Simulations, Gaming and Experiential Learning:, Volume 1, 1974

INTERACTIVE GAMING: A PRODUCTION EXAMPLE

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INTRODUCTION

Over the past ten years considerable attention has been focused on the problem of production line balancing. Numerous computer algorithms have been developed for determining either an exact or approximate balance [1]. Despite the number of computer routines available, much of the balancing has been performed either manually or by trial and error--in a study made in 1969 Lehman found that less than 20% of the industry surveyed employed a computerized balancing system [2]. A key reason for this is the lack of understanding [3, p. iii]. Quite often valid techniques have been developed, but remained unused because the technique was not fully understood by the production manager. A manager thus may elect to live with the balancing problem rather than accept a solution that is foreign and suspicious.

It has been the author's experience that interactive gaming can be used to resolve some of the "lack of understanding" of defined solution techniques for solving certain production problems. This research specifically reports and demonstrates how interactive gaming was used to expose production managers to a production line balancing technique[1].

THE PROBLEM

In engineering terms a balanced line can be defined as a series of progressively related operations each having approximately equally required production times, arranged so that work flows at a desired rate from one operation to the next. Expressed in simple terms, a balance is achieved when all production operations are functioning simultaneously at a planned manufacturing rate with no change in in-process inventories.

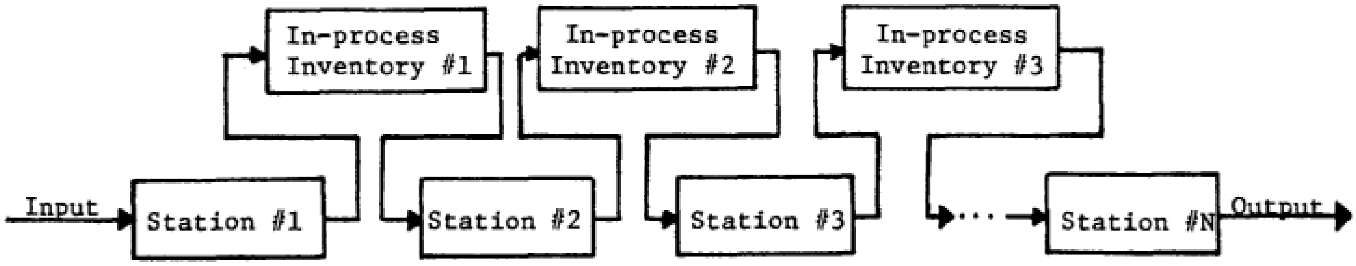
Figure 1 is a pictorial representation of the balancing problem. When the production operation is in balance a constant output results with no change in the in-process levels at any station along the line.

To achieve the balanced condition, numerous techniques are available [1,2]. Though these techniques differ somewhat in the solution approach, each basically involves the interrelating of the same general factors. These factors included the breakdown of the operation into elements, specification of times required to perform each element, determination of the efficiency of operators, identifying the sequence of operations, and finally establishing the required rate of production.

[1] A very readable text describing the concepts of interactive modeling-gaming is Computer-Aided Modeling for Managers by Steven C. Wheelwright and Spyros G. Makridakis, (Addison-Wesley, 1972).

FIGURE 1

The Balancing Problem



In interrelating these factors, many solution techniques require physical changes in the production. However, one can achieve a balance by specifying a desired output rate and back-tracing through the line to determine operator assignments. It should be recognized, however, that such a solution approach, while not requiring physical changes, may require the reassignment of production personnel. To implement the approach thus would require total acceptance by production managers.

The Existing System

The above solution approach was adopted by upper management of the XYZ Corporation (a multi-million dollar industrial firm) as a means for minimizing product cycle time and controlling work-in-process inventories[2]. A large computerized system was developed. The system was designed to furnish daily reports that specified machine and personnel utilization requirements necessary for meeting required production outputs. A data collection system was designed to support the system. The data system was to provide an efficient means for on-line collection and entry of production data. Data were to be collected on-line in the production environment, transmitted to a control processor, and recorded on magnetic tape. The input tape could then be used on a daily basis for updating the data base of the balancing system.

In addition to the balancing system, a production planning, scheduling, an inventory control, a capacity utilization, and a resource allocation system had been developed by the firm.

Eighteen months after the balancing system was installed, upper management noted that there had been little change in in-process inventories and production cycle times were still extremely high. Upon discussing the problem with production managers it was found that the majority of managers failed

[2] [2]Management within the firm requested that the identity of the firm remain anonymous.

to implement the specified personnel utilization structure given in the daily production report. Several reasons were given for the lack of utilization, but the most frequently mentioned factor was the lack of understanding of the system and unwillingness to commit the production operation to a “black box” procedure. One manager expressed his views in this manner:

> “Most production managers use the planning and scheduling systems because the systems compliment the production process. They provide useful planning information. Most fellows do not understand the concepts associated with the production line balancing and allocation systems. These systems alter the production process--I find difficult to visualize how the systems can help me.”[3]

THE GAMING EXERCISE

The Game

In an attempt to resolve some of the problems associated with the balancing system and thus increase its usage, the decision was made by upper management to develop a quantitative game to demonstrate the concepts employed in the system. The game was designed to parallel the logic employed in the system; however, it is not a simulation of the system.[4] To make usage of the game most flexible it was developed on a time sharing computer--the interactive nature of time-sharing was very amenable to the gaming activity. Portable terminals were available for exercising the game. This portable feature allowed the game to be conducted directly in the operating area.

Gaming Sessions

Using the game as the focal point, gaming sessions were conducted within the production departments. The actual sessions involved a short lecture on the theory of line balancing, an explanation of the objectives of game- play, actual game play, and finally a critique of the game and game session. Both production managers and operators were involved in the sessions.

Eleven game sessions involving one hundred and thirty-six participants were sampled to gather data on the gaming activity. A game session questionnaire was employed in gathering the data. Each participant completed the questionnaire at the conclusion of the game session. Some of the responses from the questionnaire were as follows:

> “This is a good way to communicate systems to users. I would like to see more of this same sort of communication on other systems.”

---

[3] Statement by Mr. X, September, 1971 (anonymity requested).

[4] [4]Appendix A contains a sample “run” of the game. The required data to be inputted by the game participant is underlined in the example run.

"The game gives you a chance to try different alternatives and study the effects."

"It helps you understand the problems in line-balancing and develops a better understanding of the part the system plays."[5]

RESULTS AND CONCLUSIONS

Results

To measure the effect of the gaming activity on the use of the balancing system, sixteen production operations were monitored. Data were collected before and after the gaming sessions on production indices such as levels of work-in-process inventories, required production operators, output, and cycle time. Table I is a sample of the data collected from one production operation.

An analysis of the indices data indicated the game sessions were effective--in twelve of the sixteen operations improvements were noted. Interviews with the managers in the sampled operations confirmed that the changes in the production indices were a result of usage of the line-balancing system and that use of the system was stimulated by the gaming sessions.

TABLE I

A Sample Production-Indices Data

Oper-ation	Indices	Units of Measure	Prior 3 Mo. Avg.	1970 Oct.	1970 Nov.	1970 Dec.	1971 Jan.	1971 Feb.
A	Work-in-Process Inventory	000's of units	634.1	452.0	459.0	81.8	147.7	138.8
	People	...	24	23	28	32	24	26
	Pro-duction Output	000's of units	659.8	896.5	826.6	912.7	923.3	1175.5
	Cycle time	days	8.3	8.8	6.1	4.4	3.1	2.3
	Produc-tivity	000's of units! per.	28.5	34.4	29.5	38.5	38.5	45.2

[5] ldentity of game participants responding to the questionnaire was not requested. This approach was taken on the assumption that more candid responses would result

Conclusions

Traditionally line-balancing systems have not been successfully implemented, even when theoretically sound concepts were employed. In the case reported here a somewhat basic technique was employed; implementation and usage, however, was still a failure until the gaming sessions were employed. One could thus conclude that interactive gaming can be a useful training vehicle.

A secondary conclusion, and possibly a more important result from the study, is that gaming may be a useful tool for identifying design faults or constraints in a system. During the game sessions managers repeatedly voiced the opinion that the game was too constrained--a player was forced to reduce his in-process inventories to a minimum and to balance the line in a single time period. When the game was redesigned such that a player could specify a "desired work-in-process" and could use multiple periods for balancing, participants voiced a strong, favorable reaction to the game. A majority of the sixteen managers sampled after the sessions indicated the relaxed constraints in the system was a key reason for their adopting the system--the logic changes made in the game were made in the existing systems. Gaming thus may serve as a system design tool.

APPENDIX A

HI, THIS IS THE PRODUCTION CONTROL GAME. THE PROBLEM AREA FOR THIS GAME IS THAT OF ASSEMBLY LINE BALANCING. YOU ARE PLAYING THE GAME IN ORDER TO GAIN SOME APPRECIATION FOR THE DIFFICULTIES INVOLVED IN LINE BALANCING AND TO GAIN A PERSPECTIVE OF HOW THE PRODUCTION CONTROL SYSTEM ARRIVES AT A SOLUTION TO THE PROBLEM.

THE PRODUCTION PROCESS FOR THE LINE INVOLVES A METAL BRAZING OPERATION. THE PROCESS CONSISTS OF SIX ACTIVITIES. FIRST, IT IS NECESSARY TO ASSEMBLE FOUR RING ASSEMBLIES INTO A METAL HOUSING. THE ASSEMBLY IS THEN PLACED ON A MOVING BELT CONVEYOR FURNACE IN WHICH THE BRAZING PROCESS OCCURS. AFTER PASSING THROUGH THE FURNACE THE ASSEMBLIES ARE UNLOADED AND INSPECTED, REJECTS ARE THROWN OUT. THE ACCEPTABLE ASSEMBLIES THEN PASS THROUGH A CLEANING ACTIVITY FOLLOWED BY A REAM ACTIVITY IN WHICH AN INNER PORTION OF THE ASSEMBLY IS REAMED TO A GIVEN DIAMETER. THE ASSEMBLIES THEN PASS THROUGH A SECOND AND FINAL INSPECTION AND PACKAGING OPERATION. THE CURRENT SITUATION OF THE LINE IS AS FOLLOWS:

	Station Output (Per Hr)	Yield	Operation Standard (Units/HR)	Operator Eff	No. Of Oper	Work In Progress	Allowed WIP	Cycle Time (HRS)
Assemble	267.4	1.00	37.0	1.12	6.5	45	45	.17

Furnace	267.4	1.00	0.0	0.00	0.0	480.	63.	1.80
Unload	246.0	.92	91.0	1.03	2.9	360.	20.	1.35
Clean	246.0	1.00	54.0	.96	4.7	740.	31.	3.01
Ream	246.0	1.00	28.0	1.00	8.8	265.	57.	1.08
Inspect	214.0	.87	11.0	1.03	21.7	275.	140.	1.12

Total No. of Operators = 44.5
Total Cycle Time = 8.5 Hours

THIS IS THE WAY THE LINE HAS BEEN RUNNING FOR SOME TIME NOW. AS YOU CAN SEE, THERE IS TOO MUCH WORK IN PROCESS ALL ALONG THE LINE AND THE CYCLE TINE SHOULD BE A FRACTION OF WHAT IT IS NOW.

YOU HAVE JUST BEEN PUT IN CHARGE OF THIS LINE, AND IT IS YOUR JOB TO ASSIGN OPERATORS TO ALL STATIONS SO AS TO REDUCE BOTH CYCLE TINE AND EXCESS WORK IN PROCESS. WE’RE CURRENTLY WORKING AN 8 HOUR SHIFT AND YOU HAVE TO TRY TO REBALANCE THE LINE IN THAT TIME.

NOTE THAT NO OPERATORS ARE REQUIRED AT THE FURNACE, BUT THE FURNACE SPEED MAY BE VARIED IN ORDER TO REBALANCE THE LINE. AT PRESENT IT IS RUNNING AT ITS MAXIMUM SPEED - 267.4 UNITS PER HOUR.

IN REBALANCING THE LINE YOU ARE REQUIRED TO MAINTAIN THE CURRENT OUTPUT OF 214 UNITS PER HOUR. YOU MAY TRY AS MANY SOLUTIONS AS YOU LIKE, BUT REMEMBER ALL SOLUTIONS REFER BACK TO THE CURRENT SITUATION.

LET’S PLAY.

FIRST, ENTER YOUR CHOICE FOR THE NUMBER OF OPERATORS; SEPARATE YOUR INPUTS WITH COMMAS. YOU MAY USE FRACTIONS OF PEOPLE. SECOND, ENTER THE SPEED OF THE FURNACE. AFTER EACH ENTRY PRESS THE “RETURN” KEY SO THAT THE COMPUTER WILL ACCEPT THE INPUT.

ENTER THE OPERATØR DATA:
? <u>6.5,2.9,4.7,8.8,21.8</u>
NØW ENTER THE SPEED ØF THE FURNACE:
? <u>267</u>

	Station Output (Per Hr)	Yield	Operation Standard (Units/HR)	Operator Eff	No. Of Oper	Work In Progress	Allowed WIP	Cycle Time (HRS)
Assemble	269.4	1.00	37.0	1.12	6.5	45.	45.	.17
Furnace	267.0	1.00	.0	.00	.0	499.	63.	1.87
Unload	250.1	.92	91.0	1.03	2.9	321.	20.	1.19
Clean	243.6	1.00	54.0	.96	4.7	791.	31.	3.24
Ream	246.4	1.00	28.0	1.00	8.8	243.	57.	.99

Inspect	214.9	.87	11.0	1.03	21.8	270.	140.	1.10

Total No. Operator = 44.7
Total Cycle Time = 8.6 Hours

GOOD GRIEF, WHAT ARE YOU DOING?

LET'S TRY AGAIN
NOTE THAT ALL SOLUTIONS ALWAYS REFER BACK TO THE ORIGINAL STATEMENT OF THE PROBLEMS

ENTER THE OPERATOR DATA:
? 6.0,2.9,4.7,8.8,2I.8
NOW ENTER THE SPEED OF THE FURNACE:
? 260

SOLUTION NO 2

	Station Output (Per Hr)	Yield	Operation Standard (Units/HR)	Operator Eff	No. Of Oper	Work In Progress	Allowed WIP	Cycle Time (HRS)
Assemble	248.6	1.00	37.0	1.12	6.0	45.	45.	.16
Furnace	260.0	1.00	.0	.00	.0	389.	63.	1.49
Unload	250.1	.92	91.0	1.03	2.9	265.	20.	.98
Clean	243.6	1.00	54.0	.96	4.7	791.	31.	3.24
Ream	246.4	1.00	28.0	1.00	8.8	243.	57.	.99
Inspect	214.9	.87	11.0	1.03	21.8	270.	140.	1.10

TOTAL NO. OF OPERATORS = 44.2
TOTAL CYCLE TIME = 8.0 HOURS

GOOD – YOUR CYCLE TIME IS IMPROVING
LET'S TRY AGAIN

ENTER THE OPERATOR DATA:
? 5.2,3.3,7.1,14,36
NOW ENTER THE SPEED OF THE FURNACE:
? 267.4

SOLUTION NO 10

	Station Output (Per Hr)	Yield	Operation Standard (Units/HR)	Operator Eff	No. Of Oper	Work In Progress	Allowed WIP	Cycle Time (HRS)
Assemble	215.5	1.00	37.0	1.12	5.2	45.	45.	.14
Furnace	267.4	1.00	.0	.00	.0	65.	63.	.25
Unload	284.6	.92	92.0	1.03	3.3	25.	20.	.10
Clean	368.1	1.00	54.0	.96	7.1	72.	31.	30.
Ream	392.0	1.00	28.0	1.00	14.0	74.	57.	.41
Inspect	354.9	.87	11.0	1.03	36.0	148.	140.	.96

TOTAL NO. OF OPERATORS = 65.6
TOTAL CYCLE TIME = 2.2 HOURS

CONGRATULATIONS - YOU HAVE BALANCED THE LINE.

HOWEVER, IN REBALANCING THE LINE YOU HAVE EXCEEDED THE DESIRED OUTPUT OF
214.0 UNITS PER HOUR, ALSO THIS BALANCE REQUIRES AN ADDITIONAL 20.6 OPERATORS.

WOULD YOU LIKE TO SEE THE SOLUTION THAT BALANCES THE LINE AT THE DESIRED OUTPUT RATE? ... “YES” OR “NO”

? YES

WE HOPE YOU HAVE ENJOYED PLAYING THE GAME. BY NOW YOU PROBABLY REALIZE THAT A TRIAL AND ERROR APPROACH TO LINE BALANCING COULD BE A DISASTROUS IN A PRACTICAL SITUATION. THE PRODUCTION CONTROL SYSTEM CAN HELP YOU AVOID SUCH A SITUATION. A BALANCE OF THE LINE IS POSSIBLE AT THE RUNNING RATE OF 214.0 UNITS PER HOUR. FIRST, YOU MUST IDENTIFY THE CURRENT WORK IN PROCESS AT EACH STATION, INCLUDING THE FURNACE. INPUT THESE VALUES NOW; SEPARATE YOUR INPUTS WITH COMMAS.

? 45,480,360,740,265,275

SOLUTIONS WITH A LIVE OUTPUT OF 214.0

	Station Output (Per Hr)	Yield	Operation Standard (Units/HR)	Operator Eff	No. Of Oper	Work In Progress	Allowed WIP	Cycle Time (HRS)
Assemble	29.8	1.00	37.0	1.12	0.7	45.	45.	.05
Furnace	81.9	1.00	0.0	0.00	0.0	63.	63.	.24
Unload	114.5	.92	91.0	1.03	1.3	20.	20.	.02
Clean	203.1	1.00	54.0	.96	3.9	31.	31.	.04
Ream	229.1	1.00	28.0	1.00	8.2	57.	57.	.07
Inspect	214.0	0.87	11.0	1.03	21.7	140.	140.	.17

TOTAL NO. OPERATORS = 35.9

TOTAL CYCLE TIME = .6 HOURS

REFERENCES

1. Ingnall, Edward J., “A Review of Assembly Line Balancing,” Journal of Industrial Engineering, (July-August, 1965), PP. 26-35.

2. Lehman, M., “What’s Going On in Product Assembly,” Industrial Engineering, (April, 1969), pp. 17-24.

3. Wheelwright, Steven C. and Spyros G. Makridakis, Computer-Aided Modeling for Managers, (Reading, Massachusetts: Addison-Wesley Publishing Company, Inc., 1972).