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Application of POM-QM for Windows and Multiple ARC Network Model for Scheduling in a Single-Stage, Multi-Item Compatible Process

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The importance of scheduling in the industrial world is growing rapidly. Customer-driven production scheduling is the need of the hour in the present business environment. The criteria generally considered are to maximize production volume while keeping in view the customers' requirements and not to lose focus on maximizing profits as well as maximizing machine utilization. In order to retain major customers, the customers are categorized as either priority customers or normal customers. The production planning takes into account the customers' orders, keeping in mind the nature of customers, viz., priority or normal. A production environment involving a given set of machines in a single-stage, multi-item compatible process is considered. The problem of scheduling in such an environment, with the objective of maximizing capacity utilization has been formulated [1] as a maximal flow problem in a Multiple Arc Network (MAN). The model generates an optimal production schedule with the goal of maximizing capacity utilization, ensuring that customer-wise delivery schedules are met while keeping customer priorities in mind. Implementation of the MAN System modeling has been built using POM-QM software for Windows V5. The application of the software is demonstrated using two examples. The QM software can be used by managers for any scaled-up operations to obtain production schedules.

Keywords: Scheduling; maximal flow problem; multiple arc network model; optimization; POM-QM software.

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1. INTRODUCTION

The importance of scheduling in the industrial world is growing rapidly. Companies can face stiff competition only when the efficiency of work is maintained by meeting the customers' demands. This is all the more important in the case of manufacturing industries. This can be achieved by optimal production planning without reducing the quality of the product. This brings to the fore the need for an effective and efficient approach to production scheduling. A great range of optimization models and methodologies have been presented for batch scheduling and planning. The literature presents a number of works on the planning and scheduling of batch processes [2,3,4,5,6,7]. Gunter Schmidt [8,9] has presented a decision support system for production planning.

Optimization of the production of plastic sacks in an engineering industry using Linear Programming with the POM-QM for Windows tool has been illustrated by Achmad Azhar Cholil [10]. Matheus Supriyanto Rumetna et. al. [11] have demonstrated applications of POM-QM software in determining the amount of production for a month in order to maximize profits, for a bakery factory. Imam Purwanto & Makmun [12] have applied POM-QM to maximize profit in producing bread at Win Bakery. Gloria Fenny Delavina Simanjuntak et al. [13] have used the POM-QM technique to calculate the aggregate planning strategies for a Food and Beverages company. Junaiddin et al. [14] have applied POM-QM software for the application of linear programming to arrive at an optimal production schedule for an electrical manufacturing company in order to deliver finished products to customers on time. Effendi et al. [15] have employed the software for the analysis of aggregate planning in an ice crystal home industry in the city of Palangka Raya. Mijinyawa et al. [16] have demonstrated the application of QM software in Optimal production scheduling for a beverage company.

Cipta & Widyasari [17] have used POM-QM and Goal Programming for production planning with the objective of maximizing profits for a medium-sized enterprise engaged in the production of building materials. Jong et al. [18] also have applied POM-QM and Goal Programming to arrive at optimal production schedules. Kurniawan & Phaeli [19] have employed QM software to optimize the production process for a motorcycle chain manufacturer. Handayani [20] employed the software for the optimization of organic rice production in Lampung Province.

In 1962, Ford and Fulkerson [21] proposed the use of network models and algorithms. These models and algorithms have found applications in different areas, such as road traffic controls, fluid flow through pipes, the flow of current in electrical circuits etc. A is presented by Sasidhar & Achary [22] presented a Multiple Arc Network (MAN) model for production planning in a steel mill, which used the network model and the maximal flow algorithm. The MAN model was applied for production planning in a single-stage, multi-item compatible processing environment for production planning, with the objective of maximizing capacity utilization [1]. The use of Excel Solver has been envisaged by Ibrahim & Bokkasam [23] for scheduling in a single-stage, multi-item compatible process using the Multiple Arc Network Model.

POM-QM for Windows [24] is a free software. It is a user-friendly Windows software. It includes calculation methods for PERT/CPM, Linear Programming, Decision Analysis, Transportation problems, Statistical functions, Game Theory, Goal Programming, etc. Thus it is widely used for solving problems in Management Science. Extensive applications of the software is evident from the Training programs on QM for Windows, which are being organized [25] to enable the participants to solve complex linear programming problems quickly and precisely.

1.1 Objectives of the Study

This paper demonstrates the application of POM-QM for Windows in the implementation of the MAN model for production planning. The production environment considered involves production by a given set of machines in a single-stage, multi-item compatible process. The methodology provides an optimal production schedule with the objective of maximizing capacity utilization, so that the customer-wise delivery schedules are fulfilled, keeping in view the priorities of the customers. The situations of order books being full, as well as the order books not being full, have been explored. The output provides optimal schedules together with spare capacities available, if any.

2. THE PROBLEM

A methodology for using Excel Solver has been envisaged by Ibrahim & Bokkasam [23] for scheduling in a single-stage, multi-item compatible process using MAN Model. It has been indicated that in a single-stage, multi-item compatible process the problem of utilizing the total capacity is equivalent to maximizing capacity utilization in between every setup. Further, considering the set-up costs for in-between changeovers, the methodology minimizes the associated set-up costs. In order to achieve the goal similar types of products should be processed successively so that the total number of changeovers is minimized. Further, the methodology considers priority planning as well.

3. THE PROCESSNET

Consider the MAN N=(s,t,V,A,b) with v=|V| vertices. The vertices represent the machines (equipments) and products. All possible customer-wise orders and all possible products that can be processed on various equipments are represented by the arcs A. For a given manufacturing facility, this network will have a specific structure, which can be referred to as the PROCESSNET. A typical PROCESSNET for a process consisting of “p” similar machines capable of processing “l” products, in a single stage, is shown in Fig. 1.

We use the same notations as in the paper by Ibrahim & Bokkasam [23].

4. SCHEDULING PROCEDURE USING POM-QM SOFTWARE

The procedure for planning and scheduling consists of the formulation of the equivalent Linear Programming problem and the sequential applications of POM-QM software.

Step 1: Consider the PROCESSNET. Start with single-directed arcs and with arc number i=1. Define the capacities along the arcs as follows:
Set i=1
$b(s,1,S_k)=D_{k1}$
$b(S_k,1,E_r)=A_{kr}$
For all other (x,y) εN, $b(x,y)=\infty$.

Using the equivalent linear programming model of the maximal flow problem and using POM-QM solver, determine the optimal flow.

Step 2: Set i=2
$b(s,2,S_k)=D_{k2}$
$b(S_k,2,E_r)=$ Min.[A_{kr} , A_{kr} – optimum flow along (S_k,E_r) in Step1]
For all other (x,y) εN, $b(x,y)=\infty$.
Using POM-QM solver, determine the optimal flow.

The optimal flows of steps 1 and 2 provide the optimal schedules for the prioritized and normal customer orders respectively.

Whenever the order books are not full, the methodology also provides the machine-wise spare capacities. In case the order books exceed the machine capacities, the methodology provides the optimal quantities to be supplied to the customers as well as the corresponding unfulfilled demands.

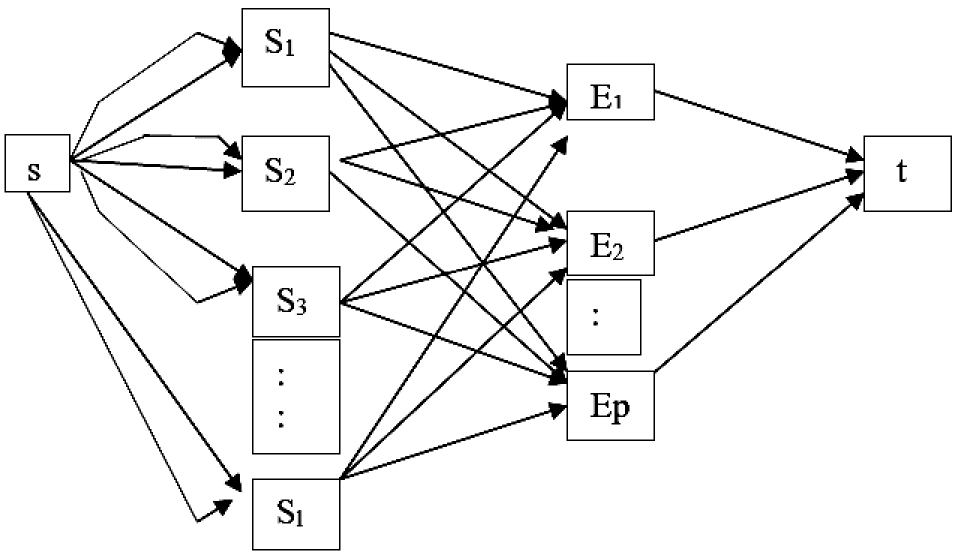

Fig. 1. A typical processnet

5. ILLUSTRATIVE EXAMPLES

Example 1- Scheduling 2 Machines with 3 Products when order books are full

Consider a manufacturing process with two lathes E_1 and E_2. Suppose the company has orders for three roller sets S_1, S_2, and S_3 which include both priority and normal orders as in Table 1. It is known that both the lathes can manufacture any of the roller sets and the capacity of each of the lathes (A_{kr}) is 400 units for each of the roller sets.

It is observed that the changeover time and the associated cost for changing the process setup from one type of roller to the other increases with the number of setups. Hence, similar types of products should be processed successively so that the total number of changeovers and the associated costs are minimized. This boils down to the problem of maximizing the capacity utilization.

The steps in scheduling the workshop using POM-QM software is illustrated in this example.

Table 1. Order position and priorities for Example 1

Order Type/Product	S_1	S_2	S_3
Priority	600	500	300
Normal	400	300	700

The PROCESSNET for the workshop is as shown in Fig. 2.

Step 1: Consider the PROCESSNET with single directed arcs (with arc number i=1) as shown in Fig. 3.

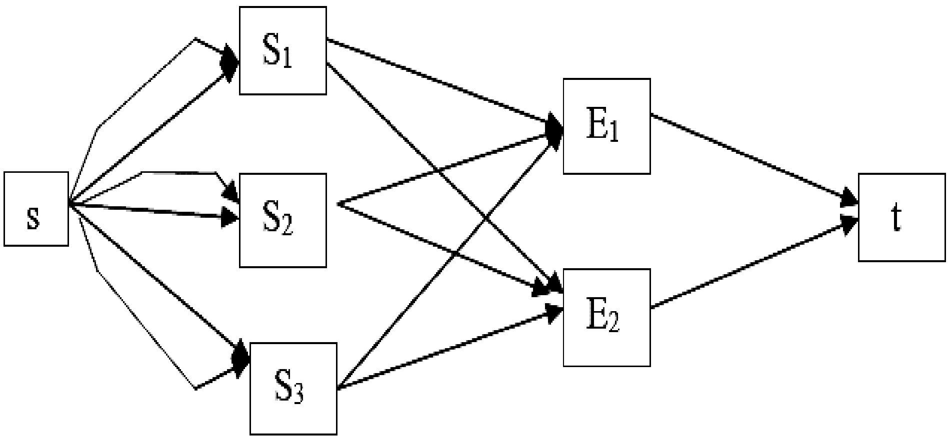

Fig. 2. PROCESSNET for the workshop of example 1

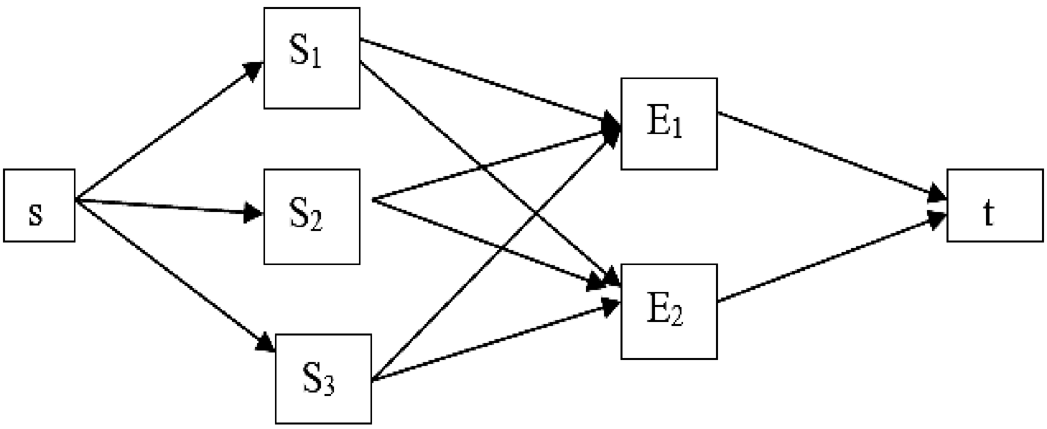

Fig. 3. PROCESSNET with single directed arcs for the Workshop of Example 1

Given the demand D_{ki} for the product S_k by Order type i are:

D_{11}=600, D_{12}=400, D_{21}=500, D_{22}=300, D_{31}=300 and D_{32}=700.

The capacity along the arc from s to S_k (k=1,2,3) is the order quantity D_{ki} for the product S_k by the order type i=1, viz., D_{11}=600, D_{21}=500, and D_{31}=300. The capacity of the arc (S_k, E_r) is considered as A_{kr} which is the capacity of processing product S_k by equipment E_r. The capacities of the arcs (E_r,t) are considered as infinity, in this example, it is considered as 100000.

The POM-QM formulation of the problem is shown in Table 2.

Using POM-QM, the maximal flow as shown in Table 3 is obtained.

Step 2: Consider the same PROCESSNET as shown in Fig. 3 with single-directed arcs (with arc number i=2)

Considering the order type i=2, we have D_{12}=400, D_{22}=300, and D_{32}=700. The capacity of the arc (S_k, E_r) is considered as Min.[A_{kr}, A_{kr} – optimum flow along (S_k,E_r) in Step1]. For example, the capacity of the arc (S_1, E_1) will be Min.[400, 400-400]=0. The capacities of the arcs (E_r,t) are considered as large quantities, say, 100000.

The POM-QM formulation of the problem is shown in Table 4.

Using POM-QM, the following maximal flow as shown in Table 5 is obtained.

The optimal scheduling is obtained by considering the optimal flows obtained in Step 1 and Step 2, which can be represented as in Table 6.

The optimal flow f^* = (600, 200, 500, 300, 300, 500) along the arcs (s,S_k).
Table 7 provides the optimal supplies and unfulfilled orders (in brackets) for both priority and normal customers. 200 roller sets each of sets S1 and S3 for normal customers is the backlog, which can be considered for rescheduling with the customer's concurrence.

Table 8 provides the capacity utilization details for the two lathes.

Example 2- Scheduling 2 Machines and 3 Products when order books are not full

This example illustrates the procedure for arriving at optimal schedules and buffer capacities when the order books are not full, for the workshop considered in Example 1 with order positions as in Table 9.

Step 1: Consider the PROCESSNET with single directed arcs (with arc number i=1) as shown in Fig. 3.

Given the demand D_{ki} for the product S_k by Order type i are:

D_{11}=100, D_{12}=200, D_{21}=250, D_{22}=300, D_{31}=500 and D_{32}=300.

The capacity along the arc from s to S_k (k=1,2,3) is the order quantity D_{ki} for the product S_k by the order type i=1, viz., D_{11}=100, D_{21}=250, and D_{31}=500. The capacity of the arc (S_k, E_r) is considered as A_{kr} which is the capacity of processing product S_k by equipment E_r. The capacities of the arcs (E_r,t) are considered as infinity, in this example, it is considered as 100000.

The POM-QM formulation of the problem is shown in Table 10.

Using POM-QM, the maximal flow as shown in Table 11 is obtained.

Step 2: Consider the same PROCESSNET as shown in Fig. 3 with single-directed arcs (with arc number i=2)

Considering the order type i=2, we have D_{12}=200, D_{22}=300, and D_{32}=300. The capacity of the arc (S_k, E_r) is considered as Min.[A_{kr}, A_{kr} – optimum flow along (S_k,E_r) in Step1]. For example, the capacity of the arc (S_1, E_1) will be Min.[400, 400-100]=300. The capacities of the arcs (E_r,t) are considered as large quantities say, 100000.

The POM-QM formulation of the problem is shown in Table 12.

Using POM-QM, the following maximal flow as shown in Table 13 is obtained.

The optimal scheduling is obtained by considering the optimal flows obtained in Step 1 and Step 2, which can be represented as in Table 14.

f^* = (100, 200, 250, 300, 500, 300) for the arcs (s,S_k).

Table 2. POM-QM formulation of Step 1 of Example 1

Example 1, Step 1														
Objective-Maximize														
	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**		**RHS**	**Equation form**
Maximize	1	1	1	0	0	0	0	0	0	0	0			Max X1 + X2 + X3
s-S1	1	0	0	0	0	0	0	0	0	0	0	<=	600	X1 <= 600
s-S2	0	1	0	0	0	0	0	0	0	0	0	<=	500	X2 <= 500
s-S3	0	0	1	0	0	0	0	0	0	0	0	<=	300	X3 <= 300
S1-E1	0	0	0	1	0	0	0	0	0	0	0	<=	400	X4 <= 400
S1-E2	0	0	0	0	1	0	0	0	0	0	0	<=	400	X5 <= 400
S2-E1	0	0	0	0	0	1	0	0	0	0	0	<=	400	X6 <= 400
S2-E2	0	0	0	0	0	0	1	0	0	0	0	<=	400	X7 <= 400
S3-E1	0	0	0	0	0	0	0	1	0	0	0	<=	400	X8 <= 400
S3-E2	0	0	0	0	0	0	0	0	1	0	0	<=	400	X9 <= 400
E1-t	0	0	0	0	0	0	0	0	0	1	0	<=	100000	X10 <= 100000
E2-t	0	0	0	0	0	0	0	0	0	0	1	<=	100000	X11 <= 100000
S1	1	0	0	-1	-1	0	0	0	0	0	0	<=	0	X1 - X4 - X5 <= 0
S2	0	1	0	0	0	-1	-1	0	0	0	0	<=	0	X2 - X6 - X7 <= 0
S3	0	0	1	0	0	0	0	-1	-1	0	0	<=	0	X3 - X8 - X9 <= 0
E1	0	0	0	1	0	1	0	1	0	-1	0	<=	0	X4 + X6 + X8 - X10 <= 0
E2	0	0	0	0	1	0	1	0	1	0	-1	<=	0	X5 + X7 + X9 - X11 <= 0

Table 3. POM-QM solution of Step 1 of Example 1

Example 1, Step 1-Solution														
Objective-Maximize														
	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**		**RHS**	**Dual**
Maximize	1	1	1	0	0	0	0	0	0	0	0			
s-S1	1	0	0	0	0	0	0	0	0	0	0	<=	600	1
s-S2	0	1	0	0	0	0	0	0	0	0	0	<=	500	1
s-S3	0	0	1	0	0	0	0	0	0	0	0	<=	300	1
S1-E1	0	0	0	1	0	0	0	0	0	0	0	<=	400	0
S1-E2	0	0	0	0	1	0	0	0	0	0	0	<=	400	0
S2-E1	0	0	0	0	0	1	0	0	0	0	0	<=	400	0
S2-E2	0	0	0	0	0	0	1	0	0	0	0	<=	400	0
S3-E1	0	0	0	0	0	0	0	1	0	0	0	<=	400	0
S3-E2	0	0	0	0	0	0	0	0	1	0	0	<=	400	0
E1-t	0	0	0	0	0	0	0	0	0	1	0	<=	100000	0
E2-t	0	0	0	0	0	0	0	0	0	0	1	<=	100000	0
S1	1	0	0	-1	-1	0	0	0	0	0	0	<=	0	0
S2	0	1	0	0	0	-1	-1	0	0	0	0	<=	0	0
S3	0	0	1	0	0	0	0	-1	-1	0	0	<=	0	0
E1	0	0	0	1	0	1	0	1	0	-1	0	<=	0	0
E2	0	0	0	0	1	0	1	0	1	0	-1	<=	0	0
Solution	600	500	300	400	200	400	100	300	0	1100	300		1400	

Table 4. POM-QM formulation of Step 2 of Example 1

Example 1, Step 2														
Objective-Maximize														
	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**		**RHS**	**Equation form**
Maximize	1	1	1	0	0	0	0	0	0	0	0			Max X1 + X2 + X3
s-S1	1	0	0	0	0	0	0	0	0	0	0	<=	400	X1 <= 400
s-S2	0	1	0	0	0	0	0	0	0	0	0	<=	300	X2 <= 300
s-S3	0	0	1	0	0	0	0	0	0	0	0	<=	700	X3 <= 700
S1-E1	0	0	0	1	0	0	0	0	0	0	0	<=	0	X4 <= 0
S1-E2	0	0	0	0	1	0	0	0	0	0	0	<=	200	X5 <= 200
S2-E1	0	0	0	0	0	1	0	0	0	0	0	<=	0	X6 <= 0
S2-E2	0	0	0	0	0	0	1	0	0	0	0	<=	300	X7 <= 300
S3-E1	0	0	0	0	0	0	0	1	0	0	0	<=	100	X8 <= 100
S3-E2	0	0	0	0	0	0	0	0	1	0	0	<=	400	X9 <= 400
E1-t	0	0	0	0	0	0	0	0	0	1	0	<=	100000	X10 <= 100000
E2-t	0	0	0	0	0	0	0	0	0	0	1	<=	100000	X11 <= 100000
S1	1	0	0	-1	-1	0	0	0	0	0	0	<=	0	X1 - X4 - X5 <= 0
S2	0	1	0	0	0	-1	-1	0	0	0	0	<=	0	X2 - X6 - X7 <= 0
S3	0	0	1	0	0	0	0	-1	-1	0	0	<=	0	X3 - X8 - X9 <= 0
E1	0	0	0	1	0	1	0	1	0	-1	0	<=	0	X4 + X6 + X8 - X10 <= 0
E2	0	0	0	0	1	0	1	0	1	0	-1	<=	0	X5 + X7 + X9 - X11 <= 0

Table 5. POM-QM solution of Step 2 of Example 1

Example 1, Step 2-Solution														
Objective-Max.														
	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**		**RHS**	**Dual**
Maximize	1	1	1	0	0	0	0	0	0	0	0			
s-S1	1	0	0	0	0	0	0	0	0	0	0	<=	400	0
s-S2	0	1	0	0	0	0	0	0	0	0	0	<=	300	1
s-S3	0	0	1	0	0	0	0	0	0	0	0	<=	700	0
S1-E1	0	0	0	1	0	0	0	0	0	0	0	<=	0	1
S1-E2	0	0	0	0	1	0	0	0	0	0	0	<=	200	1
S2-E1	0	0	0	0	0	1	0	0	0	0	0	<=	0	0
S2-E2	0	0	0	0	0	0	1	0	0	0	0	<=	300	0
S3-E1	0	0	0	0	0	0	0	1	0	0	0	<=	100	1
S3-E2	0	0	0	0	0	0	0	0	1	0	0	<=	400	1
E1-t	0	0	0	0	0	0	0	0	0	1	0	<=	100000	0
E2-t	0	0	0	0	0	0	0	0	0	0	1	<=	100000	0
S1	1	0	0	-1	-1	0	0	0	0	0	0	<=	0	1
S2	0	1	0	0	0	-1	-1	0	0	0	0	<=	0	0
S3	0	0	1	0	0	0	0	-1	-1	0	0	<=	0	1
E1	0	0	0	1	0	1	0	1	0	-1	0	<=	0	0
E2	0	0	0	0	1	0	1	0	1	0	-1	<=	0	0
Solution	200	300	500	0	200	0	300	100	400	100	900		1000	

Table 6. Optimal scheduling for Example 1

Optimal Schedules	Opt. Flow1	Opt.Flow2
Roller set s1 (Priority/Normal)	600	200
Roller set s2 (Priority/Normal)	500	300
Roller set s3 (Priority/Normal)	300	500
Lathe 1	400	0
Lathe 2	200	200
Lathe 1	400	0
Lathe 2	100	300
Lathe 1	300	100
Lathe 2	0	400
Lathe 1 Total	1100	100
Lathe 2 Total	300	900

Table 7. Optimal supply quantities and the unfulfilled demands

Order Type/Product	S_1	S_2	S_3
Priority	600 (0)	500 (0)	300 (0)
Normal	200 (200)	300 (0)	500 (200)

Table 8. Machine utilization and the spare capacities available for Example 1.

Machine	Capacity	Scheduled	Spare capacity available
E_1	1200	1200	0
E_2	1200	1200	0

Table 9. Order position and priorities for Example 2

Order Type/Product	S_1	S_2	S_3
Priority	100	250	500
Normal	200	300	300

Table 10. POM-QM formulation of Step 1 of Example 2

Example 2, Step 1														
Objective-Maximize														
	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**		**RHS**	**Equation form**
Maximize	1	1	1	0	0	0	0	0	0	0	0			Max X1 + X2 + X3
s-S1	1	0	0	0	0	0	0	0	0	0	0	<=	100	X1 <= 100
s-S2	0	1	0	0	0	0	0	0	0	0	0	<=	250	X2 <= 250
s-S3	0	0	1	0	0	0	0	0	0	0	0	<=	500	X3 <= 500
S1-E1	0	0	0	1	0	0	0	0	0	0	0	<=	400	X4 <= 400
S1-E2	0	0	0	0	1	0	0	0	0	0	0	<=	400	X5 <= 400
S2-E1	0	0	0	0	0	1	0	0	0	0	0	<=	400	X6 <= 400
S2-E2	0	0	0	0	0	0	1	0	0	0	0	<=	400	X7 <= 400
S3-E1	0	0	0	0	0	0	0	1	0	0	0	<=	400	X8 <= 400
S3-E2	0	0	0	0	0	0	0	0	1	0	0	<=	400	X9 <= 400
E1-t	0	0	0	0	0	0	0	0	0	1	0	<=	100000	X10 <= 100000
E2-t	0	0	0	0	0	0	0	0	0	0	1	<=	100000	X11 <= 100000
S1	1	0	0	-1	-1	0	0	0	0	0	0	<=	0	X1 - X4 - X5 <= 0
S2	0	1	0	0	0	-1	-1	0	0	0	0	<=	0	X2 - X6 - X7 <= 0
S3	0	0	1	0	0	0	0	-1	-1	0	0	<=	0	X3 - X8 - X9 <= 0
E1	0	0	0	1	0	1	0	1	0	-1	0	<=	0	X4 + X6 + X8 - X10 <= 0
E2	0	0	0	0	1	0	1	0	1	0	-1	<=	0	X5 + X7 + X9 - X11 <= 0

Table 11. POM-QM solution of Step 1 of Example 2

Example 2, Step 1-Solution														
Objective-Max.														
	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**		**RHS**	**Dual**
Maximize	1	1	1	0	0	0	0	0	0	0	0			
s-S1	1	0	0	0	0	0	0	0	0	0	0	<=	100	1
s-S2	0	1	0	0	0	0	0	0	0	0	0	<=	250	1
s-S3	0	0	1	0	0	0	0	0	0	0	0	<=	500	1
S1-E1	0	0	0	1	0	0	0	0	0	0	0	<=	400	0
S1-E2	0	0	0	0	1	0	0	0	0	0	0	<=	400	0
S2-E1	0	0	0	0	0	1	0	0	0	0	0	<=	400	0
S2-E2	0	0	0	0	0	0	1	0	0	0	0	<=	400	0
S3-E1	0	0	0	0	0	0	0	1	0	0	0	<=	400	0
S3-E2	0	0	0	0	0	0	0	0	1	0	0	<=	400	0
E1-t	0	0	0	0	0	0	0	0	0	1	0	<=	100000	0
E2-t	0	0	0	0	0	0	0	0	0	0	1	<=	100000	0
S1	1	0	0	-1	-1	0	0	0	0	0	0	<=	0	0
S2	0	1	0	0	0	-1	-1	0	0	0	0	<=	0	0
S3	0	0	1	0	0	0	0	-1	-1	0	0	<=	0	0
E1	0	0	0	1	0	1	0	1	0	-1	0	<=	0	0
E2	0	0	0	0	1	0	1	0	1	0	-1	<=	0	0
Solution	100	250	500	100	0	250	0	400	100	750	100		850	

Table 12. POM-QM formulation of Step 2 of Example 2

Example 2, Step 2														
Objective-Maximize														
	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**		**RHS**	**Equation form**
Maximize	1	1	1	0	0	0	0	0	0	0	0			Max X1 + X2 + X3
s-S1	1	0	0	0	0	0	0	0	0	0	0	<=	200	X1 <= 200
s-S2	0	1	0	0	0	0	0	0	0	0	0	<=	300	X2 <= 300
s-S3	0	0	1	0	0	0	0	0	0	0	0	<=	300	X3 <= 300
S1-E1	0	0	0	1	0	0	0	0	0	0	0	<=	300	X4 <= 300
S1-E2	0	0	0	0	1	0	0	0	0	0	0	<=	400	X5 <= 400
S2-E1	0	0	0	0	0	1	0	0	0	0	0	<=	150	X6 <= 150
S2-E2	0	0	0	0	0	0	1	0	0	0	0	<=	400	X7 <= 400
S3-E1	0	0	0	0	0	0	0	1	0	0	0	<=	0	X8 <= 0
S3-E2	0	0	0	0	0	0	0	0	1	0	0	<=	300	X9 <= 300
E1-t	0	0	0	0	0	0	0	0	0	1	0	<=	100000	X10 <= 100000
E2-t	0	0	0	0	0	0	0	0	0	0	1	<=	100000	X11 <= 100000
S1	1	0	0	-1	-1	0	0	0	0	0	0	<=	0	X1 - X4 - X5 <= 0
S2	0	1	0	0	0	-1	-1	0	0	0	0	<=	0	X2 - X6 - X7 <= 0
S3	0	0	1	0	0	0	0	-1	-1	0	0	<=	0	X3 - X8 - X9 <= 0
E1	0	0	0	1	0	1	0	1	0	-1	0	<=	0	X4 + X6 + X8 - X10 <= 0
E2	0	0	0	0	1	0	1	0	1	0	-1	<=	0	X5 + X7 + X9 - X11 <= 0

Table 13. POM-QM solution of Step 2 of Example 2

Example 2, Step 2-Solution														
Objective-Max.														
	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**		**RHS**	**Dual**
Maximize	1	1	1	0	0	0	0	0	0	0	0			
s-S1	1	0	0	0	0	0	0	0	0	0	0	<=	200	1
s-S2	0	1	0	0	0	0	0	0	0	0	0	<=	300	1
s-S3	0	0	1	0	0	0	0	0	0	0	0	<=	300	1
S1-E1	0	0	0	1	0	0	0	0	0	0	0	<=	300	0
S1-E2	0	0	0	0	1	0	0	0	0	0	0	<=	400	0
S2-E1	0	0	0	0	0	1	0	0	0	0	0	<=	150	0
S2-E2	0	0	0	0	0	0	1	0	0	0	0	<=	400	0
S3-E1	0	0	0	0	0	0	0	1	0	0	0	<=	0	0
S3-E2	0	0	0	0	0	0	0	0	1	0	0	<=	300	0
E1-t	0	0	0	0	0	0	0	0	0	1	0	<=	100000	0
E2-t	0	0	0	0	0	0	0	0	0	0	1	<=	100000	0
S1	1	0	0	-1	-1	0	0	0	0	0	0	<=	0	0
S2	0	1	0	0	0	-1	-1	0	0	0	0	<=	0	0
S3	0	0	1	0	0	0	0	-1	-1	0	0	<=	0	0
E1	0	0	0	1	0	1	0	1	0	-1	0	<=	0	0
E2	0	0	0	0	1	0	1	0	1	0	-1	<=	0	0
Solution	200	300	300	200	0	150	150	0	300	350	450		800	

Table 14. Optimal scheduling for Example 2

Optimal Schedules	Opt.Flow1	Opt.Flow2
Roller set s1 (Priority/Normal)	100	200
Roller set s2 (Priority/Normal)	250	300
Roller set s3 (Priority/Normal)	500	300
Lathe 1	100	200
Lathe 2	0	0
Lathe 1	250	150
Lathe 2	0	150
Lathe 1	400	0
Lathe 2	100	300
Lathe 1 Total	750	350
Lathe 2 Total	100	450

Table 15. Equipment utilization and the spare capacities available for Example 2.

Machine	Capacity	Scheduled	Spare capacity available
E_1	1200	1100	100
E_2	1200	550	650

It is noted that the requirements of both priority and normal customers are fulfilled. Table 15 provides the spare capacity available for both lathes.

6. CONCLUSIONS AND OUTCOMES

In this paper, the application of POM-QM software for production planning and scheduling a single-stage, multi-item compatible production process, where the process can handle different types of products involving changeover costs has been brought out. The methodology provides an optimal production schedule with the objective of maximizing capacity utilization, so that the customer-wise delivery schedules are fulfilled, keeping in view the priorities of the customers. For a given manufacturing process, the layout and the process flow of the plant provide the PROCESSNET and a tailor-made system for production planning and scheduling can be developed using MAN model and solving it using POM-QM software. The application of the software is demonstrated using two examples which take into account the cases of order books being full and the order books being not full, in which case the sapre capacities, if any, are also indicated with the optimal schedules. The QM software can be used by managers for any scaled-up operations to obtain production schedules.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Bokkasam Sasidhar. Multiple arc network model for scheduling in a single-stage, multi-item compatible process. International Review of Management and Business Research. 2016;5(3): 1223-1231.
2. Pinto JM, Grossmann IE. Assignment & sequencing models for the scheduling of process systems. Ann. Oper. Res. 1998:81:433–466.
3. Kallrath J. Planning and scheduling in the process industry. OR Spectrum. 2002; 24:219–250.
4. Floudas CA, Lin X. Continuous-time versus discrete-time approaches for scheduling of chemical processes: A review. Comput. Chem. Eng. 2004;28:2109–2129.
5. Burkard RE, Hatzl J. Review extensions and computational comparison of milp formulations for scheduling of batch processes. Comput. Chem. Eng. 2005; 29:1752–1769.
6. Mendez CA, Cerda J, Grossmann IE, Harjunkoski I, Fahl M. State of-the-art review of optimization methods for short-term scheduling of batch processes. Comput. Chem. Eng. 2006;30:913–946.
7. Pan M, Li X, Qian Y. Continuous-time approaches for short-term scheduling of network batch processes: Small-scale and medium-scale problems. Chem. Eng. Res. Des. 2009;87:1037–1058.
8. Gunter Schmidt. A decision support system for production scheduling. Journal of Decision Systems. 1992;1(2-3):243-260.

9. Gunter Schmidt. Modelling Production Scheduling Systems. International Journal of Production Economics. 1996;46-47: 109-118.
10. Achmad Azhar Cholil, Sugiyono Madelan. Optimization of production plastic sacks using POM-QM application for windows (Case Study: PT Rajawali Tanjungsari Engineering). International Research Journal of Innovations in Engineering and Technology. (IRJIET). 2022;6(8):15-24.
11. Matheus Supriyanto Rumetna, Tirsa Ninia Lina, Titin Puspita Sari, Piton Mugu, Adrianus Assem, Richard Sianturi. Optimasi jumlah produksi roti menggunakan program linear dan softwarePOM-QM. Computer Based Information System Journal. 2021;9(1): 42-49.
12. Imam Purwanto, Makmun. Implementation system of simplex method for optimization profit. International Journal Science Technology (IJST). 2023;2(2):53-60.
13. Gloria Fenny Delavina Simanjuntak, Hani Saffanah Putri, Intan Putri Maharani Sinaga, Nastiti Adibestari, Ardhy Lazuardy. Aggregate planning to minimize cost of production of abc company with forecasting and master production schedule approach. Proceedings of the 5th European International Conference on Industrial Engineering and Operations Management Rome, Italy. 2022; 1173-1183.
14. Junaiddin A, Syaifuddin DT, Montundu Y, Zaid S. The application of linear programming into production schedule at electrical panel company. International Journal of Membrane Science and Technology. 2023;10(3):354-371.
15. Effendi M, Tunjang H, Hidayat DR. Analysis of aggregate planning to streamline production cost in the mahakam ice crystal home industry in the city of palangka raya. Jurnal Manajemen Sains dan Organisasi. 2023;4(1):1-12.
16. Mijinyawa M, Modibbo UM, Fimba K. Optimal production scheduling for a manufacturing company: A case of Adama Beverages Ltd.(FARO), Adamawa State Nigeria. International Journal of Advanced Research in Science and Engineering (IJARSE). 2019;8(6):21-30.
17. Cipta H, Widyasari R. Goal programming model in tackling the optimal building material for production planning. Journal of Industrial Engineering and Management. 2023;1(1):1-6.
18. Jong CH, Medina N, Fakhriyah N, Hidayat C, Hamali S. Using goal programming method for optimization of production planning. In 2018 International Conference on Information Management and Technology (ICIMTech). 2018;155-159. IEEE.
19. Kurniawan S, Raphaeli SS. Optimizing production process through production planning and inventory management in motorcycle chains manufacturer. ComTech: Computer, Mathematics and Engineering Applications. 2018;9(2):43-50.
20. Handayani S. Optimization of organic rice production using linear programming analysis in lampung province. Asia Pacific Journal of Management and Education (APJME). 2022;5(3):37-47.
21. Ford LR, Fulkerson DR. Flows in networks. Princeton University Press. Princeton, NJ; 2010.
22. Sasidhar B, Achary KK. A multiple arc network model of production planning in a steel mill. International Journal of Production Economics. 1991;22:195-202.
23. Ibrahim A. Aljasser, Bokkasam Sasidhar. Scheduling in a single-stage, multi-item compatible process using multiple arc network model and excel solver. International Review of Management and Business Research. 2018;7(1):23-31.
24. Howard J Weiss. POM - QM FOR WINDOWS software for decision sciences: Quantitative methods, production and operations management. Pearson Education; 2016.
25. Gede Marendra I, Made Aryata I, IrmawanAfgani. POM QM for windows training for industrial engineering students at the university of serang raya (UNSERA) in solving linear programming problems in everyday life and the world of work. Jurnal Pengabdian MasyarakatBestari(JPMB). 2023;2(2):125-138.