23a'}$	16'-20'-23a'	$(0.9e^{.17s})(0.95e^{.1s})$
$W_{16'23b'}$	16'-20'-23b'	$(0.9e^{.17s})(0.05e^{.65s})$
$W_{16'26a'}$	16'-21'-24'-26a'	$(0.08e^{.01s})(0.65e^{.04s})$
$W_{16'26b'}$	16'-21'-24'-26b'	$(0.08e^{.01s})(0.35e^{.5s})$
$W_{16'28a'}$	16'-22'-25'-27'-28a'	$(0.02e^{0s})(1e^{.06s})(1e^{.03s})(0.75e^{.25s})$
$W_{16'28b'}$	16'-22'-25'-27'-28b'	$(0.02e^{0s})(1e^{.06s})(1e^{.03s})(0.25e^{.65s})$
$W_{16,23a}$	16-20-23a	$(0.9e^{.17s})(0.95e^{.1s})$
$W_{16,23b}$	16-20-23b	$(0.9e^{.17s})(0.05e^{.65s})$
$W_{16,26a}$	16-21-24-26a	$(0.08e^{.02s})(0.65e^{.04s})$
$W_{16,26b}$	16-21-24-26b	$(0.08e^{.02s})(0.35e^{.5s})$
$W_{16,28a}$	16-22-25-27-28a	$(0.02e^{0s})(1e^{.06s})(1e^{.03s})(0.75e^{.25s})$
$W_{16,28b}$	16-22-25-27-28b	$(0.02e^{0s})(1e^{.06s})(1e^{.03s})(0.25e^{.65s})$

$W_{16''23a''}$	16"-20"-23a"	$(0.9e^{.45s})(0.95e^{.1s})$
$W_{16''23b''}$	16"-20"-23b"	$(0.9e^{.45s})(0.05e^{.65s})$
$W_{16''26a''}$	16"-21"-24"-26a"	$(0.08e^{.04s})(0.65e^{.04s})$
$W_{16''26b''}$	16"-21"-24"-26b"	$(0.08e^{.04s})(0.35e^{.5s})$
$W_{16''28a''}$	16"-22"-25"-27"-28a"	$(0.02e^{0s})(1e^{.03s})(0.75e^{.25s})$
$W_{16''28b''}$	16"-22"-25"-27"-28b"	$(0.02e^{0s})(1e^{.03s})(0.25e^{.65s})$
$W_{23a'32'}$	23a'-29-32'	$(1e^{.3s})(0.2e^{1.65s})$
$W_{23b'32'}$	23b'-29-32'	$(1e^{.3s})(0.2e^{1.65s})$
$W_{23a'33'}$	23a'-29-33'	$(1e^{.3s})(0.6e^{1.65s})$
$W_{23b'33'}$	23b'-29-33'	$(1e^{.3s})(0.6e^{1.65s})$
$W_{23a'34'}$	23a'-29-34'	$(1e^{.3s})(0.2e^{1.86s})$
$W_{23b'34'}$	23a'-29-34'	$(1e^{.3s})(0.2e^{1.86s})$
$W_{26a'32'}$	26a'-29-32'	$(1e^{.25s})(0.2e^{1.65s})$
$W_{26b'32'}$	26b'-29-32'	$(1e^{.25s})(0.2e^{1.65s})$
$W_{26a'33'}$	26a'-29-33'	$(1e^{.25s})(0.6e^{1.65s})$
$W_{26b'33'}$	26b'-29-33'	$(1e^{.25s})(0.6e^{1.65s})$
$W_{26a'34'}$	26a'-29-34'	$(1e^{.25s})(0.2e^{1.86s})$
$W_{26b'34'}$	26b'-29-34'	$(1e^{.25s})(0.2e^{1.86s})$
$W_{28a'32'}$	28a'-29-32'	$(1e^{.4s})(0.2e^{1.65s})$
$W_{28b'32'}$	28b'-29-32'	$(1e^{.4s})(0.2e^{1.65s})$
$W_{28a'33'}$	28a'-29-33'	$(1e^{.4s})(0.6e^{1.65s})$
$W_{28b'33'}$	28b'-29-33'	$(1e^{.4s})(0.6e^{1.65s})$
$W_{28a'34'}$	28a'-29-34'	$(1e^{.4s})(0.2e^{1.86s})$
$W_{28b'34'}$	28b'-29-34'	$(1e^{.4s})(0.2e^{1.86s})$
W_{23a32}	23a-30-32	$(1e^{.3s})(0.1e^{1.86s})$
W_{23b32}	23b-30-32	$(1e^{.3s})(0.1e^{1.86s})$

W_{23a33}	23a-30-33	$(1e^{.3s})(0.8e^{1.86s})$
W_{23b33}	23b-30-33	$(1e^{.3s})(0.8e^{1.86s})$
W_{23a34}	23a-30-34	$(1e^{.3s})(0.1e^{2.02s})$
W_{23b34}	23b-30-34	$(1e^{.3s})(0.1e^{2.02s})$
W_{26a32}	26a-30-32	$(1e^{.25s})(0.1e^{1.86s})$
W_{26b32}	26b-30-32	$(1e^{.25s})(0.1e^{1.86s})$
W_{26a33}	26a-30-33	$(1e^{.25s})(0.8e^{1.86s})$
W_{26b33}	26b-30-33	$(1e^{.25s})(0.8e^{1.86s})$
W_{26a34}	26a-30-34	$(1e^{.25s})(0.1e^{2.02s})$
W_{26b34}	26b-30-34	$(1e^{.25s})(0.1e^{2.02s})$
W_{28a32}	28a-30-32	$(1e^{.4s})(0.1e^{1.86s})$
W_{28b32}	28b-30-32	$(1e^{.4s})(0.1e^{1.86s})$
W_{28a33}	28a-30-33	$(1e^{.4s})(0.8e^{1.86s})$
W_{28b33}	28b-30-33	$(1e^{.4s})(0.8e^{1.86s})$
W_{28a34}	28a-30-34	$(1e^{.4s})(0.1e^{2.02s})$
W_{28b34}	28b-30-34	$(1e^{.4s})(0.1e^{2.02s})$
$W_{23a"32"}$	23a"-31-32"	$(1e^{.3s})(0.2e^{2.03s})$
$W_{23b"32"}$	23b"-31-32"	$(1e^{.3s})(0.2e^{2.03s})$
$W_{23a"33"}$	23a"-31-33"	$(1e^{.3s})(0.7e^{2.26s})$
$W_{23b"33"}$	23b"-31-33"	$(1e^{.3s})(0.7e^{2.26s})$
$W_{23a"34"}$	23a"-31-34"	$(1e^{.3s})(0.1e^{2.37s})$
$W_{23b"34"}$	23b"-31-34"	$(1e^{.3s})(0.1e^{2.37s})$
$W_{26a"32"}$	26a"-31-32"	$(1e^{.25s})(0.2e^{2.03s})$
$W_{26b"32"}$	26b"-31-32"	$(1e^{.25s})(0.2e^{2.03s})$
$W_{26a"33"}$	26a"-31-33"	$(1e^{.25s})(0.7e^{2.26s})$
$W_{26b"33"}$	26b"-31-33"	$(1e^{.25s})(0.7e^{2.26s})$
$W_{26a"34"}$	26a"-31-34"	$(1e^{.25s})(0.1e^{2.37s})$
$W_{26b"34"}$	26b"-31-34"	$(1e^{.25s})(0.1e^{2.37s})$

$W_{28a''32''}$	28a"-31-32"	$(1e^{.4s})(0.2e^{2.03s})$
$W_{28b''32''}$	28a"-31-32"	$(1e^{.4s})(0.2e^{2.03s})$
$W_{28a''33''}$	28a"-31-33"	$(1e^{.4s})(0.7e^{2.26s})$
$W_{28b''33''}$	28b"-31-33"	$(1e^{.4s})(0.7e^{2.26s})$
$W_{28a''34''}$	28a"-31-34"	$(1e^{.4s})(0.1e^{2.37s})$
$W_{28b''34''}$	28b"-31-34"	$(1e^{.4s})(0.1e^{2.37s})$

The preceding categorizations of transmittances are next used as a shorthand method for enumerating all paths for the over-all system transmittance $W_{1,35}$. The enumeration of paths is as follows:

Path #	Path
P1	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'23a'}W_{23a'32'}W_{32'35'}$
P2	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'23a'}W_{23a'33'}W_{33'35}$
P3	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'23a'}W_{23a'34'}W_{34'35}$
P4	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'23b'}W_{23b'32'}W_{32'35}$
P5	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'23b'}W_{23b'33'}W_{33'35}$
P6	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'23b'}W_{23b'34'}W_{34'35}$
P7	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'26a'}W_{26a'32'}W_{32'35}$
P8	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'26a'}W_{26a'33'}W_{33'35}$
P9	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'26a'}W_{26a'34'}W_{34'35}$
P10	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'26b'}W_{26b'32'}W_{32'35}$
P11	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'26b'}W_{26b'33'}W_{33'35}$
P12	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'26b'}W_{26b'34'}W_{34'35}$
P13	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'28a'}W_{28a'32'}W_{32'35}$
P14	$W_{1D'}W_{D'Y'}W_{Y'16'}W_{16'28a'}W_{28a'33'}W_{33'35}$

P15	${}^{W}1D'\,{}^{W}D'Y'\,{}^{W}Y'16'\,{}^{W}16'28a'\,{}^{W}28a'34'\,{}^{W}34'35$
P16	${}^{W}1D'\,{}^{W}D'Y'\,{}^{W}Y'16'\,{}^{W}16'28b'\,{}^{W}28b'32'\,{}^{W}32'35$
P17	${}^{W}1D'\,{}^{W}D'Y'\,{}^{W}Y'16'\,{}^{W}16'28b'\,{}^{W}28b'33'\,{}^{W}33'35$
P18	${}^{W}1D'\,{}^{W}D'Y'\,{}^{W}Y'16'\,{}^{W}16'28b'\,{}^{W}28b'33'\,{}^{W}33'35$
P19	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'23a'\,{}^{W}23a'32'\,{}^{W}32'35$
P20	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'23a'\,{}^{W}23a'33'\,{}^{W}33'35$
P21	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'23a'\,{}^{W}23a'34'\,{}^{W}34'35$
P22	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'23b'\,{}^{W}23b'32'\,{}^{W}32'35$
P23	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'23b'\,{}^{W}23b'33'\,{}^{W}33'35$
P24	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'23b'\,{}^{W}23b'34'\,{}^{W}34'35$
P25	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'26a'\,{}^{W}26a'32'\,{}^{W}32'35$
P26	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'26a'\,{}^{W}26a'33'\,{}^{W}33'35$
P27	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'26a'\,{}^{W}26a'34'\,{}^{W}34'35$
P28	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'26b'\,{}^{W}26b'32'\,{}^{W}32'35$
P29	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'26b'\,{}^{W}26b'33'\,{}^{W}33'35$
P30	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'26b'\,{}^{W}26b'34'\,{}^{W}34'35$
P31	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'28a'\,{}^{W}28a'32'\,{}^{W}32'35$
P32	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'28a'\,{}^{W}28a'33'\,{}^{W}33'35$
P33	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'28a'\,{}^{W}28a'34'\,{}^{W}34'35$
P34	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'28b'\,{}^{W}28b'32'\,{}^{W}32'35$
P35	${}^{W}1D'\,{}^{W}D'0'\,{}^{W}0'16'\,{}^{W}16'28b'\,{}^{W}28b'33'\,{}^{W}33'35$
P36	${}^{W}1D'\,D'0'\,0'16'\,16'28b'\,28b'34'\,34'35$
P37	${}^{W}1D'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'23a'\,{}^{W}23a'32'\,{}^{W}32'35$
P38	${}^{W}1D'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'23a'\,{}^{W}23a'33'\,{}^{W}33'35$
P39	${}^{W}1D'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'23a'\,{}^{W}23a'34'\,{}^{W}34'35$
P40	${}^{W}1D'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'23b'\,{}^{W}23b'32'\,{}^{W}32'35$
P41	${}^{W}1D'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'23b'\,{}^{W}23b'33'\,{}^{W}33'35$
P42	${}^{W}1D'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'23b'\,{}^{W}23b'34'\,{}^{W}34'35$

P43	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'26a'\ {}^{W}26a'32'\ {}^{W}32'35$
P44	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'26a'\ {}^{W}26a'33'\ {}^{W}33'35$
P45	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'26a'\ {}^{W}26a'34'\ {}^{W}34'35$
P46	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'26b'\ {}^{W}26b'32'\ {}^{W}32'35$
P47	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'26b'\ {}^{W}26b'33'\ {}^{W}33'35$
P48	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'26b'\ {}^{W}26b'34'\ {}^{W}34'35$
P49	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'28a'\ {}^{W}28a'32'\ {}^{W}32'35$
P50	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'28a'\ {}^{W}28a'33'\ {}^{W}33'35$
P51	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'28a'\ {}^{W}28a'34'\ {}^{W}34'35$
P52	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'28b'\ {}^{W}28b'32'\ {}^{W}32'35$
P53	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'28b'\ {}^{W}28b'33'\ {}^{W}33'35$
P54	${}^{W}1D'\ {}^{W}D'Br'\ {}^{W}Br'16'\ {}^{W}16'28b'\ {}^{W}28b'34'\ {}^{W}34'35$
P55	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'23a'\ {}^{W}23a'32'\ {}^{W}32'35$
P56	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'23a'\ {}^{W}23a'33'\ {}^{W}33'35$
P57	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'23a'\ {}^{W}23a'34'\ {}^{W}34'35$
P58	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'23b'\ {}^{W}23b'32'\ {}^{W}32'35$
P59	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'23b'\ {}^{W}23b'33'\ {}^{W}33'35$
P60	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'23b'\ {}^{W}23b'34'\ {}^{W}34'35$
P61	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'26a'\ {}^{W}26a'32'\ {}^{W}32'35$
P62	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'26a'\ {}^{W}26a'33'\ {}^{W}33'35$
P63	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'26a'\ {}^{W}26a'34'\ {}^{W}34'35$
P64	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'26b'\ {}^{W}26b'32'\ {}^{W}32'35$
P65	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'26b'\ {}^{W}26b'33'\ {}^{W}33'35$
P66	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'26b'\ {}^{W}26b'34'\ {}^{W}34'35$
P67	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'28a'\ {}^{W}28a'32'\ {}^{W}32'35$
P68	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'28a'\ {}^{W}28a'33'\ {}^{W}33'35$
P69	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'28a'\ {}^{W}28a'34'\ {}^{W}34'35$
P70	${}^{W}1D\ {}^{W}DD'\ {}^{W}D'Y'\ {}^{W}Y'16'\ {}^{W}16'28b'\ {}^{W}28b'32'\ {}^{W}32'35$

P71	^{W}1D^{W}DD'^{W}D'Y'^{W}Y'16'^{W}16'28b'^{W}28b'33'^{W}33'35
P72	^{W}1D^{W}DD'^{W}D'Y'^{W}Y'16'^{W}16'28b'^{W}28b'34'^{W}34'35
P73	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'23a'^{W}23a'32'^{W}32'35
P74	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'23a'^{W}23a'33'^{W}33'35
P75	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'23a'^{W}23a'34'^{W}34'35
P76	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'23b'^{W}23b'32'^{W}32'35
P77	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'23b'^{W}23b'33'^{W}33'35
P78	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'23b'^{W}23b'34'^{W}34'35
P79	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'26a'^{W}26a'32'^{W}32'35
P80	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'26a'^{W}26a'33'^{W}33'35
P81	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'26a'^{W}26a'34'^{W}34'35
P82	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'26b'^{W}26b'32'^{W}32'35
P83	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'26b'^{W}26b'33'^{W}33'35
P84	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'26b'^{W}26b'34'^{W}34'35
P85	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'28a'^{W}28a'32'^{W}32'35
P86	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'28a'^{W}28a'33'^{W}33'35
P87	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'28a'^{W}28a'34'^{W}34'35
P88	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'28b'^{W}28b'32'^{W}32'35
P89	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'28b'^{W}28b'33'^{W}33'35
P90	^{W}1D^{W}DD'^{W}D'O'^{W}O'16'^{W}16'28b'^{W}28b'34'^{W}34'35
P91	^{W}1D^{W}DD'^{W}D'Br'^{W}Br'16'^{W}16'23a'^{W}23a'32'^{W}32'35
P92	^{W}1D^{W}DD'^{W}D'Br'^{W}Br'16'^{W}16'23a'^{W}23a'33'^{W}33'35
P93	^{W}1D^{W}DD'^{W}D'Br'^{W}Br'16'^{W}16'23a'^{W}23a'34'^{W}34'35
P94	^{W}1D^{W}DD'^{W}D'Br'^{W}Br'16'^{W}16'23b'^{W}23b'32'^{W}32'35
P95	^{W}1D^{W}DD'^{W}D'Br'^{W}Br'16'^{W}16'23b'^{W}23b'33'^{W}33'35
P96	^{W}1D^{W}DD'^{W}D'Br'^{W}Br'16'^{W}16'23b'^{W}23b'34'^{W}34'35
p97	^{W}1D^{W}DD'^{W}D'Br'^{W}Br'16'^{W}16'26a'^{W}26a'32'^{W}32'35

P98	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'26a' ^{W}26a'33' ^{W}33'35
P99	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'26a' ^{W}26a'34' ^{W}34'35
P100	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'26b' ^{W}26b'32' ^{W}32'35
P101	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'26b' ^{W}26b'33' ^{W}33'35
P102	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'26b' ^{W}26b'34' ^{W}34'35
P103	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'28a' ^{W}28a'32' ^{W}32'35
P104	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'28a' ^{W}28a'33' ^{W}33'35
P105	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'28a' ^{W}28a'34' ^{W}34'35
P106	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'28b' ^{W}28b'32' ^{W}32'35
P107	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'28b' ^{W}28b'33' ^{W}33'35
P108	^{W}1D ^{W}DD' ^{W}D'Br' ^{W}Br'16' ^{W}16'28b' ^{W}28b'34' ^{W}34'35
P109	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'23a' ^{W}23a'32' ^{W}32'35
P110	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'23a' ^{W}23a'33' ^{W}33'35
P111	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'23a' ^{W}23a'34' ^{W}34'35
P112	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'23b' ^{W}23b'32' ^{W}32'35
P113	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'23b' ^{W}23b'33' ^{W}33'35
P114	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'23b' ^{W}23b'34' ^{W}34'35
P115	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'26a' ^{W}26a'32' ^{W}32'35
P116	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'26a' ^{W}26a'33' ^{W}33'35
P117	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'26a' ^{W}26a'34' ^{W}34'35
P118	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'26b' ^{W}26b'32' ^{W}32'35
P119	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'26b' ^{W}26b'33' ^{W}33'35
P120	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'26b' ^{W}26b'34' ^{W}34'35
P121	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'28a' ^{W}28a'32' ^{W}32'35
P122	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'28a' ^{W}28a'33' ^{W}33'35
P123	^{W}1D" ^{W}D"D ^{W}DD' ^{W}D'Y' ^{W}Y'16' ^{W}16'28a' ^{W}28a'34' ^{W}34'35
P124	^{W}1D" D"D DD' D'Y' Y'16' 16'28b' 28b'32' 32'35
P125	^{W}1D" D"D DD' D'Y' Y'16' 16'28b' 28b'33' 33'35

P126	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'Y'\,^{W}Y'16'\,^{W}16'28b'\,^{W}28b'34'\,^{W}34'35$
P127	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'23a'\,^{W}23a'32'\,^{W}32'35$
P128	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'23a'\,^{W}23a'33'\,^{W}33'35$
P129	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'23a'\,^{W}23a'34'\,^{W}34'35$
P130	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'23b'\,^{W}23b'32'\,^{W}32'35$
P131	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'23b'\,^{W}23b'33'\,^{W}33'35$
P132	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'23b'\,^{W}23b'34'\,^{W}34'35$
P133	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'26a'\,^{W}26a'32'\,^{W}32'35$
P134	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'26a'\,^{W}26a'33'\,^{W}33'35$
P135	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'26a'\,^{W}26a'34'\,^{W}34'35$
P136	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'26b'\,^{W}26b'32'\,^{W}32'35$
P137	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'26b'\,^{W}26b'33'\,^{W}33'35$
P138	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'26b'\,^{W}26b'34'\,^{W}34'35$
P139	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'28a'\,^{W}28a'32'\,^{W}32'35$
P140	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'28a'\,^{W}28a'33'\,^{W}33'35$
P141	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'28a'\,^{W}28a'34'\,^{W}34'35$
P142	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'28b'\,^{W}28b'32'\,^{W}32'35$
P143	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'28b'\,^{W}28b'33'\,^{W}33'35$
P144	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'O'\,^{W}O'16'\,^{W}16'28b'\,^{W}28b'34'\,^{W}34'35$
P145	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'Br'\,^{W}Br'16'\,^{W}16'23a'\,^{W}23a'32'\,^{W}32'35$
P146	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'Br'\,^{W}Br'16'\,^{W}16'23a'\,^{W}23a'33'\,^{W}33'35$
P147	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'Br'\,^{W}Br'16'\,^{W}16'23a'\,^{W}23a'34'\,^{W}34'35$
P148	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'Br'\,^{W}Br'16'\,^{W}16'23b'\,^{W}23b'32'\,^{W}32'35$
P149	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'Br'\,^{W}Br'16'\,^{W}16'23b'\,^{W}23b'33'\,^{W}33'35$
P150	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'Br'\,^{W}Br'16'\,^{W}16'23b'\,^{W}23b'34'\,^{W}34'35$
P151	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'Br'\,^{W}Br'16'\,^{W}16'26a'\,^{W}26a'32'\,^{W}32'35$
P152	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'Br'\,^{W}Br'16'\,^{W}16'26a'\,^{W}26a'33'\,^{W}33'35$
P153	$^{W}1D''\,^{W}D''D\,^{W}DD'\,^{W}D'Br'\,^{W}Br'16'\,^{W}16'26a'\,^{W}26a'34'\,^{W}34'35$

P154	$^{W}1D''\,{}^{W}D''D\,{}^{W}DD'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'26b'\,{}^{W}26b'32'\,{}^{W}32'35$
P155	$^{W}1D''\,{}^{W}D''D\,{}^{W}DD'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'26b'\,{}^{W}26b'33'\,{}^{W}33'35$
P156	$^{W}1D''\,{}^{W}D''D\,{}^{W}DD'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'26b'\,{}^{W}26b'34'\,{}^{W}34'35$
P157	$^{W}1D''\,{}^{W}D''D\,{}^{W}DD'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'28a'\,{}^{W}28a'32'\,{}^{W}32'35$
P158	$^{W}1D''\,{}^{W}D''D\,{}^{W}DD'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'28a'\,{}^{W}28a'33'\,{}^{W}33'35$
P159	$^{W}1D''\,{}^{W}D''D\,{}^{W}DD'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'28a'\,{}^{W}28a'34'\,{}^{W}34'35$
P160	$^{W}1D''\,{}^{W}D''D\,{}^{W}DD'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'28b'\,{}^{W}28b'32'\,{}^{W}32'35$
P161	$^{W}1D''\,{}^{W}D''D\,{}^{W}DD'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'28b'\,{}^{W}28b'33'\,{}^{W}33'35$
P162	$^{W}1D''\,{}^{W}D''D\,{}^{W}DD'\,{}^{W}D'Br'\,{}^{W}Br'16'\,{}^{W}16'28b'\,{}^{W}28b'34'\,{}^{W}34'35$
P163	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,23a\,{}^{W}23a32\,{}^{W}32,35$
P164	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,23a\,{}^{W}23a33\,{}^{W}33,35$
P165	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,23a\,{}^{W}23a34\,{}^{W}34,35$
P166	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,23b\,{}^{W}23b32\,{}^{W}32,35$
P167	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,23b\,{}^{W}23b33\,{}^{W}33,35$
P168	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,23b\,{}^{W}23b34\,{}^{W}34,35$
P169	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,26a\,{}^{W}26a32\,{}^{W}32,35$
P170	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,26a\,{}^{W}26a33\,{}^{W}33,35$
P171	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,26a\,{}^{W}26a34\,{}^{W}34,35$
P172	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,26b\,{}^{W}26b32\,{}^{W}32,35$
P173	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,26b\,{}^{W}26b33\,{}^{W}33,35$
P174	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,26b\,{}^{W}26b34\,{}^{W}34,35$
P175	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,28a\,{}^{W}28a32\,{}^{W}32,35$
P176	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,28a\,{}^{W}28a33\,{}^{W}33,35$
P177	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,28a\,{}^{W}28a34\,{}^{W}34,35$
P178	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,28b\,{}^{W}28b32\,{}^{W}32,35$
P179	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,28b\,{}^{W}28b33\,{}^{W}33,35$
P180	$^{W}1D\,{}^{W}DY\,{}^{W}Y16\,{}^{W}16,28b\,{}^{W}28b34\,{}^{W}34,35$

P181	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,23a\,{}^{W}23a32\,{}^{W}32,35$
P182	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,23a\,{}^{W}23a33\,{}^{W}33,35$
P183	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,23a\,{}^{W}23a34\,{}^{W}34,35$
P184	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,23b\,{}^{W}23b32\,{}^{W}32,35$
P185	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,23b\,{}^{W}23b33\,{}^{W}33,35$
P186	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,23b\,{}^{W}23b34\,{}^{W}34,35$
P187	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,26a\,{}^{W}26a32\,{}^{W}32,35$
P188	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,26a\,{}^{W}26a33\,{}^{W}33,35$
P189	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,26a\,{}^{W}26a34\,{}^{W}34,35$
P190	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,26b\,{}^{W}26b32\,{}^{W}32,35$
P191	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,26b\,{}^{W}26b33\,{}^{W}33,35$
P192	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,26b\,{}^{W}26b34\,{}^{W}34,35$
P193	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,28a\,{}^{W}28a32\,{}^{W}32,35$
P194	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,28a\,{}^{W}28a33\,{}^{W}33,35$
P195	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,28a\,{}^{W}28a34\,{}^{W}34,35$
P196	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,28b\,{}^{W}28b32\,{}^{W}32,35$
P197	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,28b\,{}^{W}28b33\,{}^{W}33,35$
P198	${}^{W}1D\,{}^{W}DO\,{}^{W}O16\,{}^{W}16,28b\,{}^{W}28b34\,{}^{W}34,35$
P199	${}^{W}1D\,{}^{W}DBr\,{}^{W}Br16\,{}^{W}16,23a\,{}^{W}23a32\,{}^{W}32,35$
P200	${}^{W}1D\,{}^{W}DBr\,{}^{W}Br16\,{}^{W}16,23a\,{}^{W}23a33\,{}^{W}33,35$
P201	${}^{W}1D\,{}^{W}DBr\,{}^{W}Br16\,{}^{W}16,23a\,{}^{W}23a34\,{}^{W}34,35$
P202	${}^{W}1D\,{}^{W}DBr\,{}^{W}Br16\,{}^{W}16,23b\,{}^{W}23b32\,{}^{W}32,35$
P203	${}^{W}1D\,{}^{W}DBr\,{}^{W}Br16\,{}^{W}16,23b\,{}^{W}23b33\,{}^{W}33,35$
P204	${}^{W}1D\,{}^{W}DBr\,{}^{W}Br16\,{}^{W}16,23b\,{}^{W}23b34\,{}^{W}34,35$
P205	${}^{W}1D\,{}^{W}DBr\,{}^{W}Br16\,{}^{W}16,26a\,{}^{W}26a32\,{}^{W}32,35$
P206	${}^{W}1D\,{}^{W}DBr\,{}^{W}Br16\,{}^{W}16,26a\,{}^{W}26a33\,{}^{W}33,35$
P207	${}^{W}1D\,{}^{W}DBr\,{}^{W}Br16\,{}^{W}16,26a\,{}^{W}26a34\,{}^{W}34,35$

P208	^{W}1D^{W}DBr^{W}Br16^{W}16,26b^{W}26b32^{W}32,35
P209	^{W}1D^{W}Dbr^{W}Br16^{W}16,26b^{W}26b33^{W}33,35
P210	^{W}1D^{W}DBr^{W}Br16^{W}16,26b^{W}26b34^{W}34,35
P211	^{W}1D^{W}DBr^{W}Br16^{W}16,28a^{W}28a32^{W}32,35
P212	^{W}1D^{W}DBr^{W}Br16^{W}16,28a^{W}28a33^{W}33,35
P213	^{W}1D^{W}DBr^{W}Br16^{W}16,28a^{W}28a34^{W}34,35
P214	^{W}1D^{W}DBr^{W}Br16^{W}16,28b^{W}28b32^{W}32,35
P215	^{W}1D^{W}DBr^{W}Br16^{W}16,28b^{W}28b33^{W}33,35
P216	^{W}1D^{W}DBr^{W}Br16^{W}16,28b^{W}28b34^{W}34,35
P217	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,23a^{W}23a32^{W}32,35
P218	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,23a^{W}23a33^{W}33,35
P219	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,23a^{W}23a34^{W}34,35
P220	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,23b^{W}23b32^{W}32,35
P221	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,23b^{W}23b33^{W}33,35
P222	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,23b^{W}23b34^{W}34,35
P223	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,26a^{W}26a32^{W}32,35
P224	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,26a^{W}26a33^{W}33,35
P225	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,26a^{W}26a34^{W}34,35
P226	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,26b^{W}26b32^{W}32,35
P227	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,26b^{W}26b33^{W}33,35
P228	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,26b^{W}26b34^{W}34,35
P229	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,28a^{W}28a32^{W}32,35
P230	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,28a^{W}28a33^{W}33,35
P231	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,28a^{W}28a34^{W}34,35
P232	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,28b^{W}28b32^{W}32,35
P233	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,28b^{W}28b33^{W}33,35
P234	^{W}1D"^{W}D"D^{W}DY^{W}Y16^{W}16,28b^{W}28b34^{W}34,35

P235	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,23a^{W}23a32^{W}32,35
P236	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,23a^{W}23a33^{W}33,35
P237	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,23a^{W}23a34^{W}34,35
P238	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,23b^{W}23b32^{W}32,35
P239	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,23b^{W}23b33^{W}33,35
P240	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,23b^{W}23b34^{W}34,35
P241	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,26a^{W}26a32^{W}32,35
P242	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,26a^{W}26a33^{W}33,35
P243	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,26a^{W}26a34^{W}34,35
P244	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,26b^{W}26b32^{W}32,35
P245	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,26b^{W}26b33^{W}33,35
P246	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,26b^{W}26b34^{W}34,35
P247	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,28a^{W}28a32^{W}32,35
P248	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,28a^{W}28a33^{W}33,35
P249	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,28a^{W}28a34^{W}34,35
P250	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,28b^{W}28b32^{W}32,35
P251	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,28b^{W}28b33^{W}33,35
P252	^{W}1D"^{W}D"D^{W}DO^{W}O16^{W}16,28b^{W}28b34^{W}34,35
P253	^{W}1D"^{W}D"D^{W}DBr^{W}Br16^{W}16,23a^{W}23a32^{W}32,35
P254	^{W}1D"^{W}D"D^{W}DBr^{W}Br16^{W}16,23a^{W}23a33^{W}33,35
P255	^{W}1D"^{W}D"D^{W}DBr^{W}Br16^{W}16,23a^{W}23a34^{W}34,35
P256	^{W}1D"^{W}D"D^{W}DBr^{W}Br16^{W}16,23b^{W}23b32^{W}32,35
P257	^{W}1D"^{W}D"D^{W}DBr^{W}Br16^{W}16,23b^{W}23b33^{W}33,35
P258	^{W}1D"^{W}D"D^{W}DBr^{W}Br16^{W}16,23b^{W}23b34^{W}34,35
P259	^{W}1D"^{W}D"D^{W}DBr^{W}Br16^{W}16,26a^{W}26a32^{W}32,35
P260	^{W}1D"^{W}D"D^{W}DBr^{W}Br16^{W}16,26a^{W}26a33^{W}33,35
P261	^{W}1D"^{W}D"D^{W}DBr^{W}Br16^{W}16,26a^{W}26a34^{W}34,35

P262	^{W}1D" ^{W}D"D ^{W}DBr ^{W}Br16 ^{W}16,26b ^{W}26b32 ^{W}32,35
P263	^{W}1D" ^{W}D"D ^{W}DBr ^{W}Br16 ^{W}16,26b ^{W}26b33 ^{W}33,35
P264	^{W}1D" ^{W}D"D ^{W}DBr ^{W}Br16 ^{W}16,26b ^{W}26b34 ^{W}34,35
P265	^{W}1D" ^{W}D"D ^{W}DBr ^{W}Br16 ^{W}16,28a ^{W}28a32 ^{W}32,35
P266	^{W}1D" ^{W}D"D ^{W}DBr ^{W}Br16 ^{W}16,28a ^{W}28a33 ^{W}33,35
P267	^{W}1D" ^{W}D"D ^{W}DBr ^{W}Br16 ^{W}16,28a ^{W}28a34 ^{W}34,35
P268	^{W}1D" ^{W}D"D ^{W}DBr ^{W}Br16 ^{W}16,28b ^{W}28b32 ^{W}32,35
P269	^{W}1D" ^{W}D"D ^{W}DBr ^{W}Br16 ^{W}16,28b ^{W}28b33 ^{W}33,35
P270	^{W}1D" ^{W}D"D ^{W}DBr ^{W}Br16 ^{W}16,28b ^{W}28b34 ^{W}34,35
P271	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"23a" ^{W}23a"32" ^{W}32"35
P272	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"23a" ^{W}23a"33" ^{W}33"35
P273	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"23a" ^{W}23a"34" ^{W}34"35
P274	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"23b" ^{W}23b"32" ^{W}32"35
P275	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"23b" ^{W}23b"33" ^{W}33"35
P276	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"23b" ^{W}23b"34" ^{W}34"35
P277	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"26a" ^{W}26a"32" ^{W}32"35
P278	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"26a" ^{W}26a"33" ^{W}33"35
P279	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"26a" ^{W}26a"34" ^{W}34"35
P280	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"26b" ^{W}26b"32" ^{W}32"35
P281	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"26b" ^{W}26b"33" ^{W}33"35
P282	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"26b" ^{W}26b"34" ^{W}34"35
P283	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"28a" ^{W}28a"32" ^{W}32"35
P284	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"28a" ^{W}28a"33" ^{W}33"35
P285	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"28a" ^{W}28a"34" ^{W}34"35
P286	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"28b" ^{W}28b"32" ^{W}32"35
P287	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"28b" ^{W}28b"33" ^{W}33"35
P288	^{W}1D" ^{W}D"Y" ^{W}Y"16" ^{W}16"28b" ^{W}28b"34" ^{W}34"35

P289	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"23a"^{W}23a"32"^{W}32"35
P290	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"23a"^{W}23a"33"^{W}33"35
P291	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"23a"^{W}23a"34"^{W}34"35
P292	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"23b"^{W}23b"32"^{W}32"35
P293	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"23b"^{W}23b"33"^{W}33"35
P294	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"23b"^{W}23b"34"^{W}34"35
P295	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"26a"^{W}26a"32"^{W}32"35
P296	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"26a"^{W}26a"33"^{W}33"35
P297	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"26a"^{W}26a"34"^{W}34"35
P298	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"26b"^{W}26b"32"^{W}32"35
P299	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"26b"^{W}26b"33"^{W}33"35
P300	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"26b"^{W}26b"34"^{W}34"35
P301	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"28a"^{W}28a"32"^{W}32"35
P302	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"28a"^{W}28a"33"^{W}33"35
P303	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"28a"^{W}28a"34"^{W}34"35
P304	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"28b"^{W}28b"32"^{W}32"35
P305	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"28b"^{W}28b"33"^{W}33"35
P306	^{W}1D"^{W}D"0"^{W}0"16"^{W}16"28b"^{W}28b"34"^{W}34"35
P307	^{W}1D"^{W}D"Br"^{W}Br"16"^{W}16"23a"^{W}23a"32"^{W}32"35
P308	^{W}1D"^{W}D"Br"^{W}Br"16"^{W}16"23a"^{W}23a"33"^{W}33"35
P309	^{W}1D"^{W}D"Br"^{W}Br"16"^{W}16"23a"^{W}23a"34"^{W}34"35
P310	^{W}1D"^{W}D"Br"^{W}Br"16"^{W}16"23b"^{W}23b"32"^{W}32"35
P311	^{W}1D"^{W}D"Br"^{W}Br"16"^{W}16"23b"^{W}23b"33"^{W}33"35
P312	^{W}1D"^{W}D"Br"^{W}Br"16"^{W}16"23b"^{W}23b"34"^{W}34"35
P313	^{W}1D"^{W}D"Br"^{W}Br"16"^{W}16"26a"^{W}26a"32"^{W}32"35
P314	^{W}1D"^{W}D"Br"^{W}Br"16"^{W}16"26a"^{W}26a"33"^{W}33"35
P315	^{W}1D"^{W}D"Br"^{W}Br"16"^{W}16"26a"^{W}26a"34"^{W}34"35

P316	$W_{1D''}W_{D''Br''}W_{Br''16''}W_{16''26b''}W_{26b''32''}W_{32''35}$
P317	$W_{1D''}W_{D''Br''}W_{Br''16''}W_{16''26b''}W_{26b''33''}W_{33''35}$
P318	$W_{1D''}W_{D''Br''}W_{Br''16''}W_{16''26b''}W_{26b''34''}W_{34''35}$
P319	$W_{1D''}W_{D''Br''}W_{Br''16''}W_{16''28a''}W_{28a''32''}W_{32''35}$
P320	$W_{1D''}W_{D''Br''}W_{Br''16''}W_{16''28a''}W_{28a''33''}W_{33''35}$
P321	$W_{1D''}W_{D''Br''}W_{Br''16''}W_{16''28a''}W_{28a''34''}W_{34''35}$
P322	$W_{1D''}W_{D''Br''}W_{Br''16''}W_{16''28b''}W_{28b''32''}W_{32''35}$
P323	$W_{1D''}W_{D''Br''}W_{Br''16''}W_{16''28b''}W_{28b''33''}W_{33''35}$
P324	$W_{1D''}W_{D''Br''}W_{Br''16''}W_{16''28b''}W_{28b''34''}W_{34''35}$

Because the paths for the remaining system transmittances are relatively few, they are enumerated in their entirety as follows:

For system transmittance $W_{1,18}$:

P325	1-2-3-4-8'-D'-10'-12'-13'-14'-B'-17'-18'-18
P326	1-2-3-4-8'-D'-10'-12'-13'-14'-Br'-17'-18'-18
P327	1-2-3-5-8-D-D'-10'-12'-13'-14'-B'-17'-18'-18
P328	1-2-3-5-8-D-D'-10'-12'-13'-14'-Br'-17'-18'-18
P329	1-2-3-6-8"-D"-D-D'-10'-12'-13'-14'-B'-17'-18'-18
P330	1-2-3-6-8"-D"-D-D'-10'-12'-13'-14'-Br'-17'-18'-18
P331	1-2-3-5-8-D-10-12-13-14-B-17-18
P332	1-2-3-5-8-D-10-12-13-14-Br-17-18
P333	1-2-3-6-8"-D"-D-10-12-13-14-B-17-18
P334	1-2-3-6-8"-D"-D-10-12-13-14-Br-17-18
P335	1-2-3-6-8"-D"-10"-12"-13"-14"-B"-17"-18"-18
P336	1-2-3-6-8"-D"-10"-12"-13"-14"-Br"-17"-18"-18

For system transmittance $W_{1,19}$:

P337	1-2-3-4-8'-D'-10'-12'-13'-14'-Br'-Sc'-19
P338	1-2-3-4-8'-D'-10'-12'-13'-14'-Sc'-19
P339	1-2-3-4-8'-D'-10'-12'-13'-Sc'-19
P340	1-2-3-4-8'-D'-10'-12'-Sc'-19
P341	1-2-3-5-8-D-D'-10'-12'-13'-14'-Br'-Sc'-19
P342	1-2-3-5-8-D-D'-10'-12'-13'-14'-Sc'-19
P343	1-2-3-5-8-D-D'-10'-12'-13'-Sc'-19
P344	1-2-3-5-8-D-D'-10'-12'-Sc'-19
P345	1-2-3-6-8"-D"-D-D'-10'-12'-13'-14'-Br'-Sc'-19
P346	1-2-3-6-8"-D"-D-D'-10'-12'-13'-14'-Sc'-19
P347	1-2-3-6-8"-D"-D-D'-10'-12'-13'-Sc'-19
P348	1-2-3-6-8"-D"-D-D'-10'-12'-Sc'-19
P349	1-2-3-5-8-D-10-12-13-14-Br-Sc-19
P350	1-2-3-5-8-D-10-12-13-14-Sc-19
P351	1-2-3-5-8-D-10-12-13-Sc-19
P352	1-2-3-4-8-D-10-12-Sc-19
P353	1-2-3-6-8"-D"-D-10-12-13-14-Br-Sc-19
P354	1-2-3-6-8"-D"-D-10-12-13-14-Sc-19
P355	1-2-3-6-8"-D"-D-10-12-13-Sc-19
P356	1-2-3-6-8"-D"-D-10-12-Sc-19
P357	1-2-3-6-8"-D"-10"-12"-13"-14"-Br"-Sc"-19
P358	1-2-3-6-8"-D"-10"-12"-13"-14"-Sc"-19
P359	1-2-3-6-8"-D"-10"-12"-13"-Sc"-19
P360	1-2-3-6-8"-D"-10"-12"-Sc"-19

For system transmittance W_{1P}:

P361	1-2-3-4-8'-D'-9'-P
P362	1-2-3-5-8-D-D'-9'-P
P363	1-2-3-6-8"-D"-D-D'-9'-P
P364	1-2-3-5-8-D-9-P
P365	1-2-3-6-8"-D"-D-9-P
P366	1-2-3-6-8"-D"-9"-P

For system transmittance $W_{1,11}$:

P367	1-2-3-4-8'-D'-11
P368	1-2-3-5-8-D-D'-11
P369	1-2-3-6-8"-D"-D-D'-11
P370	1-2-3-5-8-D-11
P371	1-2-3-6-8"-D"-D-11
P372	1-2-3-6-8"-D"-11

For system transmittance $W_{1,7}$:

P373	1-2-7

Transmittance $W_{1,35}$

PATH	G_j	Δ_j
P1	$.00029939e^{5.15s}$	1-0.19
P2	$.00089817e^{5.15s}$	1-0.19
P3	$.00029939e^{5.36s}$	1-0.19
P4	$.00001575e^{5.79s}$	1-0.19
P5	$.00004725e^{5.79s}$	1-0.19
P6	$.00001575e^{6.00s}$	1-0.19
P7	$.00001820e^{4.97s}$	1-0.19
P8	$.00005460e^{4.97s}$	1-0.19

PATH	G_j	Δ_j
P9	$0.0000182e^{5.18s}$	1-0.19
P10	$0.0000098e^{5.43s}$	1-0.19
P11	$0.0000294e^{5.43s}$	1-0.19
P12	$0.0000098e^{5.64s}$	1-0.19
P13	$0.0000053e^{5.41s}$	1-0.19
P14	$0.0000158e^{5.41s}$	1-0.19
P15	$0.0000053e^{5.62s}$	1-0.19
P16	$0.0000018e^{5.8 s}$	1-0.19

PATH	G_j	Δ_j
P17	$0.0000053e^{5.81s}$	1-0.19
P18	$0.0000018e^{6.02s}$	1-0.19
P19	$0.0004192e^{5.15s}$	1-0.19
P20	$0.0012575e^{5.15s}$	1-0.19
P21	$0.0004192e^{5.36s}$	1-0.19
P22	$0.0000221e^{5.79s}$	1-0.19
P23	$0.0000662e^{5.79s}$	1-0.19
P24	$0.0000221e^{6.00s}$	1-0.19
P25	$0.0000255e^{4.97s}$	1-0.19
P26	$0.0000765e^{4.97s}$	1-0.19
P27	$0.0000255e^{5.18s}$	1-0.19
P28	$0.0000137e^{5.43s}$	1-0.19
P29	$0.0000412e^{5.43s}$	1-0.19
P30	$0.0000137e^{5.64s}$	1-0.19
P31	$0.0000074e^{5.41s}$	1-0.19
P32	$0.0000221e^{5.41s}$	1-0.19
P33	$0.0000074e^{5.62s}$	1-0.19
P34	$0.0000025e^{5.81s}$	1-0.19
P35	$0.0000074e^{5.81s}$	1-0.19
P36	$0.0000025e^{6.02s}$	1-0.19
P37	$0.0000239e^{5.15s}$	1-0.19
P38	$0.0007182e^{5.15s}$	1-0.19
P39	$0.0000239e^{5.36s}$	1-0.19
P40	$0.0000378e^{5.79s}$	1-0.19
P41	$0.0001134e^{5.79s}$	1-0.19
P42	$0.0000378e^{6.00s}$	1-0.19
P43	$0.0000145e^{4.97s}$	1-0.19
P44	$0.0000435e^{4.97s}$	1-0.19
P45	$0.0000145e^{5.18s}$	1-0.19
P46	$0.0000234e^{5.43s}$	1-0.19
P47	$0.0000702e^{5.43s}$	1-0.19
P48	$0.0000234e^{5.64s}$	1-0.19
P49	$0.0000042e^{5.41s}$	1-0.19
P50	$0.0000126e^{5.41s}$	1-0.19
P51	$0.0000042e^{5.62s}$	1-0.19
P52	$0.0000014e^{5.81s}$	1-0.19
P53	$0.0000042e^{5.81s}$	1-0.19
P54	$0.0000014e^{6.02s}$	1-0.19
P55	$0.0000448e^{5.15s}$	1-0.15
P56	$0.0001344e^{5.15s}$	1-0.15
P57	$0.0000448e^{5.36s}$	1-0.15
P58	$0.0000023e^{5.79s}$	1-0.15
P59	$0.0000069e^{5.79s}$	1-0.15
P60	$0.0000023e^{6.00s}$	1-0.15
P61	$0.0000027e^{4.97s}$	1-0.15
P62	$0.0000081e^{4.97s}$	1-0.15
P63	$0.0000027e^{5.18s}$	1-0.15
P64	$0.0000043e^{5.43s}$	1-0.15
P65	$0.0000129e^{5.43s}$	1-0.15
P66	$0.0000043e^{5.64s}$	1-0.15
P67	$0.0000007e^{5.41s}$	1-0.15
P68	$0.0000021e^{5.41s}$	1-0.15

PATH	G_j	Δ_j
P69	$0.0000007e^{5.62s}$	1-0.15
P70	$0.0000002e^{5.81s}$	1-0.15
P71	$0.0000006e^{5.81s}$	1-0.15
P72	$0.0000002e^{6.02s}$	1-0.15
P73	$0.0000628e^{5.15s}$	1-0.15
P74	$0.0001881e^{5.15s}$	1-0.15
P75	$0.0000628e^{5.36s}$	1-0.15
P76	$0.0000032e^{5.79s}$	1-0.15
P77	$0.0000096e^{5.79s}$	1-0.15
P78	$0.0000032e^{6.00s}$	1-0.15
P79	$0.0000037e^{4.97s}$	1-0.15
P80	$0.0000113e^{4.97s}$	1-0.15
P81	$0.0000037e^{5.18s}$	1-0.15
P82	$0.0000060e^{5.43s}$	1-0.15
P83	$0.0000180e^{5.43s}$	1-0.15
P84	$0.0000060e^{5.64s}$	1-0.15
P85	$0.0000009e^{5.41s}$	1-0.15
P86	$0.0000027e^{5.41s}$	1-0.15
P87	$0.0000009e^{5.62s}$	1-0.15
P88	$0.0000003e^{5.81s}$	1-0.15
P89	$0.0000009e^{5.81s}$	1-0.15
P90	$0.0000003e^{6.02s}$	1-0.15
P91	$0.0000359e^{5.15s}$	1-0.15
P92	$0.0001075e^{5.15s}$	1-0.15
P93	$0.0000359e^{5.36s}$	1-0.15
P94	$0.0000018e^{5.79s}$	1-0.15

PATH	G_j	Δ_j
P95	$0.0000054e^{5.79s}$	1-0.15
P96	$0.0000018e^{6.00s}$	1-0.15
P97	$0.0000021e^{4.97s}$	1-0.15
P98	$0.0000064e^{4.97s}$	1-0.15
P99	$0.0000021e^{5.18s}$	1-0.15
P100	$0.0000034e^{5.43s}$	1-0.15
P101	$0.0000103e^{5.43s}$	1-0.15
P102	$0.0000034e^{5.64s}$	1-0.15
P103	$0.0000006e^{5.41s}$	1-0.15
P104	$0.0000018e^{5.41s}$	1-0.15
P105	$0.0000006e^{5.62s}$	1-0.15
P106	$0.0000002e^{5.81s}$	1-0.15
P107	$0.0000006e^{5.81s}$	1-0.15
P108	$0.0000002e^{6.02s}$	1-0.15
P109	$0.0000040e^{5.15s}$	1
P110	$0.0000120e^{5.15s}$	1
P111	$0.0000040e^{5.36s}$	1
P112	$0.0000002e^{5.79s}$	1
P113	$0.0000006e^{5.79s}$	1
P114	$0.0000002e^{6.00s}$	1
P115	$0.0000001e^{4.97s}$	1
P116	$0.0000003e^{4.97s}$	1
P117	$0.0000001e^{5.18s}$	1
P118	0.0000000	1
P119	0.0000000	1
P120	0.0000000	1

PATH	G_j	Δj
P121	$0.0000035e^{5.41s}$	1
P122	$0.0000105e^{5.41s}$	1
P123	$0.0000035e^{5.62s}$	1
P124	$0.0000011e^{5.81s}$	1
P125	$0.0000035e^{5.81s}$	1
P126	$0.0000011e^{6.02s}$	1
P127	$0.0000056e^{5.15s}$	1
P128	$0.0000168e^{5.15s}$	1
P129	$0.0000056e^{5.36s}$	1
P130	$0.0000002e^{5.79s}$	1
P131	$0.0000006e^{5.79s}$	1
P132	$0.0000002e^{6.00s}$	1
P133	$0.0000001e^{4.97s}$	1
P134	$0.0000003e^{4.97s}$	1
P135	$0.0000001e^{5.18s}$	1
P136	0.0000000	1
P137	0.0000000	1
P138	0.0000000	1
P139	$0.0000049e^{5.41s}$	1
P140	$0.0000148e^{5.41s}$	1
P141	$0.0000049e^{5.62s}$	1
P142	$0.0000015e^{5.81s}$	1
P143	$0.0000045e^{5.81s}$	1
P144	$0.0000015e^{6.02s}$	1
P145	$0.0000032e^{5.15s}$	1
P146	$0.0000096e^{5.15s}$	1

PATH	G_j	Δj
P147	$0.0000032e^{5.36s}$	1
P148	$0.0000001e^{5.79s}$	1
P149	$0.0000003e^{5.79s}$	1
P150	$0.0000001e^{6.00s}$	1
P151	0.0000000	1
P152	0.0000000	1
P153	0.0000000	1
P154	0.0000000	1
P155	0.0000000	1
P156	0.0000000	1
P157	$0.0000028e^{5.41s}$	1
P158	$0.0000084e^{5.41s}$	1
P159	$0.0000028e^{5.62s}$	1
P160	$0.0000009e^{5.81s}$	1
P161	$0.0000028e^{5.81s}$	1
P162	$0.0000009e^{6.02s}$	1
P163	$0.0010417e^{5.41s}$	1-0.16
P164	$0.0083336e^{5.41s}$	1-0.16
P165	$0.0010417e^{5.62s}$	1-0.16
P166	$0.0000548e^{6.05s}$	1-0.16
P167	$0.0004384e^{6.05s}$	1-0.16
P168	$0.0000548e^{6.21s}$	1-0.16
P169	$0.0000633e^{5.24s}$	1-0.16
P170	$0.0005064e^{5.24s}$	1-0.16
P171	$0.0000633e^{5.49s}$	1-0.16
P172	$0.0000341e^{5.70s}$	1-0.16

PATH	G_j	Δj
P173	$0.0002723e^{5.70s}$	1-0.16
P174	$0.0000341e^{5.86s}$	1-0.16
P175	$0.0000182e^{5.67s}$	1-0.16
P176	$0.0001456e^{5.67s}$	1-0.16
P177	$0.0000182e^{5.83s}$	1-0.16
P178	$0.0000060e^{6.07s}$	1-0.16
P179	$0.0000487e^{6.07s}$	1-0.16
P180	$0.0000060e^{6.23s}$	1-0.16
P181	$0.0014583e^{5.41s}$	1-0.16
P182	$0.0116670e^{5.41s}$	1-0.16
P183	$0.0014583e^{5.62s}$	1-0.16
P184	$0.0000767e^{6.05s}$	1-0.16
P185	$0.0006137e^{6.05s}$	1-0.16
P186	$0.0000767e^{6.21s}$	1-0.16
P187	$0.0000886e^{5.24s}$	1-0.16
P188	$0.0007089e^{5.24s}$	1-0.16
P189	$0.0000886e^{5.49s}$	1-0.16
P190	$0.0000477e^{5.70s}$	1-0.16
P191	$0.0003812e^{5.70s}$	1-0.16
P192	$0.0000477e^{5.86s}$	1-0.16
P193	$0.0000254e^{5.67s}$	1-0.16
P194	$0.0002038e^{5.67s}$	1-0.16
P195	$0.0000254e^{5.83s}$	1-0.16
P196	$0.0000084e^{6.07s}$	1-0.16
P197	$0.0000681e^{6.07s}$	1-0.16
P198	$0.0000084e^{6.23s}$	1-0.16
P199	$0.0008333e^{5.41s}$	1-0.16
P200	$0.0066668e^{5.41s}$	1-0.16
P201	$0.0008333e^{5.62s}$	1-0.16
P202	$0.0000438e^{6.05s}$	1-0.16
P203	$0.0003504e^{6.05s}$	1-0.16
P204	$0.0000438e^{6.21s}$	1-0.16
P205	$0.0000506e^{5.24s}$	1-0.16
P206	$0.0004051e^{5.24s}$	1-0.16
P207	$0.0000506e^{5.49s}$	1-0.16
P208	$0.0000272e^{5.70s}$	1-0.16
P209	$0.0002178e^{5.70s}$	1-0.16
P210	$0.0000272e^{5.86s}$	1-0.16
P211	$0.0000145e^{5.67s}$	1-0.16
P212	$0.0001164e^{5.67s}$	1-0.16
P213	$0.0000145e^{5.83s}$	1-0.16
P214	$0.0000048e^{6.07s}$	1-0.16
P215	$0.0000389e^{6.07s}$	1-0.16
P216	$0.0000048e^{6.23s}$	1-0.16
P217	$0.0009370e^{5.41s}$	1-0.01
P218	$0.0007500e^{5.41s}$	1-0.01
P219	$0.0009370e^{5.62s}$	1-0.01
P220	$0.0000049e^{6.05s}$	1-0.01
P221	$0.0000394e^{6.05s}$	1-0.01
P222	$0.0000049e^{6.21s}$	1-0.01
P223	$0.0000056e^{5.24s}$	1-0.01
P224	$0.0000455e^{5.24s}$	1-0.01

PATH	G_j	Δ_j
P225	$0.0000056e^{5.49s}$	1-0.01
P226	$0.0000030e^{5.70s}$	1-0.01
P227	$0.0000240e^{5.70s}$	1-0.01
P228	$0.0000030e^{5.86s}$	1-0.01
P229	$0.0000016e^{5.67s}$	1-0.01
P230	$0.0000131e^{5.67s}$	1-0.01
P231	$0.0000016e^{5.83s}$	1-0.01
P232	$0.0000005e^{6.07s}$	1-0.01
P233	$0.0000043e^{6.07s}$	1-0.01
P234	$0.0000005e^{6.23s}$	1-0.01
P235	$0.0001312e^{5.41s}$	1-0.01
P236	$0.0010500e^{5.41s}$	1-0.01
P237	$0.0001312e^{5.62s}$	1-0.01
P238	$0.0000069e^{6.05s}$	1-0.01
P239	$0.0000552e^{6.05s}$	1-0.01
P240	$0.0000069e^{6.21s}$	1-0.01
P241	$0.0000079e^{5.24s}$	1-0.01
P242	$0.0000638e^{5.24s}$	1-0.01
P243	$0.0000079e^{5.49s}$	1-0.01
P244	$0.0000042e^{5.70s}$	1-0.01
P245	$0.0000343e^{5.70s}$	1-0.01
P246	$0.0000042e^{5.86s}$	1-0.01
P247	$0.0000022e^{5.67s}$	1-0.01
P248	$0.0000183e^{5.67s}$	1-0.01
P249	$0.0000022e^{5.83s}$	1-0.01
P250	$0.0000007e^{6.07s}$	1-0.01

PATH	G_j	Δ_j
P251	$0.0000061e^{6.07s}$	1-0.01
P252	$0.0000007e^{6.23s}$	1-0.01
P253	$0.0000749e^{5.41s}$	1-0.01
P254	$0.0006000e^{5.41s}$	1-0.01
P255	$0.0000749e^{5.62s}$	1-0.01
P256	$0.0000039e^{6.05s}$	1-0.01
P257	$0.0000315e^{6.05s}$	1-0.01
P258	$0.0000039e^{6.21s}$	1-0.01
P259	$0.0000045e^{5.24s}$	1-0.01
P260	$0.0000364e^{5.24s}$	1-0.01
P261	$0.0000045e^{5.49s}$	1-0.01
P262	$0.0000024e^{5.70s}$	1-0.01
P263	$0.0000196e^{5.70s}$	1-0.01
P264	$0.0000024e^{5.86s}$	1-0.01
P265	$0.0000013e^{5.67s}$	1-0.01
P266	$0.0000104e^{5.67s}$	1-0.01
P267	$0.0000013e^{5.83s}$	1-0.01
P268	$0.0000004e^{6.07s}$	1-0.01
P269	$0.0000035e^{6.07s}$	1-0.01
P270	$0.0000004e^{6.23s}$	1-0.01
P271	$0.0001388e^{5.99s}$	1-0.05
P272	$0.0004860e^{6.22s}$	1-0.05
P273	$0.0000694e^{6.33s}$	1-0.05
P274	$0.0000073e^{6.63s}$	1-0.05
P275	$0.0000255e^{6.86s}$	1-0.05
P276	$0.0000036e^{6.97s}$	1-0.05

PATH	G_j	Δ_j
P277	$0.0000083e^{5.56s}$	1-0.05
P278	$0.0000294e^{5.79s}$	1-0.05
P279	$0.0000042e^{5.90s}$	1-0.05
P280	$0.0000045e^{6.02s}$	1-0.05
P281	$0.0000158e^{6.25s}$	1-0.05
P282	$0.0000022e^{6.36s}$	1-0.05
P283	$0.0000024e^{5.91s}$	1-0.05
P284	$0.0000084e^{6.14s}$	1-0.05
P285	$0.0000012e^{6.25s}$	1-0.05
P286	$0.0000008e^{6.31s}$	1-0.05
P287	$0.0000028e^{6.54s}$	1-0.05
P288	$0.0000004e^{6.65s}$	1-0.05
P289	$0.0001943e^{5.99s}$	1-0.05
P290	$0.0006804e^{6.22s}$	1-0.05
P291	$0.0000971e^{6.33s}$	1-0.05
P292	$0.0000102e^{6.63s}$	1-0.05
P293	$0.0000357e^{6.86s}$	1-0.05
P294	$0.0000050e^{6.97s}$	1-0.05
P295	$0.0000116e^{5.56s}$	1-0.05
P296	$0.0000411e^{5.79s}$	1-0.05
P297	$0.0000058e^{5.90s}$	1-0.05
P298	$0.0000063e^{6.02s}$	1-0.05
P299	$0.0000221e^{6.25s}$	1-0.05
P300	$0.0000030e^{6.36s}$	1-0.05
P301	$0.0000033e^{5.91s}$	1-0.05
P302	$0.0000117e^{6.14s}$	1-0.05

PATH	G_j	Δ_j
P303	$0.0000016e^{6.25s}$	1-0.05
P304	$0.0000011e^{6.31s}$	1-0.05
P305	$0.0000039e^{6.54s}$	1-0.05
P306	$0.0000005e^{6.65s}$	1-0.05
P307	$0.0001111e^{5.99s}$	1-0.05
P308	$0.0003888e^{6.22s}$	1-0.05
P309	$0.0000555e^{6.33s}$	1-0.05
P310	$0.0000058e^{6.63s}$	1-0.05
P311	$0.0000204e^{6.86s}$	1-0.05
P312	$0.0000028e^{6.97s}$	1-0.05
P313	$0.0000066e^{5.56s}$	1-0.05
P314	$0.0000235e^{5.79s}$	1-0.05
P315	$0.0000033e^{5.90s}$	1-0.05
P316	$0.0000036e^{6.02s}$	1-0.05
P317	$0.0000126e^{6.25s}$	1-0.05
P318	$0.0000017e^{6.36s}$	1-0.05
P319	$0.0000019e^{5.91s}$	1-0.05
P320	$0.0000067e^{6.14s}$	1-0.05
P321	$0.0000009e^{6.25s}$	1-0.05
P322	$0.0000006e^{6.31s}$	1-0.05
P323	$0.0000050e^{6.54s}$	1-0.05
P324	$0.0000003e^{6.65s}$	1-0.05

Transmittance $W_{1.18}$

PATH	G_j	Δ_j
P325	$0.0014006e^{1.91s}$	1-0.2
P326	$0.0061279e^{1.91s}$	1-0.2
P327	$0.0002100e^{1.91s}$	1-0.2
P328	$0.0009187e^{1.91s}$	1-0.2
P329	$0.0000188e^{1.91s}$	1-0.2
P330	$0.0000822e^{1.91s}$	1-0.2
P331	$0.0097469e^{1.91s}$	1-0.2
P332	$0.0426426e^{1.91s}$	1-0.2
P333	$0.0008772e^{1.91s}$	1-0.2
P334	$0.0038377e^{1.91s}$	1-0.2
P335	$0.0006497e^{1.92s}$	1-0.2
P336	$0.0028424e^{1.92s}$	1-0.2
P337	$0.0000140e^{1.88s}$	1-0.2
P338	$0.0012635e^{1.88s}$	1-0.2
P339	$0.0000921e^{1.87s}$	1-0.2
P340	$0.0829350e^{1.56s}$	1-0.2
P341	$0.0000021e^{1.88s}$	1-0.2
P342	$0.0002626e^{1.88s}$	1-0.2
P343	$0.0000691e^{1.87s}$	1-0.2
P344	$0.0124402e^{1.56s}$	1-0.2
P345	$0.0000001e^{1.88s}$	1-0.2
P346	$0.0000236e^{1.88s}$	1-0.2
P347	$0.0000062e^{1.87s}$	1-0.2
P348	$0.0011196e^{1.56s}$	1-0.2

PATH	G_j	Δ_j
P349	$0.0000974e^{1.93s}$	1-0.2
P350	$0.0121837e^{1.93s}$	1-0.2
P351	$0.0032062e^{1.92s}$	1-0.2
P352	$0.5771250e^{1.57s}$	1-0.2
P353	$0.0000087e^{1.93s}$	1-0.2
P354	$0.0010965e^{1.93s}$	1-0.2
P355	$0.0002885e^{1.92s}$	1-0.2
P356	$0.0519412e^{1.57s}$	1-0.2
P357	$0.0000064e^{2.05s}$	1-0.2
P358	$0.0008122e^{2.05s}$	1-0.2
P359	$0.0002137e^{2.03s}$	1-0.2
P360	$0.0384750e^{1.59s}$	1-0.2
P361	$0.0009500e^{1.61s}$	1-0.2
P362	$0.0001425e^{1.61s}$	1-0.2
P363	$0.0000128e^{1.61s}$	1-0.2
P364	$0.0213750e^{1.61s}$	1-0.2
P365	$0.0019237e^{1.61s}$	1-0.2
P366	$0.0213750e^{1.61s}$	1-0.2

Transmittance $W_{1,11}$

P367	$0.0009500e^{1.50s}$	1-0.2
P368	$0.0001425e^{1.50s}$	1-0.2
P369	$0.0012825e^{1.50s}$	1-0.2
P370	$0.0071250e^{1.5s}$	1-0.2
P371	$0.0006412e^{1.5s}$	1-0.2

PATH	G_j	Δ_j
P372	$0.007125e^{1.50s}$	1-0.2

Transmittance $W_{1,7}$

P373	$0.05e^{1.50s}$	1-0.2

The mean cost is defined as $E_{(cost)} = \frac{d}{ds} \left. \frac{W_E(S)}{W_E(0)} \right|_{S=0}$

where $W_E(S) = \sum G_j\Delta_j/\Delta$, and $W_E(0)$ is $W_E(S)$ evaluated at $S =$ zero.

Calculating $W_E(S)_{1,35}$:

$$
\begin{aligned}
\sum G_j\Delta_j = {} & (0.0036164e^{5.15s}+0.0007425e^{5.36s}+0.0003026e^{5.79s} \\
& +0.0000757e^{6.00s}+0.0002328e^{4.97s}+0.0000582e^{5.18s} \\
& +0.0001877e^{5.43s}+0.0000469e^{5.64s}+0.0000674e^{5.41s} \\
& +0.0000169e^{5.62s}+0.0000226e^{5.81s}+0.0000057e^{6.02s})(0.81) \\
& +(0.0005735e^{5.15s}+0.0001435e^{5.36s}+0.0000292e^{5.79s} \\
& +0.0000073e^{6.00s}+0.0000305e^{4.97s}+0.0000085e^{5.18s} \\
& +0.0000549e^{5.43s}+0.0000137e^{5.64s}+0.0000088e^{5.41s} \\
& +0.0000022e^{5.62s}+0.0000028e^{5.81s}+0.0000007e^{6.02s})(0.85) \\
& +(0.0000512e^{5.15s}+0.0000128e^{5.36s}+0.0000020e^{5.79s} \\
& +0.0000005e^{6.00s}+0.0000008e^{4.97s}+0.0000002e^{5.18s} \\
& +0.0000449e^{5.41s}+0.0000112e^{5.62s}+0.0000143e^{5.81s} \\
& +0.0000035e^{6.02s})(1) +(0.03000007e^{5.41s}+0.0108330e^{5.62s} \\
& +0.0015778e^{6.05s}+0.0001753e^{6.21s}+0.0018229e^{5.24s} \\
& +0.0002005e^{5.49s}+0.0009803e^{5.70s}+0.0001090e^{5.86s} \\
& +0.0005239e^{5.67s}+0.0000581e^{5.83s}+0.0001749e^{6.07s} \\
& +0.0000192e^{6.23s})(0.84) +(0.0035431e^{5.41s}+0.0002110e^{5.62s} \\
& +0.0001418e^{6.05s}+0.0000157e^{6.21s}+0.0001637e^{5.24s}
\end{aligned}
$$

$+0.0000180e^{5.49s}+0.0000875e^{5.70s}+0.0000096e^{5.86s}$
$+0.0000469e^{5.67s}+0.0000051e^{5.83s}+0.0000155e^{6.07s}$
$+0.0000016e^{6.23s})(0.99)+(0.0004442e^{5.99s}+0.0015552e^{6.22s}$
$+0.0002220e^{6.33s}+0.0000233e^{6.63s}+0.0000816e^{6.86s}$
$+0.0000114e^{6.97s}+0.0000265e^{5.56s}+0.0000940e^{5.79s}$
$+0.0000133e^{5.90s}+0.0000144e^{6.02s}+0.0000542e^{6.25s}$
$+0.0000069e^{6.36s}+0.0000076e^{5.91s}+0.0000268e^{6.14s}$
$+0.0000025e^{6.31s}+0.0000117e^{6.54s}+0.0000012e^{6.65s})(0.95)$

$$
\begin{aligned}
\sum G_j\Delta_j = {} & 0.0034678e^{5.15s}+0.0007361e^{5.36s}+0.0003612e^{5.79s} \\
& +0.0000680e^{6.00s}+0.0002152e^{4.97s}+0.0000545e^{5.18s} \\
& +0.0001986e^{5.43s}+0.0000495e^{5.64s}+0.0001068e^{5.41s} \\
& +0.0093351e^{5.62s}+0.0000349e^{5.81s}+0.0000222e^{6.02s} \\
& +0.0287081e^{5.41s}+0.0014656e^{6.05s}+0.0001627e^{6.21s} \\
& +0.0016932e^{5.24s}+0.0001862e^{5.49s}+0.0009100e^{5.70s} \\
& +0.0001010e^{5.86s}+0.0004864e^{5.67s}+0.0000538e^{5.83s} \\
& +0.0002122e^{6.07s}+0.0000176e^{6.23s}+0.0004219e^{5.99s} \\
& +0.0014774e^{6.22s}+0.0002109e^{6.33s}+0.0000221e^{6.63s} \\
& +0.0000775e^{6.86s}+0.0000108e^{6.97s}+0.0000251e^{5.56s} \\
& +0.0000126e^{5.90s}+0.0000514e^{6.25s}+0.0000065e^{6.36s} \\
& +0.0000072e^{5.91s}+0.0000254e^{6.14s}+0.0000023e^{6.31s} \\
& +0.0000111e^{6.54s}+0.0000011e^{6.65s}
\end{aligned}
$$

Setting S = 0, $\sum G_j\Delta_j = 0.05101$ The value of Δ was calculated earlier to be 0.80784 Therefore, $W_E(0)_{1,35}$ is determined to be:

$$0.05101/0.80784 = 0.0631436$$

$$W_E(0)_{1,35} = \boxed{0.0631436}$$

$$\frac{d}{ds}\left(\frac{W_E(S)_{1,35}}{W_E(0)_{1,35}}\right)\Bigg|_{S=0} = (0.0178591+0.0039454+0.0020913+0.0004080+0.0010695+0.0002823+0.0010783+0.0002791+0.0005777+0.0524632+0.0002027+0.0001336+0.1553108+0.0088668+0.0010103+0.0088723+0.0010222+0.0051870+0.0005918+0.0027578+0.0003136+0.0012880+0.0001096+0.0025271+0.0091894+0.0013349+0.0001465+0.0005316+0.0000752+0.0001395+0.0000743+0.0003212+0.0000413+0.0000425+0.0001559+0.0000145+0.0000725+0.0000073)(0.80784 \times 0.0631436)^{-1}$$

$$= (0.3470911)(0.80784 \times 0.0631436)^{-1}$$

$$= \boxed{\$5.4968532}$$

Therefore, the cost of harvesting sea urchins and of processing and transporting fresh sea urchin roe to Japan is \$5.50 per pound. It is noted at this point that harvesting and packaging the bulk urchin for shipment to New York at a total of \$1.50+0.11+0.25= \$1.86 per pound of roe, and harvesting, processing, and packaging sea urchin roe for shipment domestically at a total of \$1.50+0.38+0.54+0.25= \$2.67 per pound of roe, and finally the cost of scrap that is sold for fertilizer, etc. all add to the total cost of the operation. However, to simplify the analysis, it is assumed that all amounts shipped by either of these routes will be sold at cost and not affect the cost incurred at the Tokyo market.

Because the \$5.50 per pound value represents the mean of a cost distribution, it becomes desirable to know what the

distribution looks like. Calculation of the distribution's variance provides this information. The distribution's variance, defined by σ^2, is expressed as:

$$\sigma^2 = \frac{d^2}{ds^2} \frac{W_E(S)_{1,35}}{W_E(0)_{1,35}}\Bigg|_{S=0} - \left(\frac{d}{ds} \frac{W_E(S)_{1,35}}{W_E(0)_{1,35}}\Bigg|_{S=0} \right)^2$$

$$\frac{d^2}{ds^2} \frac{W_E(S)_{1,35}}{W_E(0)_{1,35}}\Bigg|_{S=0} = (0.0919743+0.0211473+0.0121086+0.0024480$$
$$+0.0053154+0.0014623+0.0058551+0.0015741$$
$$+0.0031253+0.2948431+0.0011776+0.0008042$$
$$+0.8402314+0.0536441+0.0062739+0.0464908$$
$$+0.0056118+0.0295659+0.0034679+0.0156361$$
$$+0.0018282+0.0078181+0.0006828+0.0151373$$
$$+0.0571580+0.0084499+0.0009712+0.0036467$$
$$+0.0005241+0.0007756+0.0004383+0.0020075$$
$$+0.0002626+0.0002511+0.0009572+0.0000914$$
$$+0.0004741+0.0000485)(0.80784 \times 0.0631436)^{-1}$$

$$= (1.5442798)(0.80784 \times 0.0631436)^{-1}$$

$$= \boxed{30.274103}$$

$$\sigma^2 = 30.274103 - (5.4968532)^2$$
$$= 30.274103 - 30.215395$$
$$= \boxed{0.058708}$$

Which signifies that the distribution is very tight. This further indicates that the costs will not vary significantly from the \$5.50 per pound ad valorem amount. This tight variation could have been much greater if more factors had been varied.

CHAPTER VI

CONCLUSION

General

The original hypothesis to be tested was:

The harvesting and processing of sea urchin roe for export is an economically feasible venture for certain fisheries industries in New England.

The specific case of processing sea urchin roe in the state of Maine for export to Japan was used to test the validity of this hypothesis. A new managerial decision tool called SMART was developed for the purpose of conducting this test. The SMART method used the systems approach and GERT (Graphical Evaluation and Review Technique) to model the total system and to derive a projected distribution of costs. In Chapter V, an average cost of $5.50 per pound of fresh processed sea urchin roe was calculated. This figure included a correction factor which enabled the costs derived from the SMART model to be compared directly to the price being offered in the Tokyo market. In other words, the actual cost seen by the Maine processor would be $4.80 per pound but this figure cannot be compared directly to the prices offered on the Tokyo exchange because of an approximate 36 hour difference in freshness between the Maine product and its Japanese competitor.

Therefore a correction factor was derived as depicted in Figure 5-1 to compensate for the difference in freshness, and was then added to the costs seen by the processor so that direct comparisons could be made.

Comparing the $5.50 per pound amount with the January 1973 price range for sea urchin roe in the Tokyo market, which ranged between $5.32 and $6.64 per pound, it can be concluded that the venture is feasible but not particularly profitable. This is based on the assumption that the quoted price range represents that which could be expected for the "seasonal high" in the same month of succeeding years. It is anticipated that the price range would be somewhat lower in the month of December and February, even lower in November and October, and significantly lower in March. Therefore, at $5.50 per pound the venture would be marginal at best. There are many other influencing factors that should be considered, however, before passing final judgement on the economic feasibility of the venture.

The revaluation of the Yen should serve to raise the U.S. dollar price offered for processed sea urchin roe in the Japanese market. Further dollar devaluations which could be anticipated over a five year planning horizon would shift the offered price further upward making the venture even more attractive. In short, the evaluation of this venture's economic feasibility must be considered against expected future market conditions as well as against current conditions.

Another very important consideration is the definition of purpose for evaluating the venture in the first place. If

it is the processor's desire to maintain employment for his work force through the winter months and to utilize facilities which would otherwise stand idle, then the overall profitability consideration might not be as important as the economic feasibility consideration. If the processor is concerned about profit potential the venture may not seem feasible. But from the standpoint of providing year round employment and utilizing idle plant capacity at little or no loss, the venture becomes economically feasible.

In actuality, the only way to truly test the economic feasibility of the venture is to conduct one or more "test runs." Had the predicted costs of the SMART analysis been higher, there would have been little justification for conducting a test run. But the $5.50 per pound cost places the venture in the "maybe" category which certainly warrants further investigation and justifies a test run through the entire system.

During the course of any "test run," careful attention should be paid to the following parameters: (1) Number of sea urchins harvested per hour; (2) Survival rate of the captured sea urchins when kept in holding tanks for 12, 24, 36, 48, 60, and 72 hours; (3) Number of pounds of roe processed per person per day. A minimum of 100 pounds of roe should be processed by a team of 9 workers during the initial test run. A second test run, if conducted, should yield a minimum of 175 pounds per team per day; (4) Percentage breakdown actually encountered in the test sample of sea urchin roe by grade: high quality yellow, intermediate quality orange, low quality brown, and

percentage lost or broken during the processing operation; (5) Quality loss of the processed roe over periods of 12, 24, 36, 48, 60, and 72 hours under refrigerated conditions; (6) Actual costs of obtaining dry cedar wood trays. Price of each tray should not exceed 20 cents; (7) Percentage of roe damaged during domestic transit via privately owned vehicle and, if possible, as compared to percentage damaged during domestic transit via a common carrier trucking firm, and/or via Delta Airlines from Portland, Maine to Kennedy International Airport in New York; (8) Percentage of roe damaged during international transit; (9) Actual price obtained in the Tokyo market as compared to that which was expected.

Such a test as the one just described is absolutely essential before any final judgement can be made as to the economic feasibility of the venture. The data derived from the test should then be used to validate the assumptions used during the SMART approach. Since the SMART approach attempted to envision the most pessimistic outcome for the venture, the actual data should improve the cost figures by some amount. The revised figures can only be obtained, however, through an actual test run.

Recommendations

It has been shown that processing sea urchin roe in New England for export is economically feasible if the venture is undertaken as a means for utilizing idle resources and for providing employment. It has also been shown that profit

potential in the current market is near zero. Yet the profit potential always has been, is, and always will be a primary consideration for assessing economic feasibility regardless of an entrepreneur's motivation for undertaking a particular venture. Therefore, the task remains to look at the aggregate system and to determine what changes, if any, can be made to improve the profitability picture of the "sea urchin roe for export" venture.

In keeping with the theme just described, the following recommendations are offered:

(1) A test run must be conducted, actually harvesting, processing, and transporting sea urchin roe to Japan. The data and information listed in the preceding section should be collected and recorded.

(2) The SMART model can be used to demonstrate the sensitivity of the cost of the final delivered product to the cost of transportation. It should be obvious that domestic and international transport costs account for a substantial portion of the overall cost. It logically follows that larger bulk shipments could result in economies of scale and a significant reduction in transportation costs. However, the processing operation is extremely labor intensive, a factor which has a profound impact on available alternatives for reducing costs in the transportation segment of the aggregate system.

It has been estimated that a medium to large processing plant can produce from 400 to 700 pounds of roe per day on a regular basis. Yet approximately 800 pounds of roe per day

must be produced at a minimum before any significant savings in transportation costs are to be realized. In terms of the network modeled in this thesis, a regular output of 800 pounds of processed roe reduces the cost seen be the processor from the corrected $5.50 to a corrected $4.96 per pound. An output of 1200 pounds per day reduces the amount to a corrected $4.80 per pound. The last significant break occurs at the minimum sustained ouput of 1700 pounds per day. At this rate, the cost seen by the processor is reduced to a corrected $4.68 per pound. At this point the processor is realizing a profit of $0.70 to $0.90 per pound during the seasonal high in January.

One final break point in the cost structure could be manufactured at a steady output of processed roe in excess of 2500 pounds per day. At this point a commodity rate can be negotiated with domestic and international common carriers. At 2500 pounds, the total gross weight per shipment would be in excess of 6000 pounds per day.

Since one processing plant is not capable of producing a regular minimum output of 800 pounds per day, due primarily to the labor intensive characteristics of the process, the venture would seldom, if ever, be profitable. However, if two or three processors were to ship together, the less costly shipping rates could be attained and higher profits could be realized. The recommendation, therefore, is that interested processors seriously consider some type of processor's cooperative, or at least some form of mutual shipping pool.

(3) Before any substantial harvesting and processing operation is undertaken, research should be conducted to

determine the current size of the sea urchin population, and to further determine the maximum sustainable yield.

Summary

This thesis has tested the economic feasibility of harvesting and processing sea urchin roe in New England for export, using the specific case of Maine to Japan. A new decision tool was developed and was termed SMART for Systems Management Analysis and Review Technique. This tool's development necessitated a lengthy elaboration of systems theory, modeling practices, and GERT (Graphical Evaluation and Review Technique) methodology.

SMART was then developed as a managerial decision tool. Its advantages were shown to lie in three areas. First, SMART deals with stochastic networks and deals with both probabilistic and deterministic data inputs. Second, SMART has the capability of integrating many different sub-models of various and diverse subsystems into one representative model of the entire system. This capability enables the decision maker to evaluate subsystem parameters and vary them to assure the optimal performance of the entire system. Third, SMART allows the decision maker to define his own "depth of analysis." The decision maker is free to choose the level of aggregation at which he chooses to work, and therefore to change this level to suit situational pressures and demands.

SMART procedures were then utilized to model the harvesting, processing, and transporting subsystems. After explicitly enumerating all necessary assumptions, quantitative data were

assigned to the qualitatively structured sub-models. Using the GERT procedure known as Mason's Reduction, the mean cost of the total system's operation was calculated as $5.50 per pound with a calculated variance of 0.058708 for the cost distribution.

The conclusion was that the venture was economically feasible but not potentially profitable. This conclusion was based on the assumption that Maine processor's would consider undertaking the venture to provide year round employment and to make use of plant facilities which would normally stand idle during the winter months. In this case the venture could be deemed "feasible" even if the processor would not realize any profit. It was noted, however, that the venture was marginal in terms of pessimistic estimates and in terms of the current international market. It was therefore suggested that changes might be initiated which could help shift the venture from the marginally profitable but feasible area to the profitable and feasible area. These changes were reflected in the recommendations which followed.

The recommendations stated that (1) A test run was certainly justified and should be conducted; (2) Processors should seriously consider forming some type of transportation cooperative to take advantage of economies of scale offered in the domestic and international transportation subsystems; and (3) Further research should be conducted to determine the maximum sustainable yield of the Maine sea urchin.

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