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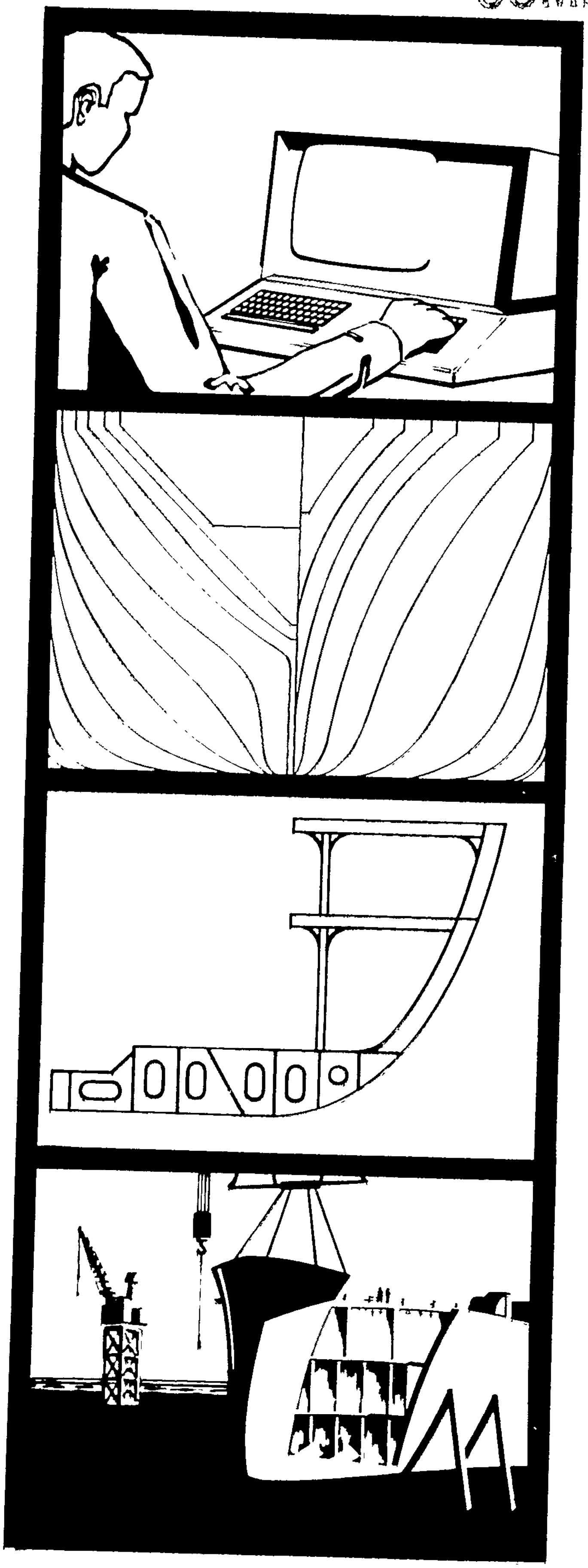

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MAR. 82

THE ROLE OF OPERATIONS RESEARCH IN SHIPBUILDING

James Low
Systems Analyst
National Steel and Shipbuilding Company
San Diego, California

Mr. Low is currently participating in the design and development of a computer-aided estimating system for shipbuilding under the auspices of REAPS.

Mr. Low is a graduate of the University of Strathclyde in Glasgow, Scotland, with a degree in operations research and economics. He has in-depth knowledge of the shipbuilding process, and 4 years experience in shipbuilding research with the British Ship Research Association including: operations research projects, productivity analyses, market studies, and simulations. He also has 7 years experience in data processing including: environmental monitoring systems, modeling of shipbuilding process, simulation, and project management systems.

Steve Knapp
Systems Analyst
National Steel and Shipbuilding Company
San Diego, California

Currently Mr. Knapp is engaged in designing a major computer system which will logically connect the major planning department systems by utilizing a new work definition technique, and incorporating this company's new planning philosophy.

Mr. Knapp has a degree in computer science from Pennsylvania State University, and has completed course work toward a masters degree in computer science at San Diego State University. He has 10 years experience in numerous facets of the data processing environment, including: military NTDS systems, simulation, operations research, advanced aerospace systems, general accounting, and shipbuilding production control, project management systems, and labor tracking systems.

Recent evaluations of the shipbulding industry indicate that a substantial reduction of potential revenues, both by industry and individual shipyards, will occur during the next decade. Foreign competition, limited military procurements, a tightening of the commercial market, and the economy of the country in general are all affecting the order books of all U.S. shipyards.

Realizing that increased technology can be of use to improve these shipbulding conditions, the authors prepared a short presentation for the recent REAPS Symposium which was held in San Diego in September, 1979. This paper describes the basic content of that presentation.

Operations Research in Shipbuilding

To evaluate the potential of Operations Research in the shipbuilding environment, we chose to demonstrate two applications of these techniques using an actual shipyard, which regrettably, is no longer in business. Investigation into recorded history presented us with an authentic case study, namely "Noah's Shipbuilding Company."

Noah had a small yard, incorporating a single ways, two shops, and miscellaneous support facilities. Recent negotiations with the Ultimate Customer gave Noah a veritable flood of orders, precipatated by very fluid market conditions.

Noah's yard had normally constructed only one type of ship, the Animal Retrieval Kraft (ARK). After subseqeunt redesign, coupled with an increased demand for larger capacities, he reorganized his facilities to build only

VLARKs, or Very Large ARK. To this end, the yard's construction services centered around this vessel with facilities and manpower necessary to support its construction.

Noah's latest contract, however, was for a ship capable of large capacities along with an increased loading/offloading capability. The ship, called the Tromp-on/Tromp-off (TO/TO), consisted basically of the original VLARK with a redesigned ramp system for high speed access by the animals.

This new ship caused Noah to re-evaluate his yard's potential because of the following reasons:

- 0 The TO/TO yielded a smaller profit margin over the VLARK.
- 0 Although the contract allowed for 40 rain days, the overall ship's construction schedule was tighter than Noah was accustomed to. For this contract, he literally had a drop-dead-date.
- 0 The ship's design called for an increased amount of venting than Noah's vent shop could' comfortably produce.

Understanding these constraints, Noah decided to employ Operations Research techniques to evaluate the problems of:

- 0 What product mix of VLARKs and TO/TOs would yield the best profit margin, and
- 0 What arrangements could be used to improve the productivity and output of his vent shop.

The O.R. techniques that he used will be discussed here. The product mix problem will be addressed by a Linear Programming, or L.P., model. The vent shop problem will be evaluated using Discrete Event Oriented Simulation techniques.

LINEAR PROGRAMMING PRODUCT MIX MODEL

By James Low

Linear Programming, or more commonly referred to as L.P., is a mathematical technique used in the allocation of scarce resources among competing demands in an optimal manner with respect to a predefined measure of effectiveness.

L.P. is most commonly used in product-mix situations to determine what quantities of which products should be produced to maximize profit, when many possible combinations and permutations exist. L.P. determines the best, or optimal, solution to the problem in a systematic and efficient manner.

In Noah's case, his products are competing for the limited facilities available, working against time constraints and also market limitations. The problem may be defined as follows:

0 The variables in the model are the number of ships of each type which will be constructed.

V = Number of VLARKs
T = Number of TO/TOs

These are referred to as the "Decision Variables."

0 The objective function which is to be optimized is defined as the profit resulting from ship construction.

VLARK profit = 1000 Shekels
TO/TO profit = 750 Shekels

The function is assumed to be linear and may be expresed as

PROFIT = 1OOOV + 750T

If the two ship-types utilized the same amounts of the same resources, it is obvious that Noah would build only VLARKs. But unfortunately, there are differing resource requirements and also a finite limit to the number of VLARKs which can be sold.

These resource requirements may be stated in the form of linear constraints on the model. The resource availabilities are also constraining factors. The labor force consists of two hundred people, evenly divided between ship and shop functions. In a year, the period in which Noah must make his killing, there are 313 "inside" working days, Sunday work being banned by decree. There are 273 "outside" working days due to a very reliable forecast of rain for 40 days and nights (never on Sundays). A VLARK requires 1500 man-days in the shop and 800 man-days on the ways. A TO/TO requires 900 man-days in the shop and 1200 man-days on the ways. In addition, there exists a finite demand for VLARKs, estimated by market analysis at 16 ships.

The linear constraints discussed can be expressed as follows:

0 Shop constraint

15OOV + 900T <= 31300

0 Ship constraint

800V + 1200T <= 27300

0 Market constraint

V<= 16

In addition to system constraints, certain assumptions must be made about the system.

0	"Certainty"	Noah was an accomplished prophet
0	"Linearity"	In the "objective function" and constraints
0	"Non-negativity"	Cannot build negative ships
0	"Additivity"	The whole = sum of the parts
0	Independence of Coefficients	
0	"Divisibility"	I.E. Continuous variables

Note that the last assumption is not realistic since we are dealing with integer variables, but it has been shown that the solution under the continuous assumption is sufficiently close in most situations to render integer programming techniques uneconomic.

The solution to the model can be obtained by a mathematical technique known as the "simplex method," or simply by graphing the feasible region. The feasible region is defined as the area bounded by the constraints and assumptions.

In order to depict the constraints graphically, we determine the intersection of any constraint line and the "V" and "T" axes. This gives us a straight line (we have assumed linearity) for that constraint. Referring to Figures LPl, LP2, and LP3, we note the straight-line ship, shop, and market constraints.

Overlaying the three constraint lines, we obtain *a* picture of the "feasible region," as shown in Figure LP3.

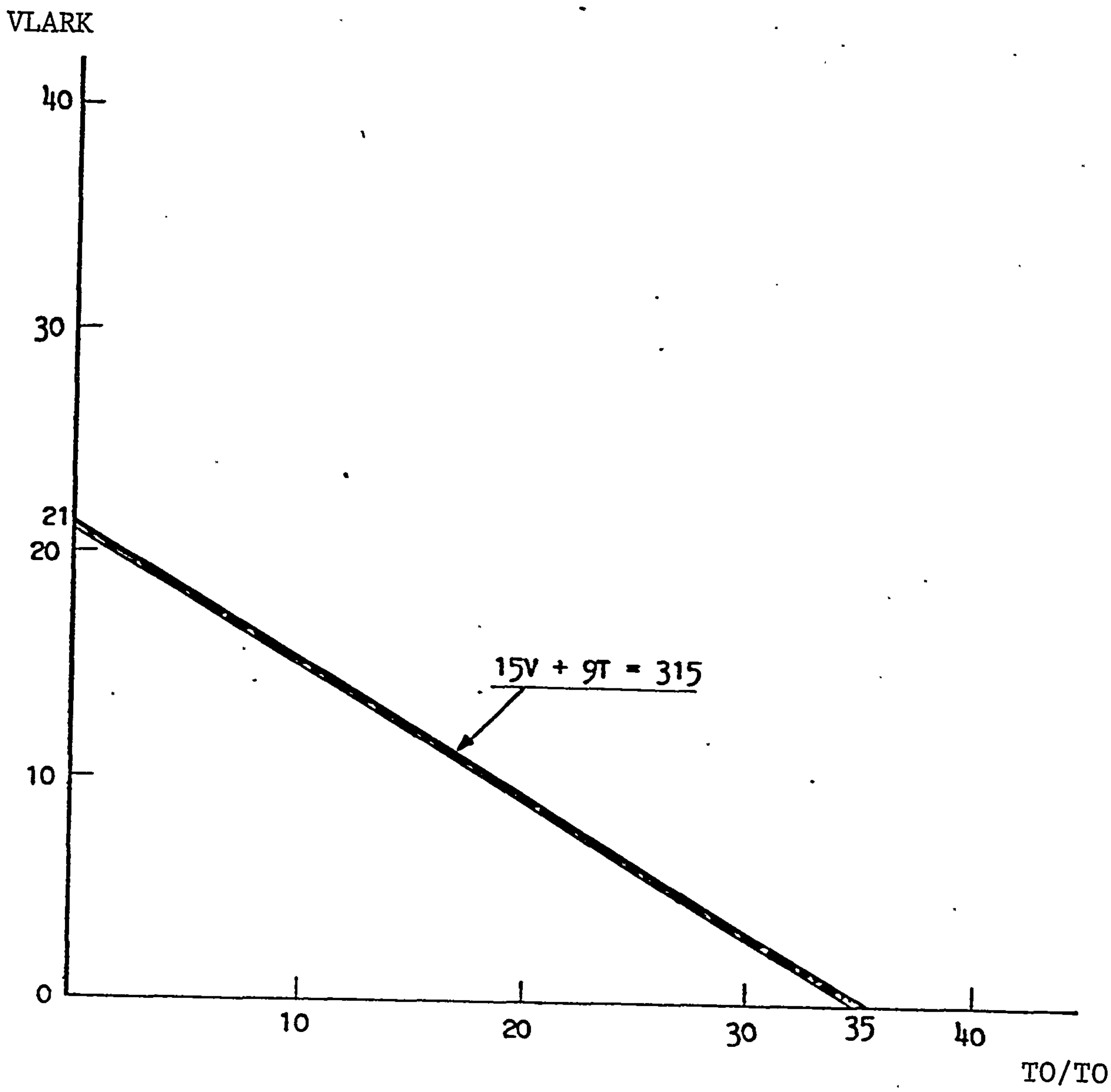


FIGURE LP1

SHIP CONSTRAINTS

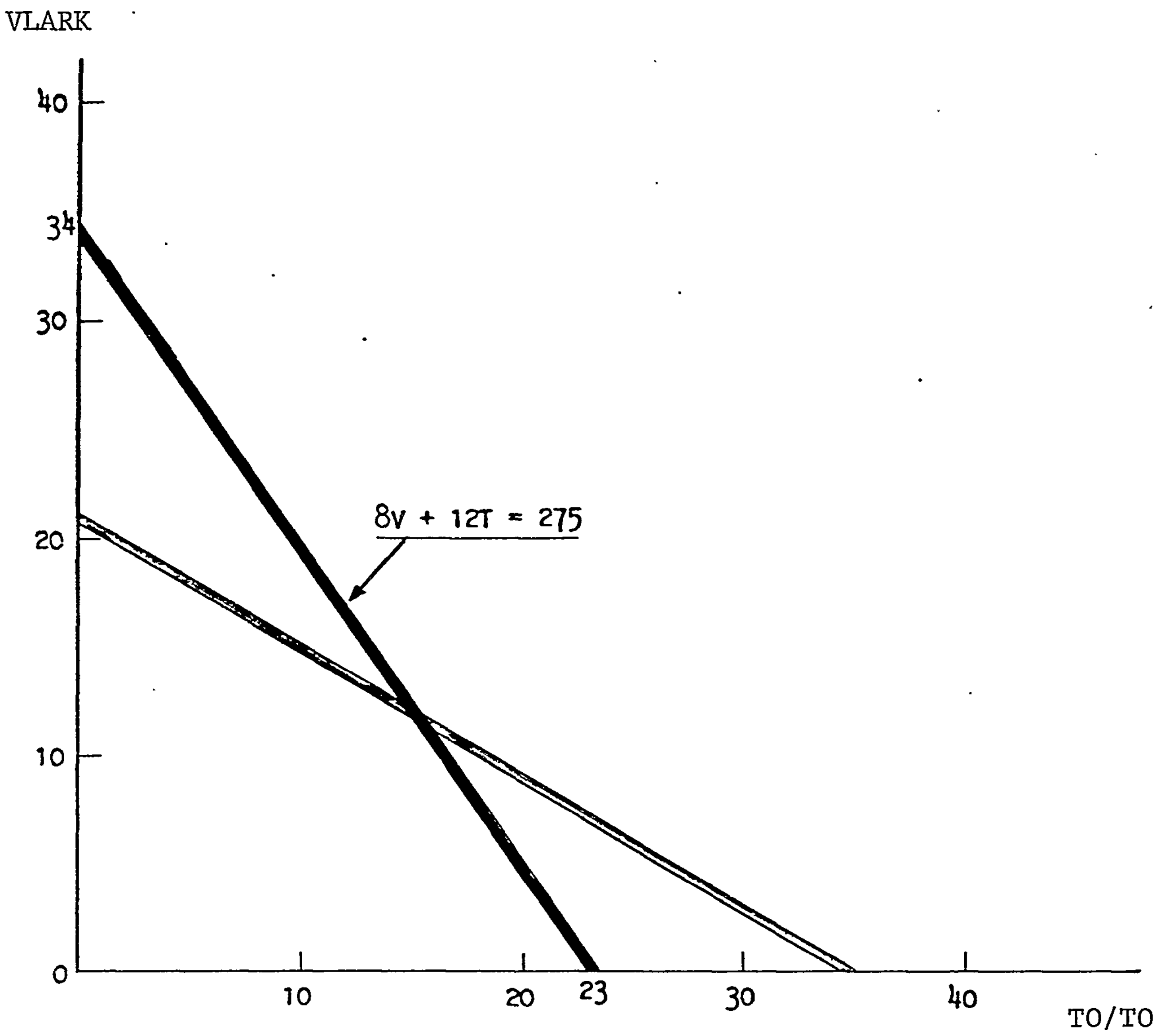


FIGURE LP2

ADD SHOP CONSTRAINTS TO SHIP CONSTRAINTS

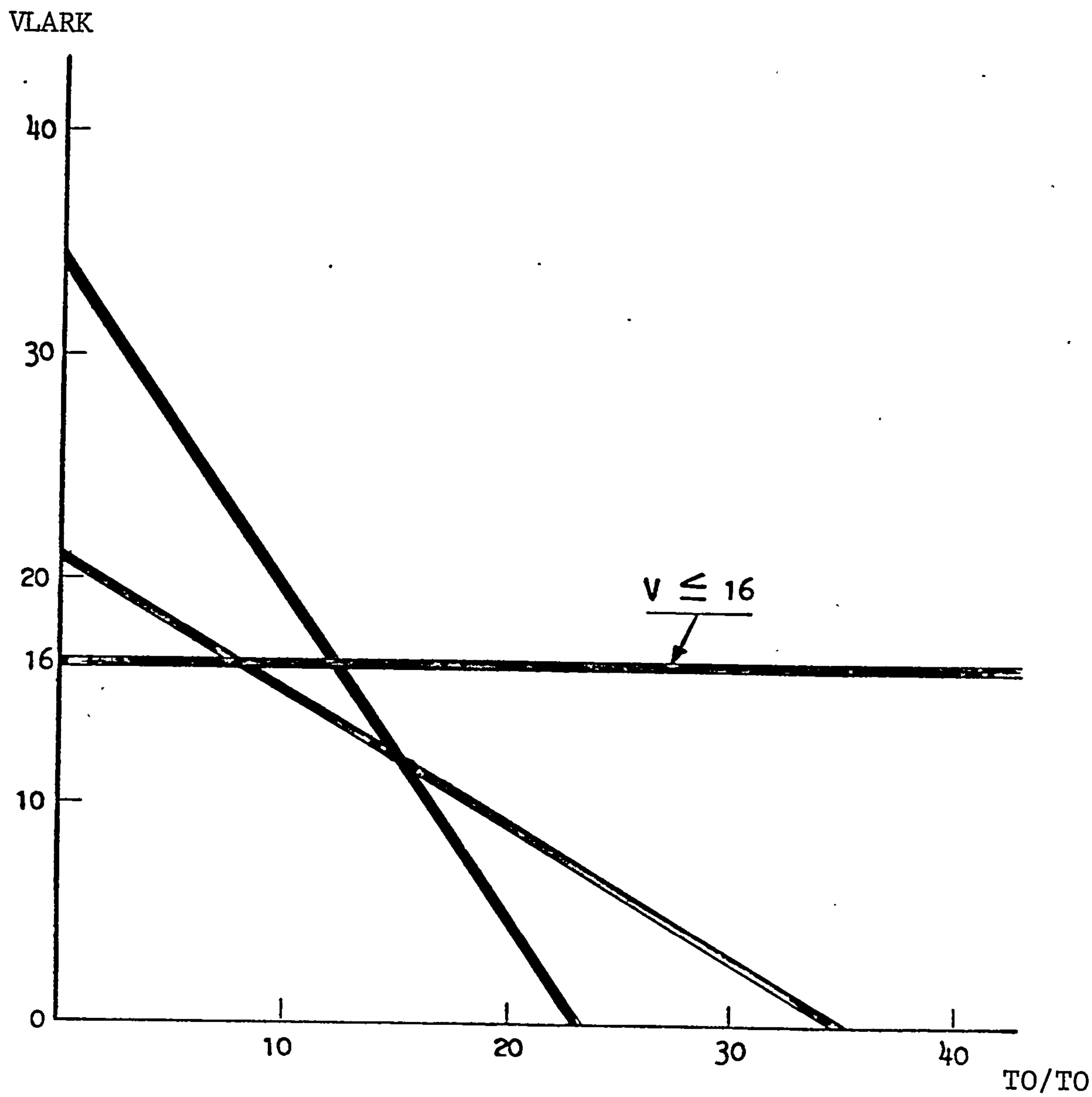


FIGURE LP3

MARKET CONSTRAINT OVER SHIP AND SHOP CONSTRAINTS

The profit is greatest along the boundary of the feasible region, and any optimal solution will lie on the boundary. The optimal solution may be obtained by enumeration of the intersections of the boundaries of the feasible region, or by the production of a graphical representation of the objective function. Refer to Figure LP4.

The objective function is graphed in the same way as the constraints. This function Line depicts the total profits which can be obtained by building entirely VLARKs or entirely TO/TOs. Note that, for any number of ships built, this objective function always represents the "best" profit picture possible, no matter how far that line is from the origin of the graph. This line is called the "isoprofit" line, and is drawn to cross the other constraint lines at the outermost point of the feasible region. As can be seen in Figure LP5, the coordinates of this coincident point represent the optimal solution.

From that point, we drop perpendicular Lines to both the "V" and "T" axes to determine how many VLARKs and TO/TOs should be built to best utilize Noah's resources, meanwhile realizing the maximum profits possible.

The example we have used is, of necessity, simplistic, and normal usage of Linear Programming requires sophisticated and powerful computer tools available as packages from sofware vendors. What we have attempted to do here is illustrate the principle of L.P. in such *a* manner that the concept of the methodology may be understood and the black art of Operations Research become less of an enigma.

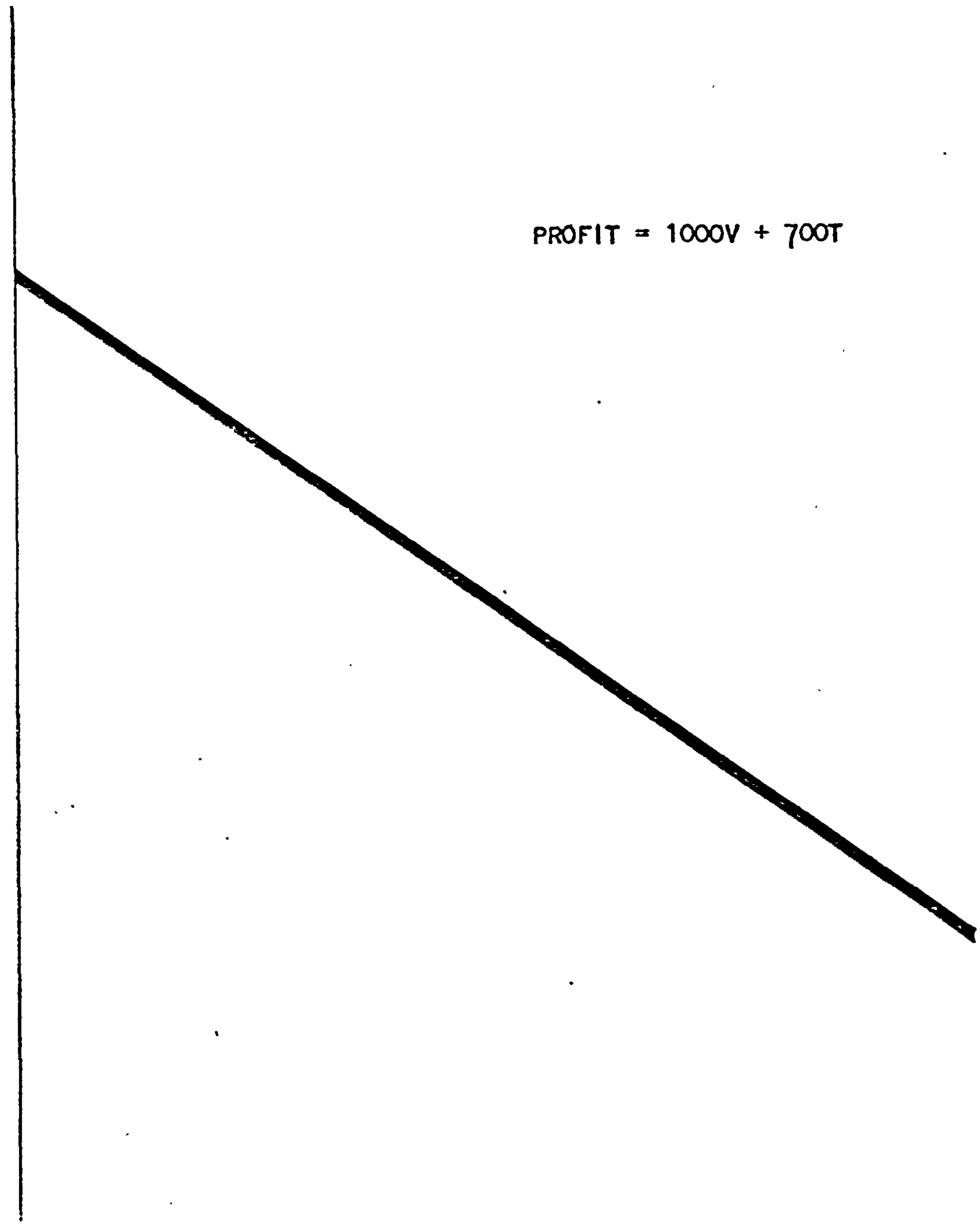


FIGURE LP4

"ISOPROFIT" LINE

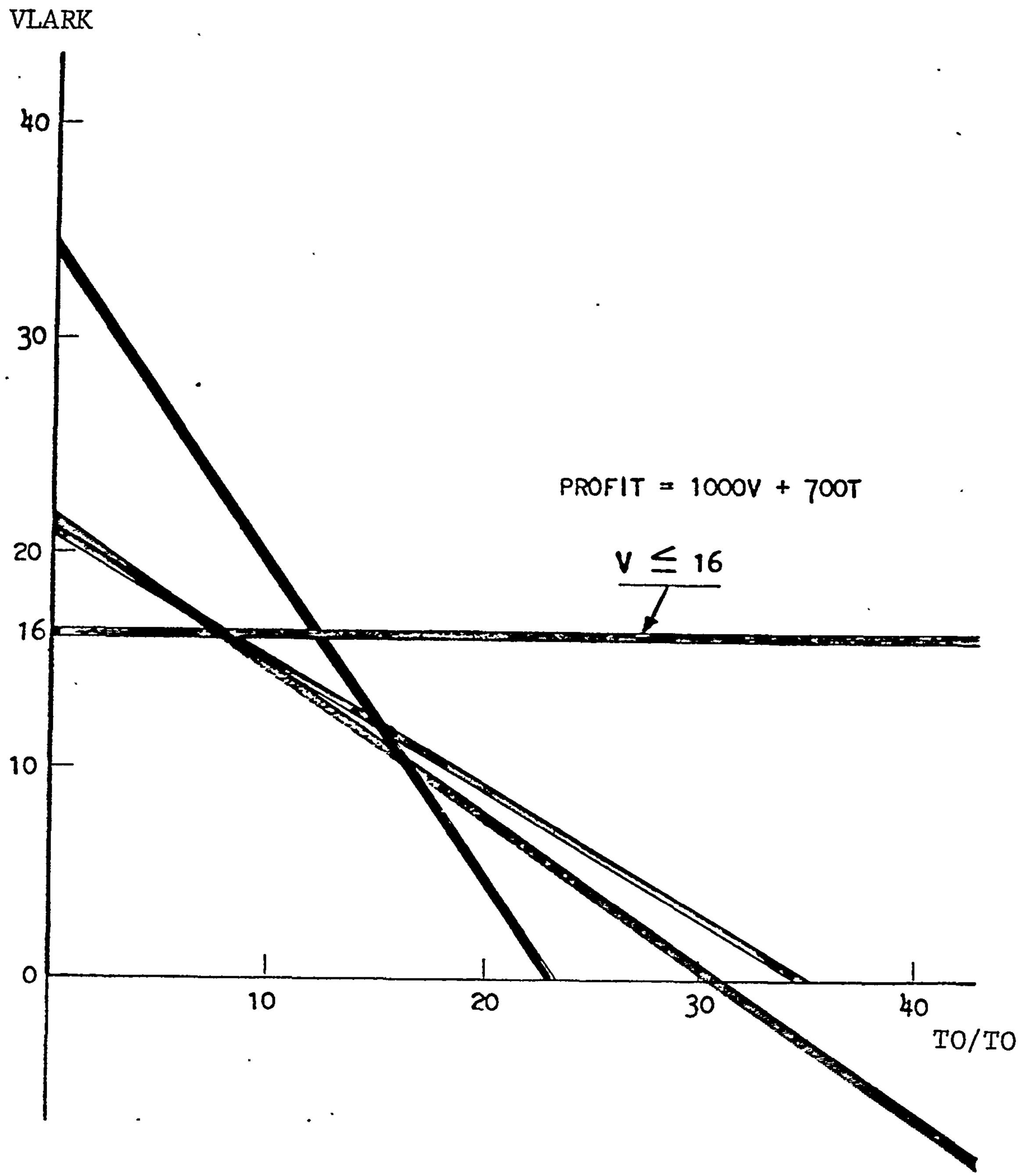


FIGURE LP5

ISOPROFIT LINE GRAPHED OVER CONSTRAINTS

DISCRETE SIMULATION OF THE VENT SHOP ENVIRONMENT

by Steve Knapp

As mentioned in the introduction, the TO/TO's design called for much more venting than Noah was accustomed to for the VLARK. The extreme vent requirements came from the fact that the high speed loading/off-loading caused the animals' metabolic rate to increase, resulting in a very unpleasant atmospheric condition within the hull.

Noah's primary concerns were as follows:

0 To determine the maximum output capabilities of the vent shop as currently configured.

0 To determine the required output to support the TO/TO's construction schedule.

0 To ascertain the extent of facility enhancements needed to support the TO/TO. (Noah felt sure that his vent shop could not support the TO/TO).

0 To analyze the material flow thru the vent shop in an attempt to improve material flow without expanding that shop's facilities.

Noah decided to approach these problems by employing a discrete, event oriented simulation model. Utilizing appropriate computer tools, most of which are off-the-shelf from mainframe vendors, Noah had his Operations Research staff create the necessary input entities to depict the vent shop as it currently existed. Material flow, machine set-up times, realistic labor consumption, standard management decisions, and machine utilization times *were* among the many items that the O.R. team measured, analyzed, and placed into the model.

To insure that the model would properly simulate the intended shop modifications, the Operations Research group chose to first set up the model to simulate the vent shop as currently configured. Not only would this validate the model against known thru-put, but would provide valuable insights necesary to modifying the model with regards to the proposed shop layout to support the TO/TO. Thus, by building the model *to* simulate the current shop facilities, material flow, available labor, and other known constraints, Noah was able to:

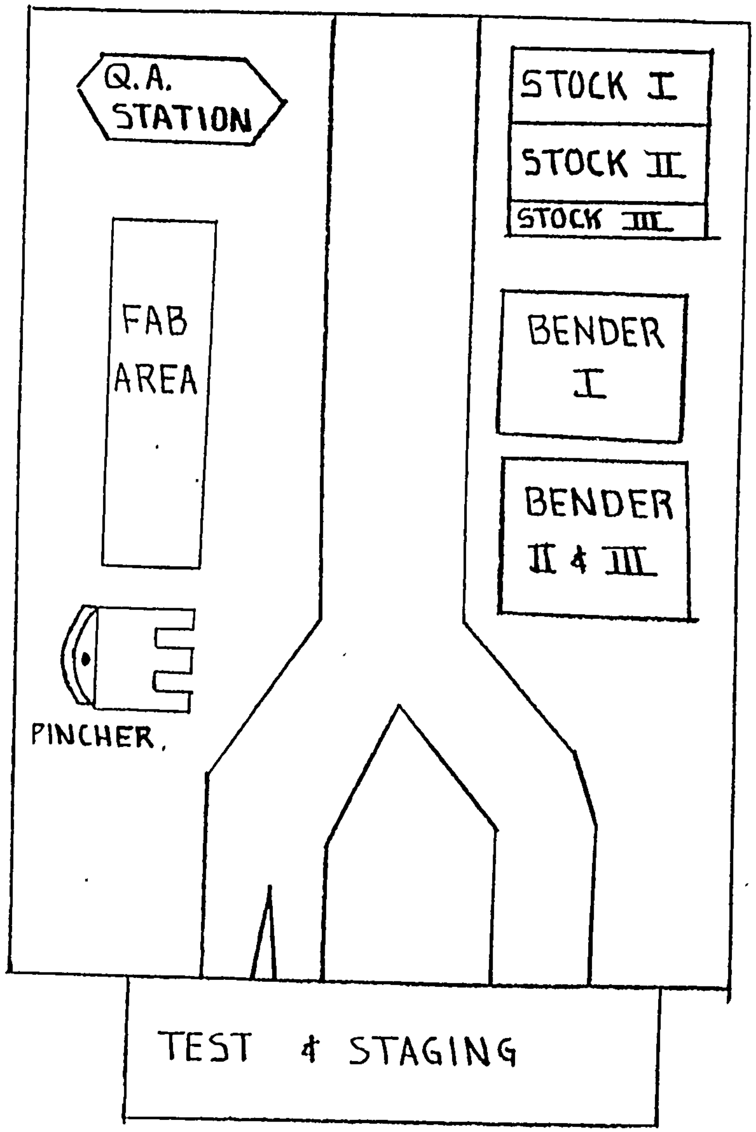
- 0 validate the model for accuracy,
- 0 recognize existing bottlenecks and limitations,
- 0 provide a vehicle for analyzing potential changes, and
- 0 establish a baseline of information for subsequent evaluation of the modified model.

Figure DSl depicts the vent shop layout and indicates some of the criteria for the simulation.

SIMULATION METHODOLOGY

A discrete event oriented model can best be used to simulate any environment where work occurs in isolated time periods. That is, if material (called "transactions") take finite amounts of time to travel (called "advancing") between storage (called "storage") and machinery (called "facilities"), then a model can be built to simulate that activity. Therefore, our vent shop model can be comprised of the following simulation entities:

ENVIRONMENT & MODEL OBJECTIVES



REPRODUCE EXISTING ENVIRONMENT

* CURRENT CONSTRAINTS
* THRUPUT
* FACILITY USE

ADJUST FUNCTIONS, ALGORITHMS, "TIMING", CONTROL DATA, ETC,

DETERMINE SHORT TERM SOLUTIONS WITHOUT DISRUPTING THE SHOP

. EVALUATE MAJOR CHANGES TO SUPPORT SALES POTENTIAL, SHIP'S SCHEDULE, PROFITS, ETC,

FIGURE DSl

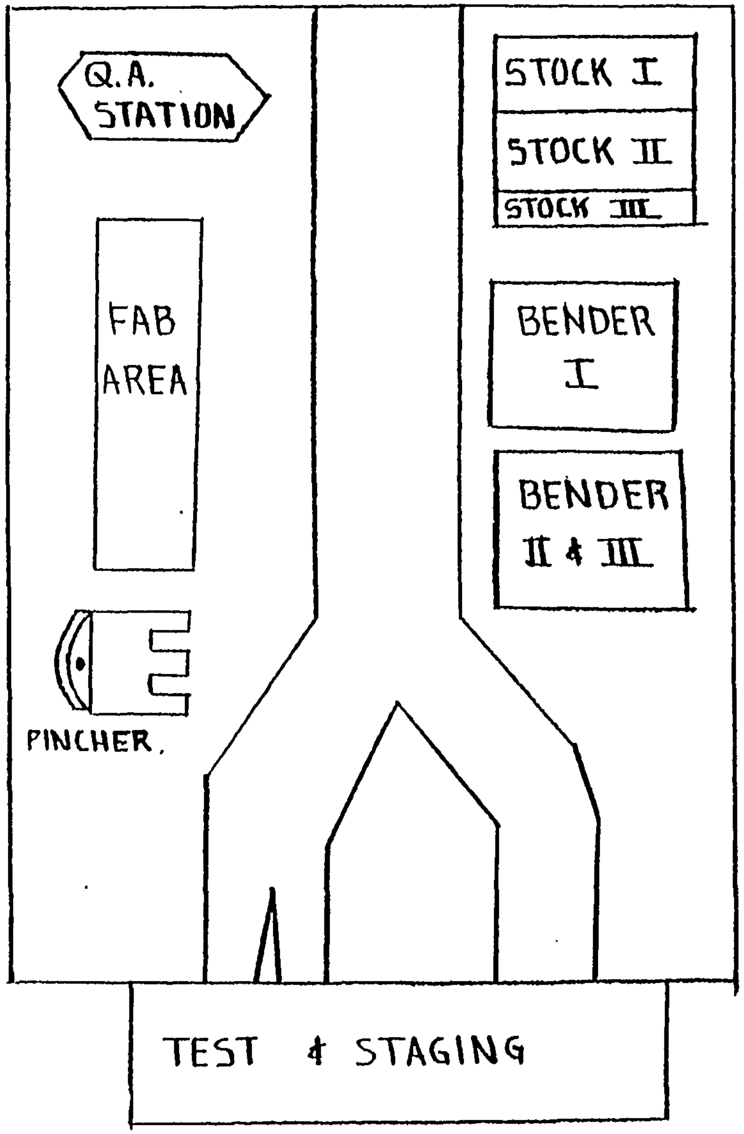
- 0 Faciliites — Machines, check points
- 0 Queues — On-floor staging
- 0 Storages — Bins, warehousing, in-shop storages
- 0 Advances — Travel, dead, or wait time consumption
- 0 Savevalues — Accumulators for measuring quantity flow at any point in the shop's model
- 0 Gates — Management decision points
- 0 Matches — Gathering of material, labor, or management decision to continue a process. I.E., two pieces of vent and a Q.A. action coming together to build a subassembly.
- 0 Functions — Machine up/down time curves, manpower availability curves, raw material arrival rates, inspection rates by material class, Q.A. rejection rates by material class, etc., etc.

Figure DS2 depicts the same vent shop along with a partial representation of the simulation model for that shop configuration.

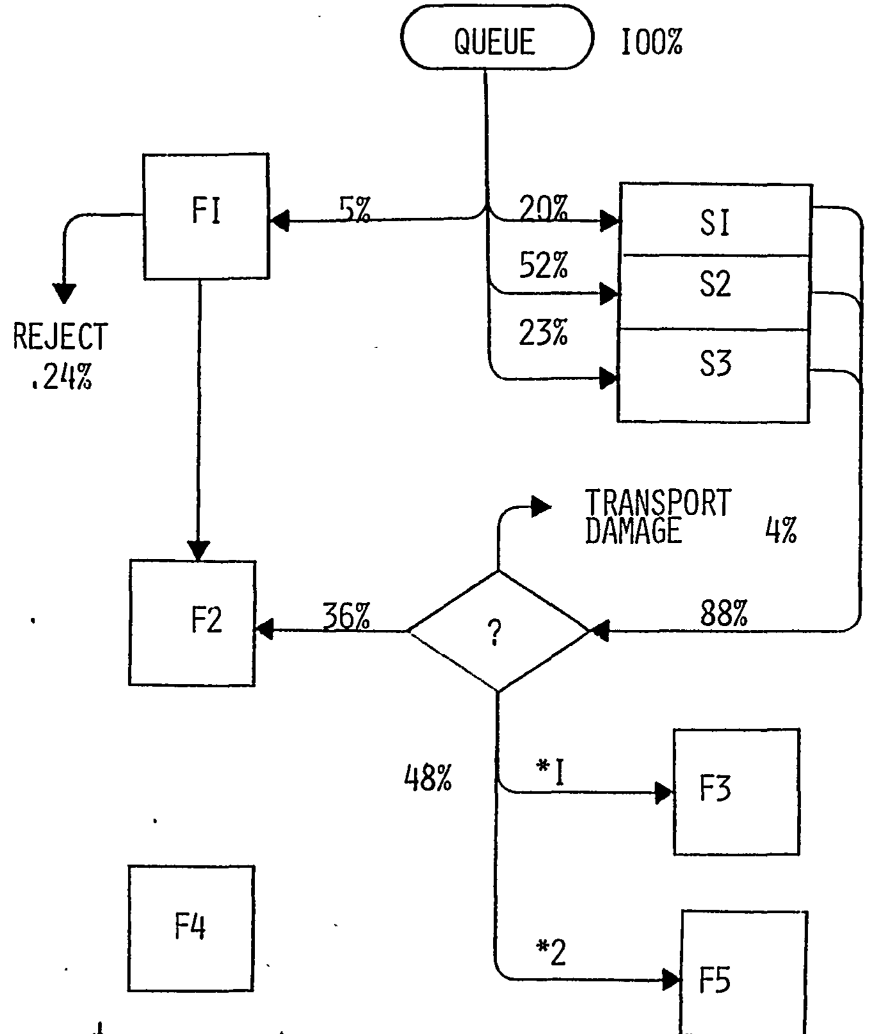
APPLICATION OF THE MODEL

Once a model is created which will simulate the existing environment, the model can then be modified in any manner conceivable to demonstrate potential changes to the vent shop, without actually spending large amounts of capital to actually upgrade the shop.

Thus, known material bottlenecks can be smoothed out without shutting down the shop for any required facility changes. The anticipated TO/TO demand can be placed on the model to determine just how well the actual shop will respond to the real demand. Proposed new machinery procurements can be simulated prior to purchase to determine whether or not that machinery will support the increased vent requirements.



Q.A. STATION
STOCK I
STOCK II
STOCK III
FAB AREA
BENDER I
BENDER II & III
PINCHER.
TEST & STAGING



QUEUE
100%
FI
5%
20%
52%
23%
SI
S2
S3
REJECT
.24%
TRANSPORT DAMAGE
4%
F2
36%
?
88%
48%
*I
F3
*2
F5
F4

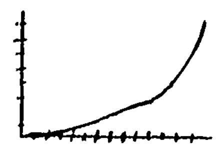


FIGURE DS2

In addition, should vendor specifications for a proposed piece of machinery be doubted, the simulation can be instructed to downplay the performance of a particular machine. This is easily done by changing the machine's performance "function," thus causing more simulated down time, setup time, or processing time. Numerous simulation runs can then be executed to determine the optimum arrangements of machinery, both new and existing.

Material flow can be evaluated using the simulation model. Storage and queue sizes can be modified to reflect in-shop material staging. Material transportation can be isolated and studied by supplying more material handing capabilities, re-arranging the shop floor, improving handling techniques, or modifying the material expediting methodology. All of these can be done without actually disrupting the normal day-to-day working environment of the existing shop.

RESULTS OF THE SIMULATION

Figure DS3 depicts one possible output from the computer simulation exercise. Referring to the figure, we see a detailed presentation of "faciities" and storages." While the columnar titles do not reflect shipbuilding nomenclature, we can interpret the data as follows:

- Facility Average Queue Length

  The amount of material items in staging within the confines of the shop. For each "facility," this tells us how many items are waiting the use of each machine.

FACILITIES

	AVERAGE LENGTH	AVERAGE TIME	MAXIMUM QUEUE SIZE	MAXIMUM USE TIME	TOTAL ENTRIES
FI	24	2.3412	31	3,4561	42
F2	12	37.8375	22	4114503	3s
F3	0	25,1000	0	32,5000	120
F4	G	10,2388	0	12,0000	38
F5	31	18,2500	32	46,1285	201

STORAGES

	AVERAGE QUANTITY	MAXIMUM QUANTITY	AVERAGE TIME/IN	MAXIMUM TIME/IN	TOTAL IN	CAPACITY
SI	101	120	102,234	120,000	327	500
S2	I64	203	95,200	100,120	253	1000
S3	35	100	202,101	23.114	I5I	200

FIGURE DS3

- Facility Average Use Time

  The amount of time consumed by each facility during the simulated real time. We can observe the time constraints of each machine or inspection area over the time span of the simulation. Time of use based on material class can also be simulated by enhancing the model (not shown here).

- Facility Maximum Use Time

  Averages give nominal use only. Maximum values augment our information by demonstrating upper limits on the timing of the shop.

- Storage Total Entries

  This helps us to determine if adequate in-shop storage is available for the incoming raw stock. Note that the next column, "Capacity," is preset by the simulation analyst to reflect the absolute capacity of each storage bin for each type of material. Possible bottlenecks for material storage can thus be evaluated by comparing these two pieces of data.

One single simulation run would be insufficient to evaluate all of the possibilities for streamlining Noah's vent shop. Numerous iterations would be performed on the model, changing key items in an attempt to optimize the model, and its resultant shop configuration. Such an evaluation would require involvement from various departments on the yard, such as:

- Production
- Planning/Scheduling
- Facilities
- Material Control
- Engineering

The model's results, once optimized and evaluated against all of the known criteria which influences the yard, would provide the basis for new facilities, machine procurement, ship's schedule relationships, and management visibility. All of this was done on the computer, without impacting the current activities of that shop as construction continues on existing vessels.

CONCLUSION

Our presentation at the REAPS Symposium was intended to demonstrate two possible applications of Operations Research techniques to the shipbuilding industry. The contents of this paper reflects that presentation and explains some of the technical arguments in greater detail.

It is the contention of the authors that such technology is necessary in our industry in an attempt to improve the shipbuilding methodology, increase. productivity, and generally upgrade our discipline by employing state-of-the-art analytical concepts. Through conversations with others and our own observations, we conclude that little emphasis is placed on Operations Research in terms of being a viable tool within our computer systems.

All too often, the computer use is limited to writing payroll checks, performing general accounting, and attempting material control. More advanced uses, such as Project Management Systems or advanced Material Requirements Planning systems, are seldom found. There seems to be a definite split between the technology of the computer and the “romance of shipbuilding.”

Considering the predictions of the shipbuilding future, this industry must begin investigating and investing in such technology to insure our competitive position in the world-wide market.

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