O-GERT MODELING AND ANALYSIS IN A PRODUCTION PLANNING AND SCHEDULING

BALABAN, M. Erdal and KARPAK, Birsen
Istanbul University
Faculty of Business Administration

1. Introduction

The purpose of this paper is to present an application of Q-GERT network model oriented production planning and scheduling of a manufacturing company. In this model, the routings of the items are modeled by inserting user functions into the model. Therefore, network model of a complex routing situation has been simplified by eliminating conditional branches used to schedule routings of the items.

Development of the Q-GERT network model was based on utillzation of actual data and providing the desired outputs.

This model has been anaysed by Q-GERT Analysis Program supplied with user subroutines and functions. Three major objectives are considered for this network model development:

1. Determination of the system configuration.
2. Selection of priorlty rule to meet orders on time.
3. Specification of the manufacturing scheduling.

Alternative decisions have been evaluated on this model to realize the objectives given above. Besides, the following information requested by management have been obtained:

1. Daily reports of order situation
2. Monthly reports of work station situation

In this paper, firstly the structure of the system will be introduced and then Q-GERT model will be reviewed. The paper concludes with some discussions on the simulation results of network analysis.

2. *The Structure of the System*

The system which has been studied is a manufacturing company that produces gears and groups of gears according to arriving orders. The production of the company is based on two types of orders:

1. Regular periodical orders and
2. Irregular orders.

Regular orders with contracts arrive to the system periodically whereas irregular orders arrive to the system at uncertain times in small quantities. It is very important for manegement to meet regular orders by the specified deadline. Regular orders in large quantities also require the use of a large portion of the capacity.

The activities related to orders can be considered in two main groups:

1. Activities before manufacturing and
2. Activities during manufacturing.

The first group involves activities from receiving orders up to manufacturing. The second group involves the flows and operations of the gears through the production shop.

2.1 *Problems Encountered in the System*

As known, planning and controlling of a production system is one of the most difficult problems encountered by management. Arriving of orders occur at different times and each order requires that operations be performed at specified kinds of work stations in a specified sequence. Operation times and routings of items are different for each order. Each work station consists of a number of identical machines.

In this system, there are three major problems that need solution:

1. Determination of the system configuration
2. Meeting of regular orders within the specified deadline
3. Specification of the manufacturing scheduling

Besides, it is desired that management has the answers to the following questions:

1. What is the situation of the orders in the manufacturing process at certain times?

2. Where and when do the bottleneck points occur in the production line?

3. When are the work stations idle or busy?

2.2 *System Elements and Assumptions*

The specification of the significant element of the system is important for model building. The most significant element of this system is 30 different types of regular orders and their flows and operations through the manufacturing process. 14 different work stations are used in the system and each station consists of a number of identical machines. Although we could model the entire production process, we are only interested in the operations of regular orders in order to solve the manufacturing problems.

Before building the model, some assumptions are made in the system as follows:

1. Historical data of the system indicates that machine breakdowns occur rarely. Because of this, machine breakdowns have been assumed out of the system limit.

2. It is assumed that workers are always ready at work stations.

3. Set up times of machines have been considered in the processing time of items.

4. Orders are routed according to the specified order sequence

5. All machines in each work station are assumed to be indenticai.

6. Transportation delays of items between work stations are ignored.

7. It is assumed that machines are initially idle.

The assumptions above don't effect teh major problems encountered in the system. The system can be modeled and analysed as a complex queuing and routing situation with Q-GERT network technique.

3. Q-GERT Network Model

The description of the Q-GERT network model is prensented in figure 1. This model is a graphical representation of the flow of orders and their operations through the manufacturing. Starting point of the model is represented by source node 1. Transactions represent the various types of regular orders and items of orders. Service operations indicated by branches following Q-nodes represent the work stations. Each work station has a number of identical machines that in the circle below the service branch. The time to perform operation is specified as (AT, 6) so that operation time is obtained from attribute 6. Q-nodes with «hash» mark are used as storage area for work stations. There are no initial items at the queues and the maximum queue length permitted is infinite in the network model. Queues are ranked on attribute 3 as specified at Q-nodes. Node 92 is a sink node that calculates statistics between departures of items. This node is also used te terminate the analysis of network. Ali completed items are routed to node 92.

30 transactions are generater and 14 Q-nodes and service operations are modeled. There is no branch for routing of the items which has been provided by inserting user functions to model. Thus, this model consists of disjoint networks. Although 33 user functions are inserted in various places of Q-GERT network model, they are called for only 6 purposes:

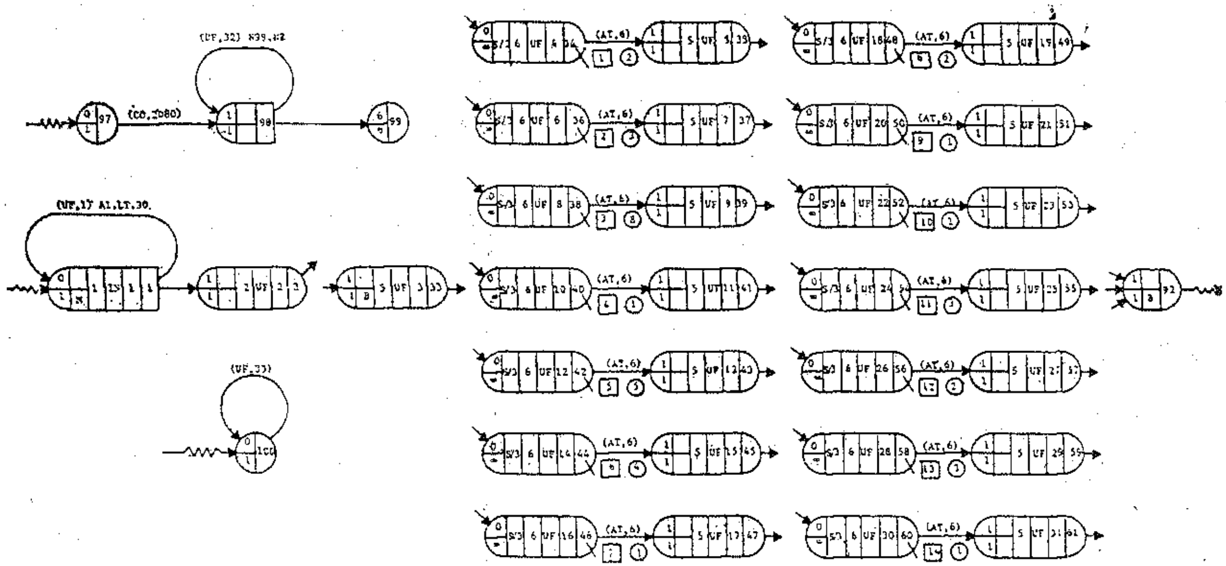

Figure 1. The Q-GERT Network Model of a Production System

3.1 Schedulling of Order Arrivals

User function 1 is identified to schedule arriving of orders on the self-loop around source node 1. Source node 1 with conditional-take ali branching is modeled to generate 30 differeten types of orders. The first order is entered to the system at time zero. It is also routed back to node 1 to generate to the next order. The actual interarrival times are obtained by computing the difference between the actual arrival times of orders in user function 1 during the simulation process.

3.2 Assigning of Order Specifications to Attributes

items associated with orders which flow through the network have 6 attributes.

Order number is assigned to attribute 1 according to the sequence of arrival by using incremental function at source node 1. (i, IN, 1)

When attribute 1 is greater than 29, no further orders are generated at the source node 1. This condition is specified on the branch from node 1 to 1 that is A1. LT. 30

The value of attribute 1 is used as an order identifier in the later portion of the network model to distinguish the types of orders.

Order code number, priority value and the number of items for each order are assigned to arttribute 2, 3, 4 respectively by using user function 2 at node 2.

Current simulation time is stored in attribute 5 of item being routed to any Q-node in order to compute waiting time of the item when it is taken to service from the Q-node.

Processing time of an item is assigned to attribute 6 by calling user function when an item departs from Q-node for processing. The processing time is taken from attribute 6 of the item being processed and it is modeled on the service branch as (AT, 6).

Attribute 1 of the item being processed and user function number (IFN) are required to access processing time value in the simulation process as indicated below:

J=GATRB(1)
M=(IFN-2)/2
P=PROC (J, M)

The function GATRB(1) is used to access the first attribute of item being processed. Each order routed to node 2 is marked with the arrival time that is stored in attribute 7 at source node 1 automatically.

3.3 *Routing of the Items Through Network*

Routing of the items to Q-nodes has been provided by using user functions. There is no conditional branch to model routings of the items to Q-nodes. Therefore, the network model of the complex routing situation has been simplified by eliminating the conditional branches.

The primary use of user functions at regular nodes is to specify the routings of items. Q-node number can be specified by accessing the routing array previously specified. User function number (IFN) and the value of attribute 1 associated with the item being routed are used to access the routing array and to specify Q-node number in the simulation process as indicated below:

J=GATRB(1)
L=(IFN-1)/2
M=IROTA(Ğ,L)
Q=IROT2+*2 ,IROT2=32

Ali completed items are routed to sink node 92. Number of items at Q-node is increased by 1 when an item is routed to Q-node in order to know the number of waiting items.

3.4 *Collection of Queue Statistics*

Current number of waiting items and waiting times of items for a certain order at any Q-node can be obtained by the use of user functions at Q-nodes. The waiting time of an item is computed as the time it departs the queue minus the value of attribute 5 that contains the arrival time of the item to Q-node. User functions at Q-nodes are called at the Q-node release time.

3.5 Collection of Daily Order Statistics

The disjoint network with node 97, 98, 99 at the upper side of Q-GERT network model is identified for the reporting of order situation. User function 32 is called every 8 hours on the self loop branch around node 98 in order to trace the order position at each work station.

In this model, it is desired that the order situation be reported for the last 5 days of simulation process. So the branch from node 97 to 98 is determined with 2080 hours delay.

3.6 Collection of Monthly Work Station Statistics

Node 100 with self-loop at the lower side of the Q-GERT model is determined to collect statistical data associated with work stations. User function 33 is called every 176 hours (monthly) on the branch from node 100 to node 100.

Average utilization of each work station, average number of waiting items, average waiting times, completed items and the number of current waiting items at each work station are calculated by the use of user function 33.

4. Analysis of the Q-GERT Network Model

The analysis of the Q-GERT network has been performed on the digital computer by the Q-GERT Analysis supplied with programming inserts. This program developed by Pritsker(1) employs simulation technique for the analysis of flow of the items through the network.

Q-GERT Analysis Program calls subroutine UI to initialize some variables to assign actual data to variables at the beginning of simulation. User functions are called during simulation and user subroutine UO is called when a run is completed in order to provide some desired outputs.

As stated previously, the development of the Q-GERT model was based on three major objectives. First, determination of the system configuration; second, selection of order priority rule to meet orders on time; and third, specification of manufacturing scheduling.

4.1 Determination of the System Configuration

The number of machines for each work station is a significant decision factor for efficient utilization of system capacity without decreasing production level. There are many alternative system configurations but here heuristic method will be used to generate a limited number of alternatives as explained below:

1. Maximum number of machines available for each work station will be the initial capacity of the system as the first alternative. Average utilization of each work station is obtained by the results of simulation.

2. The least utilized work station with more than one machine is determined. Then, the capacity of this station is decreased by one. Thus, the next alternative system configuration is obtained. In this system configuration, performance measures are obtained by the results of simulation.

3. If the production level has decreased in spite of the increased rate of utilization of system capacity, then choose the previous alternative as the best system configuration. Otherwise, go to step 2 to generate the next alternative.

The effects of alternative system configurations on system performance are shown in Table 1.

As given in Table 1, capacity utilization rate could be increased from .50 to .60 approximately, although the production level in the selected system configuration has kept the initial level, that is .78 for alternative 8.

Table 1. Performance Measures For Alternative System Configurations.

	Alternatives								
Work Stations	Number of Machines at work stations								
	1	2	3	4	5	6	7	8*	9
WS # 1	3	2	2	2	2	2	2	2	2
WS # 2	3	3	3	3	3	3	3	3	3
WS # 3	8	8	8	8	8	8	8	8	8
WS # 4	1	1	1	1	1	1	1	1	1
WS # 5	5	5	5	5	5	5	5	5	5
WS # 6	5	5	5	5	5	5	4	4	3
WS # 7	1	1	1	1	1	1	1	1	1
WS # 8	5	5	5	4	4	3	3	2	2
WS # 9	1	1	1	1	1	1	1	1	1
WS # 10	2	2	1	1	1	1	1	1	1
WS # 11	3	3	3	3	3	3	3	3	3
WS # 12	3	3	3	3	2	2	2	2	2
WS # 13	3	3	3	3	3	3	3	3	3
WS # 14	1	1	1	1	1	1	1	1	1
Number of Machines Average	44	43	42	41	40	39	38	37	36
Waiting Time (hours)	480.4	480.6	494.6	495.	507.6	508.4	526.2	526.9	557.5
Average Queue Length	145.8	145.9	150.1	150.2	154.1	154.3	159.7	160.5	169.2
Product.	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.75
Rate of Utilized Capacity	0.50	0.52	0.53	0.54	0.55	0.57	0.58	0.60	0.60

* It is the best alternative to utilize the system capacity efficiently.

4.2 *Selection of Order Priority Rule*

Selection of a priorty rule among alternatives is a very important decision to meet orders by the deadline. 10 different priorty rules given in Table 2 have been evaluated to select the best one. Delays of the orders have to be determined for each priroty rule in order to compare the alternative priorities. The model has been analyesed for each alternative. If 641 items are routed to node 92 then simulation will end and delay times of orders would be computed at the end of simulation.

As indicated in Table 3, priority rule 9 that gives the shortest time when the total processing time of item is subtracted from the dead line time is selected as the best alternative.

Table 2. Alternative Priority Rules

1. First in queue first processed (F)
2. Last in queue first processed (L)
3. First in system first processed (S/1)
4. Last in system first processed (B/1)
5. Shorter processing time first processed (S/6)
6. Longest processing time first processed (B/6)
7. Smaller customer code first processed (S/3)
8. Smaller deadline first processer (S/3)
9. Smaller (deadline - total processing time) first (S/3)
10. Bigger (number of items * total processing time) / (deadline-arrival time) first processed (B/3)

Table 3. Delay Statistics Associated with Priority Rules

Priority Rules	Total delay (days)	Average delay (days/order)	Standard Deviation (days)	Maximum delay (days)
Rule 1	681	22.70	32.75	109
Rule 2	951	31.70	47.82	177
Rule 3	421	14.03	18.41	61
Rule 4	936	31.20	62.71	222
Rule 5	655	21.83	36.64	119
Rule 6	387	12.90	19.40	68
Rule 7	447	14.90	19.68	59
Rule 8	354	11.80	17.51	53
*Rule 9	243	8.10	13.46	49
Rule 10	888	29.60	44.14	185

* It is the best alternative rule.

Table 4. Manufacture Scheduling (Starting and Completing Days of the Items)

ORDER	WS #1		WS #2		WS #3		WS #4		WS #5		WS #6		WS #7		WS #8		WS #9		WS #10		WS #11		WS #12		WS #13		WS #14	
NUMBER	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.	ST.	CM.
1	0	35	0	0	3	40	0	0	9	80	0	0	0	0	0	0	0	0	12	87	0	0	0	0	13	88	0	0
2	0	0	0	0	0	59	0	0	3	112	0	0	0	0	0	0	0	0	6	124	0	0	0	0	0	0	0	0
3	35	40	0	0	56	71	0	0	110	140	0	0	0	0	112	140	0	0	0	0	0	0	0	0	0	0	0	0
4	1	24	0	0	3	28	0	0	6	63	0	0	0	0	10	64	0	0	0	0	11	65	0	0	0	0	0	0
5	0	0	0	50	6	56	0	0	10	61	0	0	0	0	0	0	0	0	0	0	0	0	13	63	0	0	0	0
6	0	0	50	123	56	127	0	0	60	131	0	0	0	0	0	0	0	0	0	0	0	0	63	132	0	0	0	0
7	0	0	80	108	88	113	0	0	92	117	0	0	0	0	0	0	0	0	0	0	0	0	95	120	0	0	0	0
8	79	100	0	0	95	104	0	0	143	158	0	0	0	0	145	160	0	0	146	168	0	0	0	0	0	0	147	189
9	0	0	118	165	124	167	0	0	137	174	0	0	0	0	0	0	0	0	0	0	0	0	140	176	0	0	0	0
10	0	0	0	0	79	122	0	0	0	0	82	187	0	0	87	190	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	82	98	0	0	0	0	87	131	0	0	94	133	0	0	0	0	0	0	0	0	0	0	0	0
12	100	122	0	0	120	129	0	0	0	0	183	203	0	0	186	206	0	0	0	0	0	0	0	0	0	0	189	230
13	0	0	0	0	100	115	0	0	0	0	125	161	0	0	130	165	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	160	186	166	192	0	0	174	196	0	0	0	0	0	0	0	0	0	0	0	0	178	204	0	0	0	0
15	0	0	185	215	190	221	0	0	195	226	0	0	0	0	0	0	0	0	0	0	0	0	203	237	0	0	0	0
16	0	0	214	223	219	229	0	0	225	234	0	0	0	0	0	0	0	0	0	0	0	0	235	244	0	0	0	0
17	0	0	0	0	164	175	0	0	166	212	0	0	0	0	170	214	0	0	171	217	0	0	0	0	172	219	230	282
18	0	0	0	0	190	227	0	0	0	0	201	247	0	0	210	256	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	232	248	0	0	266	312	0	0	0	0	271	313	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	173	191	0	0	212	258	0	0	0	0	249	259	0	0	0	0	220	261	0	0	0	0	0	0
21	194	197	0	0	195	216	0	0	0	0	0	0	203	253	209	255	210	257	0	0	0	0	0	0	212	262	0	0
22	0	0	0	0	224	239	0	0	253	266	0	0	255	280	257	281	0	0	0	0	0	0	0	0	258	283	0	0
23	0	0	0	0	245	256	0	0	0	0	0	0	0	0	0	0	248	265	0	0	249	266	0	0	250	267	0	0
24	0	0	0	0	261	272	269	310	0	0	0	0	0	0	274	311	0	0	0	0	275	315	0	0	278	318	0	0
25	0	0	0	0	269	284	310	352	0	0	0	0	0	0	315	353	316	355	0	0	0	0	0	0	317	356	0	0
26	0	0	0	0	284	309	0	0	0	0	0	0	0	0	0	0	0	0	0	0	290	325	0	0	293	326	0	0
27	0	0	234	283	241	296	0	0	255	303	0	0	0	0	0	0	0	0	0	0	0	0	261	307	0	0	0	0
28	0	0	276	301	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	282	301	0	0
29	234	234	0	0	254	261	0	0	0	0	0	0	0	0	0	0	0	0	255	261	256	263	0	0	0	0	0	0
30	234	235	0	0	260	261	260	269	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	262	269	0	0

Table 5. Daily Report of Order Situation (Number of Wating, Processing and Completed Items at 260. the day)

ORD.	WS #1			WS #2			WS #3			WS #4			WS #5			WS #6			WS #7			WS #8			WS #9			WS #10			WS #11			WS #12			WS #13			WS #14		
NO.	W.	P.	C.	W.	PR.	C.	W.	P.	C.	W.	P.	C.	W.	P.	C.	W.	P.	C.	W.	P.	C.	W.	P.	C.	W.	P.	C.	W.	P.	C.	W.	P.	C.	W.	P.	C.	W.	P.	C.	W.	P.	C.
1	0	0	25	0	0	0	0	0	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	25	0	0	0
2	0	0	0	0	0	0	0	0	45	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	45	0	0	0	0	0	45	0	0	0	0	0	45	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	45	0	0	0	0	0	45	0	0	0	0	0	45	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	30	0	0	30	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0
6	0	0	0	0	0	25	0	0	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0
7	0	0	0	0	0	15	0	0	15	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0
8	0	0	20	0	0	0	0	0	20	0	0	0	0	0	20	0	0	0	0	0	0	0	0	20	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	20
9	0	0	0	0	0	25	0	0	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
13	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	16	0	0	16	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0
15	0	0	0	0	0	21	0	0	21	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0
16	0	0	0	0	0	5	0	0	5	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0	25	11	1	13
18	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	25	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	1	1	23	0	0	0	0	0	0	0	0	0
21	0	0	10	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	10	0	0	10	0	0	10	0	0	0	0	0	0	0	0	0	0	1	9	0	0	0
22	0	0	0	0	0	0	0	0	10	0	0	0	6	2	2	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
23	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	5	0	0	0	0	1	4	0	0	0	0	0	4	0	0	0
24	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	7	3	9	0	6	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	10	0	0	0	1	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	1	1	5	0	0	0	0	0	0	0	0	0
30	0	0	10	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6. Montly Reports

1. st Month Report of Work Station Situation

WORK-STATION GROUPS	NO. OF MACHINES	AVE. QUEUE LENGTH	AVE. WAITING TIME(hours)	AVE. UTIL. RATE	BUSY TIME OF WORK ST.	NO.OF COMP. ITEMS	CUR. NO. OF WAIT. ITEMS
WS #1	2	92.0000	140.8000	1.0000	352.0000	44	71
WS #2	3	46.8182	149.8181	1.0000	528.0000	15	40
WS #3	8	39.0000	69.3333	1.0000	1408.0000	64	35
WS #4	1	0.0000	0.0000	0.0000	0.0000	0	0
WS #5	5	9.6992	30.4643	0.8580	755.0000	30	26
WS #6	4	0.0000	0.0000	0.0000	0.0000	0	0
WS #7	1	0.0000	0.0000	0.0000	0.0000	0	0
WS #8	2	0.0966	1.7000	0.2273	80.0000	10	0
WS #9	1	0.0000	0.0000	0.0000	0.0000	0	0
WS #10	1	0.9545	18.6667	0.4091	72.0000	9	0
WS #11	3	0.0114	0.2000	0.1761	93.0000	10	0
WS #12	2	0.0568	1.6667	0.1591	56.0000	6	0
WS #13	3	0.0800	0.0000	0.0189	10.0000	1	0
WS #14	1	0.0000	0.0000	0.0000	0.0000	0	0

2. nd Month Report of Work Station Situation

WORK-STATION GROUPS	NO. OF MACHINES	AVE. QUEUE LENGTH	AVE. WAITING TIME(hours)	AVE. UTIL. RATE	BUSY TIME OF WORK ST.	NO.OF COMP. ITEMS	CUR. NO. OF WAIT. ITEMS
WS #1	2	39.1818	97.1267	0.8466	298.0000	71	0
WS #2	3	33.7273	148.3999	1.0000	528.0000	12	28
WS #3	8	48.8977	71.7166	1.0000	1408.0000	56	64
WS #4	1	0.0000	0.0000	0.0000	0.0000	0	0
WS #5	5	34.2841	73.5853	1.0000	755.0000	32	50
WS #6	4	0.0000	0.0000	0.0000	0.0000	0	0
WS #7	1	0.0000	0.0000	0.0000	0.0000	0	0
WS #8	2	0.1193	1.0500	0.4347	80.0000	20	0
WS #9	1	0.0000	0.0000	0.0000	0.0000	0	0
WS #10	1	0.0000	0.0000	0.0000	72.0000	0	0
WS #11	3	0.0000	0.0000	0.3447	93.0000	18	0
WS #12	2	0.0852	1.2500	0.3523	56.0000	12	0
WS #13	3	0.0000	0.0000	0.0000	10.0000	0	0
WS #14	1	0.0000	0.0000	0.0000	0.0000	0	0

4.3 The Specification of Manufacture Schedulling

Determination of the best system configuration and selection of the best priroty rule among given alternatives is not adequated for manufacturing. In this system configuration, It is desired to specify the applicable manufacturing scheduling. The scheduling given in Table 4 shows the times that the orders have to be started and finished at each work station.

4.4 Daily Reports of Order Situation

Management needs to know the position of orders in the manufacturing process, i.e. how many items of a certain order are being waited, being processed and completed in a certain work station daily.

Management desires to trace the situation of orders daily. Daily report shows the number of waiting, being processed and completed items associated with orders at work stations for the 260.th day. Detailed information about orders at manufacturing can be taken daily from the daily reports given in Table 5.

4.5 *Monthly Reports of the Work Station Situation*

Work station utilization results have been obtained as given in Table 6. Thus detailed information about work stations has been taken from the monthly reports. At the same time, the utilization of work stations can be obtained from the standard summary results of simulation but this information is not adequate for detailed statistical information of work stations.

5. *Conclusions*

In this paper, the Q-GERT network model has been developed as a function of actual order data. Actual arrival times, processing times and the production routing are used in the model by inserting user subroutines and functions into Q-GERT model. It is also simplified by eliminating conditional branches to model the routings of the items by calling function PTIN in user functions at the regular nodes. Three major objectives are realized by the analysis of the network model:

1. Efficient utilization of the system capacity has been provided

2. Delays of orders have been reduced by specifying the priority rule

3. Manufacture scheduling has been obtained.

In addition to the reports given above, daily and monthly reports have been obtained during simulation. Therefore, detailed and useful information related to orders and work stations has been generated from the network model.

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