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AN APPROACH TO THE QUESTIONNAIRE STAGE IN THE KNOWLEDGE-BASED OPERATIONS MANAGEMENT SYSTEM

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ABSTRACT

This paper discusses some preliminary thoughts about the development of a questionnaire for the Knowledge-based Operations Management System (KOMS) project. The questionnaire is designed to elicit information from managers, regarding the type of operating problems faced by them in terms of decisions which have to be made. This information is to be used to design the type of operating system appropriate for the case in question.

The role of the questionnaire in relation to KOMS is discussed, with an account of the tasks that this stage would perform in the system. The type of information needed at each point has been outlined briefly.

The Knowledge-based Operations Management System (KOMS)

THE QUESTIONNAIRE STAGE

The purpose of the KOMS project is to develop a system that interacts with management, and through a questionnaire approach builds up a customised optimisation model. This model is to enable the manager to make a wide spectrum of operating and planning decisions that are optimal or near optimal in the model framework.

The range of decisions that might conceivably be considered is qualitatively highly variegated and quite vast in terms of time horizon and physical scope. Hax [1] has pointed out that it is unrealistic to attempt to develop a single model to deal with the situation. Rather an approach that partitions the problem into hierarchically organized and interrelated subproblems is likely to prove fruitful.

Our primary interest at this stage is to study the nature of the models that we might use in formulating these decisions and to focus on how to design a questionnaire which elicits the information necessary to build such models. It seems clear that design of the questionnaire cannot proceed without a good idea of the kind of models we want to build now or in the future.

Partitioning the Problem:

In partitioning the problem into pieces of manageable size, certain desiderata have to be met :

i) The subproblems should have some correspondence to traditional management identification of decisions. This will aid in reducing the credibility gap between manager and model.

ii) It should be possible to cast the subproblems in a standard mathematical form which can be tackled with existing methodology.

iii) The partitioning should minimise the interaction and interdependence between subproblems.

iv) If significant interactions exist, it should be possible to obtain suboptimal solutions which can be sequentially improved by iteratively passing information from one subproblem to another.

v) Whenever it is necessary to transfer information from one subproblem to another, an attempt should be made to give it an intuitive or real-world interpretation. This would also allow interaction with management in validating the structure of the model and the numbers that are produced. It also provides a way of introducing subjective inputs into the model. Typically such information would consist of shadow prices, resource constraints and summarised information such as average prices and statistics.

The first two of these desiderata are pragmatic considerations which could be expected to dominate the partitioning decision. The next two suggest criteria which are theoretically and methodologically desirable. While it is worthwhile to explore such approaches, for the time being it seems to be reasonable to assume a broad hierarchical partitioning as described by Hax. It will also be assumed that we are restricting our attention to medium and short term operating and control decisions.

Model Building :

There are certain natural specifications or constraints that the design of the system must meet. As was pointed out above, two of the major ones are :

- to communicate with management at the input end, and
- to produce tractable models at the output end.

Thus while we are free to choose how to accomplish the transition from one to the other, we have to keep track of the limitations at either end of the process. To amplify a bit further --

At the top end, regardless of the range of decisions to be made in a particular case, it appears useful to obtain a description of the structure and physical nature of the production and distribution system. This is a subject that management is likely to be familiar with rather than abstract models.

At the bottom end it must be recognised that in order to produce answers which are meaningful, the problem has to be represented in some standard formulation to which the solution is known. There is furthermore, a continuing development in the formulation of decision problems in operations management and concurrently in the methodology for their solution. It is therefore necessary to maintain a certain amount of flexibility in the system to allow for the incorporation of new methods.

Questionnaire development :

In order to lend some perspective to the position of the questionnaire in the system let us briefly discuss some strategic issues relative to KOMS. We are concerned here with what an eventual system might look like, and what the role of the questionnaire might be.

1) Preliminary questions should focus on determining information relevant to basic issues such as

- the range of decisions to be studied in terms of time horizon and physical scope.
- the manner in which the overall decision problem is to be partitioned.

2) The modelling effort should concentrate on the physical aspects of the system which are to be taken as given and should avoid modelling existing policy and routine.

3) At the "top" of the system, the questionnaire should aim at building a standardised description of the physical structure of the production and distribution system as existing (or envisaged). This is a qualitative description coded in some standard manner which can be used as a reference in discussion and interaction with management.

4) Based on the descriptive model the system should be able to formulate internally (and possible interactively) a mathematical model of the situation. This model should be sufficiently detailed so that it incorporates all relevant aspects of the situation without making too many approximations. It could conceivably provide a simulation capability. Specifically it should not be structured according to any particular solution methodology. This model would be able to accept numerical input in terms of data and parameter values.

5) Based on the complex model the system could either set up data specifications and data requests, or depending on the size of the problem and the nature of the operating system required, undertake the design of a data-base and data management system.

6) The complex model could then be used as a basis for obtaining tractable and optimisable models by suitable simplification and adaptation. This presupposes an available menu of standard model formulations from which the appropriate model(s) can be chosen . This customization requires the system to have a decision making and design capability.

7) With regard to the models, it would appear to be useful to model the physical production and distribution system as a network or flow type of model. This type of model is desirable from an intuitive point of view, and has also proved important theoretically.

8) All cost functions in the complex model should be interms of real world costs (i.e. avoid formulations such as opportunity loss). This will facilitate communication and interaction with management.

9) To build up the structural model, finished product inventory for each plant product combination will be used as the starting point. From here, we can work backwards to determine the production system and forwards for the distribution system.

10) In describing the production system, we should focus on production operations between intermediate product inventories rather than in terms of physical production facilities such as machines.

Tactical issues:

As a first cut , KOMS will be using the structure proposed by Hax & Meal in [2] and described in detail elsewhere in the KOMS material. The available models are limited but still capable of handling many typical problems in operations management. In the present setup, the available models will be in the form of modules that can be linked together on the basis of what the problem is thought to require.

The information desired through the questionnaire is mainly at a structural level, and should be sufficient to design an appropriate operating system in terms of the components required. At this point no specific data or parameter values are to be collected, except for quantitative information relating to the size of the problem, or otherwise relevant in making decisions about problem format.

Specifically, the following tasks are to be completed:

- A qualitative description of the situation under consideration.
- A statement of feasibility (at KOMS' present state of knowledge).
- Determination of general problem characteristics in terms of decisions to be made, current level of aggregation and size of problem.
- Determination of need for a planning model.
- Determination of need for further aggregation; feasibility of aggregation, and interactive support for aggregation decisions.
- Listing and labelling of all products,work centres, plants, labour categories etc. at the appropriate level of aggregation.
- Determination of the production process for each product-plant pair at the appropriate level of aggregation.
- Preliminary choice of output system elements (modules).

We will briefly discuss some of these below:

QUALITATIVE DESCRIPTION :

i) Does the problem involve production, or is it a pure distribution problem ?

ii) Is the problem multiproduct or single product?

iii) Is the distribution system multilocation or single location?

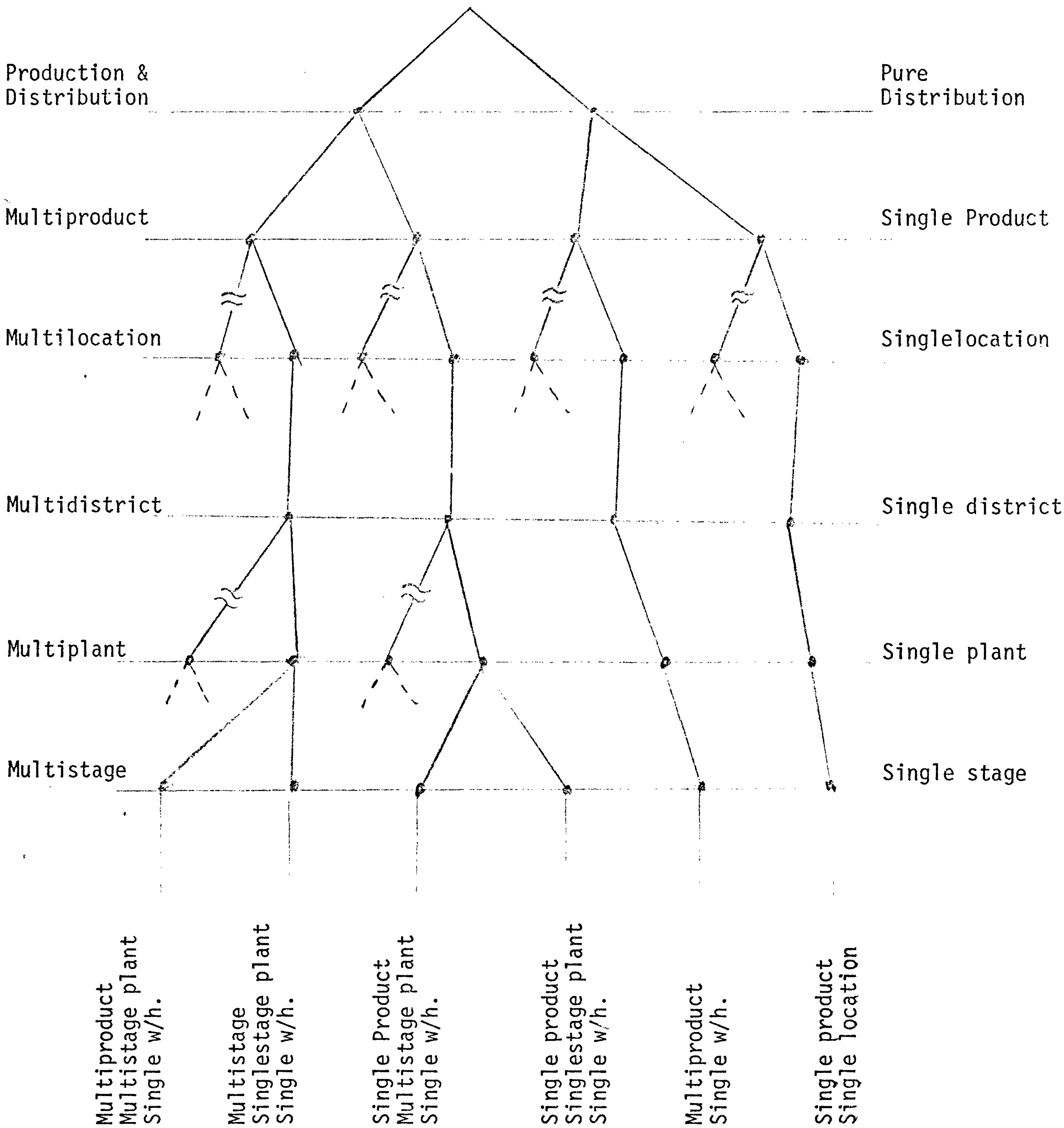
iv) Does the distribution system have several districts (segments)?

v) Is the problem multiplant?

vi) Is the problem multistage or single stage?

The answers to these six questions complete a basic qualitative description of the situation. The results of these questions will classify the problem as shown in the tree representation in Figure 1. In feasible branches have been pruned but in these cases limited assistance may be possible.

Figure 1 : QUALITATIVE DESCRIPTION



The meanings of the terms used in the qualitative description are :

Multiproduct : (Multicommodity) : More than one product sharing one or more limited resources.

Multilocation : More than one warehouse (location) supplying exogenous demands.

Multiplant : At least one product is produced by more than one plant

Multistage : Production process has inprocess inventories separating stages. Special cases include :

Serial - Each stage has single successor and single pre decessor.

Parallel - Several parallel stages between inprocess inventories.

Assembly - Each stage has a single successor.

Multidistrict : The market is segmented into districts with the distribution in each district managed independently.

AGGREGATE QUANTITATIVE DESCRIPTION :

Degree of Product aggregation:

1) How many products? (Total no. of Stock Keeping Units)
2) How many product lines?
3) How many models in each line?

Preliminary Demand Characterization :(May be on aggregate basis)

4) Do some or all products (product lines) have seasonal demand variations? How many products have uniform demand?
5) Is demand highly variable and unpredictable for some products?(stochastic)
6) Is there is a regular periodic component to the demand for some products? How many ?

Production Process : (according to product or product line)

7) Are products discrete, homogenous, both? (How many in each type?)
8) Is the production process continuous, batch or a combination ? (How many in each type?)

Time Horizon :

9) Is long term planning required (a year or more)?
10) What is the maximal planning horizon (in months)?
11) What is the minimal planning period in which decisions are made(months or fractions of months)?

Raw Materials Management : Raw material is defined as anything used in the production process that is purchased exogenously.

12) Is raw materials planning support desired?
13) Is availability of raw materials a factor due to possible shortages? (how many such raw materials?)
14) Are raw material prices highly variable? Seasonal? Are quantity discounts available?
15) Are there variations in quality ?
16) Are alternate sources of raw materials available? Do they differ in transport costs, prices, quality, lead times, availability?
17) Are there long term constraints ?
18) Do raw material inventory constraints operate?

Production Capacity :

19) Are short term capacity changes feasible within the proposed planning horizon?
20) How many work centrès (capacity types) are there?
21) How many capacity types are constraining?

Work Force :

22) Are workforce decisions to be made within planning period?
23) Howmany workforce categories are there?
24) How many are to be considered for hiring-firing decisions?
25) How many categories have overtime possibilities?

INTERNAL DECISIONS:

At this point it is necessary for the system to make preliminary decisions about the nature of the models required:

1) Is an aggregate capacity planning model required?
The major purpose of the planning model is production and workforce smoothing in a dynamic situation. The variability may be chiefly due to demand variability and seasonality. Planning may also be require for raw materials where availability and price factors are a problem.

2) Is aggregation required beyond the existing level ?
If a planning model is required, it may be necessary to aggregate the problem variables further to ensure that the size of the problem is not excessive. The size of the problem refers to the total number of decision variables and the total number of constraints that have to be included in the problem formulation. The decision variables include production quantities for each product, rawmaterial order quantities by source, variable capacity levels, hiring and firing decisions for each workforce category, with each of these decisions to be made for each time period. The constraints for the problem include demand satisfaction, capacity constraints, inventory constraints, workforce, raw material availability, raw material inventory capacity etc.

3) How to aggregate ?

i) Time periods : It may be possible to aggregate the number of time periods, by using a variable schedule in which time periods later in the horizon are longer.

ii) Products should be aggregated hierarchically into item groups, item families, product groups etc. upto the desired level of aggregation.

iii) Hierarchical planning: it may be possible to plan aggregated variables over a large horizon and to do medium and short range planning for various product types independently.

iv) Raw materials should be aggregated similar to products where possible.

v) Reduction of constraints : It may be possible to ignore certain capacity constraints and to adjust for infeasibility outside the planning model.

Each aggregation possibility has to be handled separately. For example:

PRODUCT AGGREGATION:

1) Group together products (product families) with uniform demand.

2) Group products with similar demand patterns.

3) For each demand pattern, separate into subgroups having similar inventory holding costs.List final grouping of product types and list individual items.

4) In each product grouping , group items together based on common setup costs, where items are similar except for minor modifications.

5) List item families for each product grouping and list items in each family.

In a similar manner we may aggregate raw materials based on cost variations, availability, and usage .

DETAILED DESCRIPTIONS :

Once the need for planning is established, and the desired level of aggregation has been achieved, it is necessary to obtain a detailed description of the problem. This procedure consists in the main of listing and labelling all relevant factors:

1) List all products (product types or families)
2) State which of these are Homogenous(continuous)/Discrete/ or both.
3) For which of these is the production process continuous/batch.
4) List raw materials (aggregated if necessary)
5) Identify raw materials with
   - Variable prices
   - Availability restrictions
   - Long procurement lead times
   - Common inventory capacity.
6) List production capacity types (work centres)
7) Which of these have fixed levels/ variable levels?
8)List workforce categories; identify variable levels.

9) List finished product inventory locations if inventory capacity is scarce.
10) List raw material inventory locations.

When the listing of all variables is complete, information has to be collected to enable the planning model to be formulated. This information relates to the dependencies amongst variables.

PRODUCTION PROCESS DESCRIPTION :

1) For each product (type, family)
   Which raw materials are required
   Which production resources are required (capacity types, labour categories)

2) For each finished product inventory location, list products stored.

3) For each raw material inventory location, list raw materials stored.

The latter operate only where capacity restrictions apply. Questions such as the above establish aggregate constraints on the variables. The other large class of constraints are equality constraints which are of two main types :

a) Mass balance equations such as those relating inventory,production and demand; and
b) Conversion equations which describe how resources are combined to produce a final or intermediate product.

The former set may be thought of as describing temporal relationships and the latter as spatial and physical. These need to be described to complete the description of the production process.

MODULE SELECTION :

We have described very briefly the general nature of the questionnaire stage in KOMS. At this point it is necessary to make a decision on the components of the proposed system. The available components are :

i) Regression Analysis package . This is required for long range forecasting, for purposes of aggregate capacity planning. The general information required to design the particular package that is appropriate includes a description of the model in termsof the independent and dependent variables, presence of seasonality and variability, information on promotions and advertising etc.

ii) Inventory Control package : This is required for raw material management, and may also be used for finished products. The forecasting routines require general information on the presence of trends and seasonality, and on the nature of the service criteria to be adopted for each controlled unit.

iii) Aggregate planning model : This has been extensively discussed above.

iv) Scheduling subsystems : These mainly require details on levels of aggregation for hierarchical scheduling if this is required.

The above discussion has not tackled the problem of data collection for actual parameter values. This is a vast task and may require the design of a data base and a data management system. This would be the next stage in building up the output package.

References :

[1] Hax, A; "The Knowledge-based Operations Management System" ; Internal Memorandum to KOMS group; M.I.T. ,July 1973.

[2] Hax, A; H.C.Meal; "Hierarchical Integration of Production Planning and Scheduling"; Alfred P.Sloan School Working Paper #656-73. (forthcoming in Management Science).