TESTCAP: A MANAGEMENT DECISION-MAKING TOOL

John J. Bruggeman

and Tom E. Salveson

International Business Machines Corporation

ABSTRACT

TESTCAP is a powerful new management tool which was specifically developed for decision makers. It quantifies risk, removes uncertainty and increases precision. It's objective is improving the capital investment decision process. This paper describes TESTCAP, its origin, and how it fits in the total resource-commitment decision process.

WHAT IS TESTCAP?

TESTCAP is a simulator designed to assist management assess the amount of risk implicit in a resource plan for a specific production-level plan. The key is quantifying the amount of risk being incurred, given the large number of stochastic elements in the production process. Quantifying risk is always difficult. Production environment is usually not completely defined. Operating policies are still in the formative stage and many of the equipment performance figures are guesses based on another plant's experience and our projected start-up learning curves.

TESTCAP deals with these complexities by providing a laboratory which can simulate the behavior of the production line under various experimental conditions. This allows testing various operating policies and assumptions. For each set of policies and assumptions, TESTCAP provides a risk analysis which quantifies the precise amount of risk being incurred.

BACKGROUND

TESTCAP was developed during the early planning phases of a new production line for our San Jose plant. Associated with the proposed production facility were three major areas of risk:

1. The resource plan would be inadequate to support the production-level plan.

2. The production-level plan seriously understated the actual level of demand which would be placed on the line.

3. Problems inherent in the start up of any new, highly complex, production process.

The extremely high cost of the capital equipment invalidated minimizing risk by taking an infinite capacity approach toward resources. On the contrary, sound management practice dictated adopting an aggressive risk-management posture.

Ordinarily, long lead times are involved in procuring equipment for production lines which require sophisticated technology. If later experience proves that additional resources are required to meet customer demands, it may well be too late to recover. Therefore, adopting a passive wait-and-see attitude is not practical.

This was the basic dilemma confronting the management team developing the resource plan. To aid the decision makers, the authors developed TESTCAP, a Monte Carlo simulation model, designed to:

1. Quantify the amount of risk associated with a proposed (equipment) resource plan, given any anticipated level of demand.

2. Quantify the impact of alternative strategies which may evolve during the decision-making process.

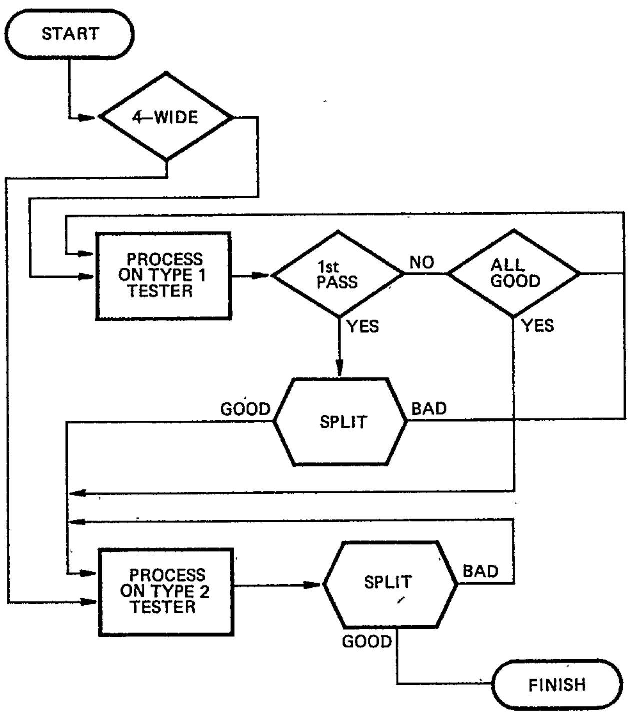
The intial resource plan for one portion of the new production facility called for two testers. Figure 1 shows the job flow logic which relates the testers. The production-level plan placed anticipated demand at 3000 units per day

Given this planning base, the decision alternatives* (extreme) confronting management were

* This characterization of the decision problem is actually a simplification of the real-world problem. The latter involved consideration of several different resource and production-level plans. Some of

ILLUSTRATION 1

Logic Flow Relating Type 1 and Type 2 Testers



1. High risk approach -- adopt the initial resource plan regardless of its associated risks.

2. Overly cautious approach -- augment the initial resource plan sufficiently to insure zero risk.

Obviously, a preferable choice would be to select a resource plan which involves a reasonable amount of risk and then rely on aggresive-risk management approach.

UNDERSTANDING THE RISKS

An intelligent risk-management policy must be based on a clear understanding of three factors:

1. Exact nature of the risk being incurred.

2. Amount of risk being incurred.

3. Costs associated with accepting and/or changing the risk.

---

the resource plans included alternate types of testers. Various shifting (2-shift v 3-shift; 5-days v 7-days, etc.) assumptions were considered, and so on. This simplified problem, however is adequate for illustrative purposes.

The primary risk associated with the tester procurement decision is simply a risk that the tester hours required per day will be greater than the tester hours available. The tester hours available are given in the resource plan. The difficulty is determining the number of tester hours required.

DETERMINING THE NUMBER OF TESTER HOURS REQUIRED

One of our other plants has used deterministic models to calculate the number of hours that are required. Averages (i.e., average thruput/hour, average yield, etc.) were used in these models. No specific consideration was given to fluctuations around these averages. Risk was heuristically assessed and discounted outside the formal calculations.

Three basic factors allowed this approach to be successful:

1. A large production base: Over 40,000 assembly parts are built, with extremely high daily volume on many. The advantage of large numbers comes into play, definitely working in their favor. Observed actuals tend to compare favorably with theoretical projections. Random fluctuations tend to dampen each other out.

2. A large resource base: Since multiple units of each type of tester, strong second-source backup, and an experienced labor pool are available, the minor fluctuations in individual tester performance, yield drift, etc., tend to disappear in the long-run stability of the total process.

3. Extensive practical experience in risk assessment for card assembly/test.

Unfortunately, none of these factors work for us. Our production level is an order of magnitude lower. Our resource base is considerably smaller (consistent with our lower production levels). Finally, despite the fact that the high-volume production of units is not new to the industry, it is new to San Jose.

WHY PRODUCTION REQUIREMENTS ARE NOT DETERMINISTIC

Despite the planning assumption that the production-level plan is fixed (e.g., 3000 units per day), actual production will vary above and below that figure on a day-to-day basis. Three primary factors cause this variation:

1. The ultimate demand for units comes from box schedules. Such schedules are independently

smoothed at the ship line. Adding together several independently smoothed (ship) schedules to create a composite (unit) subassembly schedule can result in a widely fluctuating schedule for the subassembly area. This fluctuation can be severely aggrevated by order sizing, miscellaneous demands, etc.

2. The order release system (which will be used to load the planned facility with work) was designed to operate in a resource rich environment. It basically assumes a relatively infinite resource production facility and, therefore, has only limited capability to keep actual release close to planned release. Even with smooth schedules, therefore, the order release system will introduce perturbations.

3. Even if orders are released close to the plan, the floor tracking system has minimal ability to keep the job streams arriving at the testers in balance and to keep the queues reasonably full*. Jobs may well get bunched and arrive at the testers in clusters. To the testers, this will appear as a wide swing in the daily going rate.

These factors are further compounded by the highly dynamic nature of the process itself.

To reflect this state of affairs, TESTCAP treats actual production, within a product family, as a random variable distributed uniformly about the mean daily going rate (quota) for the product family.

WHY TESTER TIME REQUIREMENTS ARE NOT DETERMINISTIC

The amount of tester time required to support a given level of production can be separated into two components: Setup time and pure test time. Each is subject to substantial variation.

Pure test time is a function of total unit thruput. Total unit thruput is the sum of good unit thruput and recycles. Yield, of course, determines the number of recycles required. Therefore, a major determinate of pure test time is yield.

The shear volume of production flow in other plants makes yield a relatively stable statistic which, in turn, is treated as a constant. The smaller rate of flow that we have results in high sensitivity to short-run fluctuations away from the average. Therefore, TESTCAP incorporates the ability to represent this short-run fluctuation with a random variable distributed normally about the mean yields. Mean yields are based on observing the results by tester, by pass.

Setup time depends directly on the number of setups required. Both testers require one setup per job per pass through the tester. A job is composed of one or more assemblies of the same part number/engineering change.

Variability in the number of setups is primarily attributable to lot-size variation. Lot size, in this context, is the actual quantity associated with a job when it reaches the test area. In many studies, lot size is considered a control variable whose value can be selected at will be the process manager. Unfortunately, this assumption is not valid in connection with the proposed unit assembly facility.

Lot size is expected to vary randomly, and widely. It is not amenable to control. Several factors contribute to its variability:

1. Certain part numbers have demands which are relatively unpredictable, and therefore, subject to highly variable lot sizes (since demand patterns cannot be predicted, and logically grouped into stable lot sizes). These demands arise from feature changes and other miscellaneous field demands.

2. Component availability constraints have existed for some time. They restrict the availability of the work dispatcher to release his preferred lot sizes. The result as seen by manufacturing is erratic lot-size patterns. Although the situation is becoming better in internally produced modules, market forecasts (as well as actual procurement experience) indicate that discrete components may well become a serious lot-size inhibitor.

3. High E/C activity can vary, although usually heaviest from product release through a period ranging from 6 - 9 months. The economics of scrap and rework often preclude releasing 'preferred lot sizes'.

4. Down-level field returns represent another challenge. Current logistic and financial systems require that rework cannot be combined with new production. Further, current systems necessitate keeping rework from different predecessor EC's separated. The apparent random pattern of down-level returns acts as a serious inhibitor to release of preferred lot sizes.

5. The term preferred lot size is used frequently above. It connotes recognition of the economics of scale which can be realized by keeping lot sizes large (thereby minimizing setups). A more subtle benefit is the fact that the larger the lots, the fewer the number of jobs in process (for a given level of production). Control is the crucial element in the volume production of units. Therefore, every effort will be made to release large jobs. This in itself can introduce considerable lot size fluctuation. Commonality of components could mean that the

* The failure of jobs to arrive on time, and smoothly, at the testers cannot be mitigated by artificially smoothing workload. San Jose will be measured on its ability to ship boxes. Therefore, due-date constraints must be rigorously observed. If jobs arrive late at testers, the lag must be made up immediately. This precludes artificially smoothing tester time by carrying over (to the next shift) larger queues than normal.

release of one large job for one part number causes several small jobs for other part numbers. None of the systems currently available protect against this possibility.

The above five factors are not the sole contributors to lot-size variability. They are, however, indicative of the constrained environment within which the production control job dispatcher must operate.

Production Control undertook an extensive study to determine the probable lot size distributions which manufacturing would see. Two conclusions of that study were used in the design of TESTCAP:

1. The mean lot size can be represented by a random variable which is distributed as follows:

5% chance that its value is 20-24
90% chance that its value is 25-65
5% chance that its value is greater than 65

2. The individual lot sizes can be represented by a family of random variables distributed Poisson about the above means.

TESTCAP incorporates a weekly mean lot size random variable and an individual lot-size random variable to represent the above findings. During the tester procurement decision process, the weekly mean lot size was held constant at 30 (or 20 in some cases). Only the individual lot size random variate was allowed to vary.

APPLICATION OF TESTCAP OUTPUT

An example is presented to illustrate the application of TESTCAP output (Table 1). The assumption is that man/machine availability is 75%, and that 2 hours per day are required for test-data generation.

TABLE 1

Risk Analysis Depicting Risk Associated with Various Levels of Tester Time Available per Day

Number of Tester Hours Available/Day	Chance that Tester Hours are Adequate	Risk that Tester Hours are Inadequate
8	0.0	100.0
9	1.5	98.5
10	18.2	81.8
11	54.9	45.1
12	89.3	11.7
13	100.0	0.0

The analyst using the output begins by determining the number of tester hours available/day:

2-Shift Calculation

16.0	Total hours in 2-shifts
x 0.75	Availability factor
12.0	Gross hours available
- 2.0	Required test data generation time
10.0	Total number of tester hours available/day

He refers to Table 1 and determines that the risk is 81.6% that tester hours will be inadequate.

3-Shift Calculation

21.5	Total hours in 3-shift
x 0.75	Availability factor
16.1	Gross hours available
- 2.0	Required test-data generation time
14.1	Total number of tester hours available/day

He refers to Table 1 and determines that the risk is 0% that tester hours will be inadequate.

If management wishes to assess an alternative such as planned 20% overtime, the calculation is also straightforward:

2-Shift = 20% O. T. Calculation

16.0	Total hours in 2-shifts
x 1.2	Factor to reelect 20% O. T.
19.2	Total hours in 2-shifts ÷ 20% O. T.
x 0.75	Availability factor
14.4	Gross hours available
- 2.0	Required test data generation time
12.4	Total number of tester hours available

He can then interpolate from Table 1 to determine that quantifiable risk is approximately 5% that tester hours will be inadequate.

If management finds that the straight 2-shift risk of 8.6% is too great, the analyst can show that 2-shifts + 20% O. T. could reduce the risk to a more manageable 5% or that 3-shifts would eliminate virtually all quantifiable risk.

TESTCAP AND THE TOTAL DECISION PROCESS

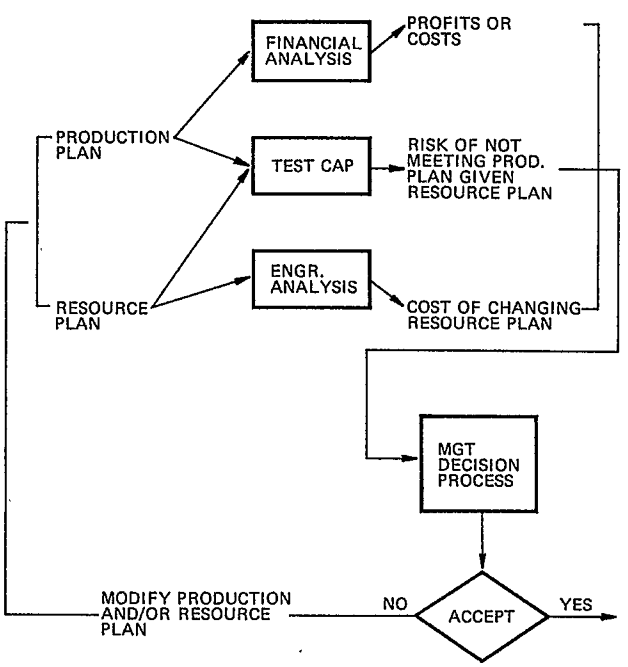
The ultimate value of TESTCAP is that it is an integral element in a total decision-making process. It is one of three major inputs to that process.

TESTCAP provides a logical description of the behavior of the production line, given the (1) resource plan (i.e., number of testers, number of shifts, etc.), and (2) production level plan (i.e., number of units per day, mix, etc.). TESTCAP calculates the probable number of tester hours required per day to support production test requirements. It explicitly excludes tester time required for test-data generation and it does not factor in man/machine availability. The output consists of a risk analysis supported by a variety of descriptive statistics on the behavior of the production line. This risk analysis then becomes the first of three key inputs to the tester-procurement decision process.

The second input to the total decision-making process is an analysis of the financial consequences of taking the gamble (risk) and losing. Such an analysis would consider the utilization of overtime, alternate methods of shipment, and possible loss of customer good will.

ILLUSTRATION 2

Total Decision Making Process



The third major input consists of a test engineering study of the increment cost of increasing/decreasing the resource plan.

Figure 2 depicts the total tester resource-procurement decision process.

The information supplied from these three input scores can be utilized by the management team to answer such basic questions as:

- What is the risk that our resources are inadequate?
- What will it cost if we don't meet the production plan?
- What will we lose if we cut back the production plan?
- How much can we reduce risk by planned overtime? By adding a shift? By getting more equipment?
- How much will each of the alternatives cost?

Obviously, providing the answers is not equivalent to making the decision. But the answers are key aids to the decision makers.

ACKNOWLEDGEMENTS

D. Brewer provided data, reviewed the model logic, and analyzed the output. V. Madden and R. Nobles granted the time and computer budget for this work.