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Product Scheduling in a Multi-Product Colour Processing Facility - Case Study at TN Textiles (Pvt) Ltd

William M. Goriwondo, Walter Chipambwa and Samson Mhlanga
Department of Industrial and Manufacturing Engineering
National University of Science and Technology, Bulawayo, Zimbabwe

Michael Mutingi
Department of Industrial Engineering
University of Botswana, Gaborone, Botswana

Abstract

An integrated computer decision making system is developed to help in product scheduling for a multi-product colour system. It is an attractive option that will enhance flexibility of supply in fast-changing areas, fashion design, and consumer tastes. Problems in the production system will be solved by designed models. The transformation of the local manufacturing industry towards CIM systems has already begun to take root. This paper examines the potential benefits to TN Textiles and how it can exploit CIM technology. CIM simultaneously facilitates production of high product variety at optimum costs as TN must work with increasingly scarce resources.

Keywords
Computer Decision Making System, Multi-product colour processing, product scheduling, textile manufacturing

1 Introduction

One of the many challenges that are faced by manufacturing companies is production scheduling in the face of multi-product variety and compatibility. This paper outlines a case study of a company where an Integrated Computer Decision Making system was developed to improve optimization in multi-product colour processing in a textile manufacturing company.

Scheduling a set of products requires multi-objectives to be met. A setup is required for each production batch of common components, and hence it has an incentive to combine common components for several products into a single batch. This, however, may delay the completions of other products, and the problem of batching, in addition to scheduling, arises naturally. Within the multi-product batch manufacturing environment, effective control is a highly complex task, as short-term fluctuations in sales volume and product mix must be met by the manufacturing system in response to business and marketing requirements.

To solve the problems found in these manufacturing industries mathematical programming has been widely used though it presents challenges in solving large-size problems, hence simple rule-base methods are often used in the industry. Metaheuristic methods, such as genetic-algorithm and tabu-search, combined with suitable heuristic rules, are often applied as they are effective in obtaining near-optimal solution for these large-size problems.

In scheduling problems the focus on time is more detailed and may require even time formulations. Furthermore one faces rather conflicting goals than objectives. The optimal use of resources, minimal makespan, and minimal operation cost, against more qualitative goals such as reliability (meet demand in time, proper quality etc) such qualitative goals are often hard to quantify.

Planning in the textile processing industry is used to create production, distribution, sales and inventory plans based on customer and market information while observing all relevant constraints. It is a common practice that based on these operational plans, detailed schedules are worked out which define the precise timing and sequencing of the individual operations as well as assignment of the required resources over time.

Decision Support Systems (DSS) application in the area of scheduling and machine loading for the dyeing of piece goods with multi-port dyeing machines is believed to be rewarding. The origins of the problem start at the headquarters where an aggregate capacity planning system prioritizes and groups the incoming customer orders on a weekly basis (Saydam and Cooper, 2002). Ever-increasing demands for improved quality, customization, and shorter delivery lead times require textile firms, like other globally competitive firms, to optimize their operations. Long-term successes largely depend on optimal or near optimal scheduling and processing of customers' dye orders. At the plant level, operators struggle to maximize the number of dye-lots processed on a daily basis.

1.1 Aim and Objectives

To develop a computer based system that can be used for multi-product colour production scheduling to minimise lateness.

1.2 Company Overview

The study company, TN Textiles is one that manufactures textiles and dyeing is one of the processes. The company receives various orders of different quantities for various colours and colour combination. Faced with this situation, the company intends to establish a production schedule that revolves around the dyeing process so that setup time and costs are reduced while meeting promised delivery lead-times. This scenario is defined as a flexible job shop scheduling problem (Laoboonlur, 2004).

1.3 Statement of the Problem

Colour engineering and scheduling the different colour shades for processing with minimal set-up costs while attaining the required quality within delivery deadlines is a major challenge for TN Textiles. Due to the differences in colour compositions, machines have to be cleaned between batches but the intensity of cleaning differs on the preceding colour shades. Some need deep cleaning while others requires light cleaning and this has impact on the set-up costs. The other challenge of getting the right colour the first time and this is due to the nature of the dyeing operation. It is a key industry success factor to be able to schedule colours with minimum setup costs while achieving right colour quality as required by the different customers.

In this research, the production scheduling problem arising in the dyeing process at TN Textiles was solved using Linear Programming (LP).

1.3.1 The conflicting objectives

In order to see the different results that can be achieved, different rules were used based on the required importance of orders received using the following conflicting objectives.

- *The Accountant*: In order to maximize revenue there is need to process the most profitable orders first regardless of their due dates. This means running the orders with more colours that have less processing time since the price per kilogram is the same for light, medium and heavy shades.
- *The Marketing Manager*: In order to maximize on-time delivery performance, there is need to process all the orders according to their due dates. This means processing earliest due date orders irrespective of order size or colours thereby increasing customer satisfaction and loyalty.
- *The Dyehouse manager*: In order to minimize changeover effects within colour ranges there is need to sequence all orders by colour so as to ensure that all like colours are manufactured back-to-back. This is because cleaning in-between colour ranges result in production time lost. There is need to schedule production using colour groups and colour ranges and try to process all related colours first.
- *The Plant manager*: Orders should be scheduled such that all order due dates are met at optimum cost. There is no need to build up excessive Work In Process (WIP).

These conflicting objectives give a challenge to the scheduling of production. However, the ultimate solution would be one that optimizes the requirements of the various stakeholders as outlined above. Quality product should be attained at optimum cost and delivery deadlines should be adhered to.

2 Literature Review

Literature reviewed concentrated on aspects of production planning and control with emphasis on multi-colour scheduling in the textile industry. The overview of production planning and control is reviewed in relation to the different manufacturing scenarios and to the textile manufacturing in particular. Scheduling scenarios are also considered in order to identify the appropriate algorithm to use for this research.

2.1 Production Planning and Control

Production Planning and Control involve generally the organization and planning of manufacturing process (Gorden and Carson, 2011). The ultimate objective is to organize the supply and movement of materials and labour in order to achieve machine utilization. The plan for the processing of materials through the plant is established by the functions of process planning, loading, and scheduling. The dispatching function puts the plan into effect in accordance with available resources. Actual performance is then compared to the planned performance whereupon corrective action is done when necessary. In some instances re-planning is necessary to ensure the effective utilization of the manufacturing facilities and personnel (Guide and Shiverasta, 2000).

2.2 Factors Affecting Production Planning and Control

The factors that affect the application of production planning and control to manufacturing are the same as those that affect inventory management and control.
Type of Product: It is the complexity of the product that is important, not what the product is, except as this may in turn relate to the market being served.
Type of Manufacturing: This is probably the most influential factor in the control situation. For a large continuous manufacturing plant producing a standard product, routing is included in the planning of the plant layout.

2.3 Scheduling

It is stated that scheduling deals with the allocation of limited resources to jobs over time in order to perform a number of tasks (Baker, 1974). The allocation is in relation to the number of jobs and the machines that are available for processing during that time (Nawaz et al, 1983). Production Scheduling scenarios have been outlined as below (Senthilkumar and Narayanan, 2010) :-

- Single machine scheduling with single processor
- Single machine scheduling with parallel processors
- Flow shop scheduling
- Job shop scheduling
- Open shop scheduling
- Batch scheduling

Some research has been devoted to the problem of scheduling n jobs on a single machine to minimize the total weighted completion time in the presence of sequence-dependent setup times and release times. Solving such problems has used the branch-and-bound methods for small problems and modified weighted shortest processing time (MWSPT) based on non-delay concepts for large problems (Chou et al, 2008). There has been application of genetic algorithms in solving scheduling problems that deal with colour scheduling with the objective of optimizing on production cost while achieving delivery targets. Classical job shop is concerned with completion time related objectives (e.g. flow time and makespan). In such cases scheduling to process a light colour product after a dark colour has a major impact on the setup costs (Manakis and Yih-long, 2008).

2.4 Optimized Production Technology (OPT)

Planning and Scheduling can be integrated and this has received increasing attention in recent years (Grossman and Erdirik-Dogan, 2008). This is enforced by the Optimized Production Technology (OPT) that was developed by Goldratt from the Theory of Constraints (TOC). OPT is defined as a proprietary scheduling system that uses computer software to establish constraints in systems and focus attention on these bottlenecks. The TOC offers an opportunity for businesses to realize opportunities for improvement. The theory can be summarized as (Goldratt, 1988 ; Rahman, 1998):-

- Every system must have at least one constraint which represents opportunities for improvement.

It is thus critical to identify the resource constraint and focus attention on this resource. It is in this light that the dyeing operation at TN Textiles is singled out for improvement through analysis.

3 Model Design

The identified problems were solved through development of an algorithm that can always be applied universally so that customer orders are met on time. The system developed can generate dyelot numbers for each economic batch quantity processed so that traceability can be improved. The colour ranges are therefore ranked according to colour families, which are Red, Yellow, Blue, Green and Grey. Grouping the colours in their respective colour families allows the algorithm to calculate faster the setup and cleaning times involved for the shift from one colour to another. Also a ranking of these colours is done within each colour family with respect to light, medium or dark shade. The processing times are also assigned for each colour and these vary from medium to the dark. Since one of the objectives is to reduce production time lost due to setup of the machine or cleaning time each colour is also assigned a cleaning time against all the other colours. The database containing all this information provides a base for computing the time differences involved for each colour processed.

The risk of uncertainty when one colour is processed can be reduced by scheduling within colour families first then shift to the other colour when finished. Also records of the reworks can be used for reference and this also helps in keeping track of any problems. The algorithm developed should therefore address all these areas through manipulation of the database created.

3.1 Model building

The following is an explanation of the computer program done in Visual basic (VB6). The details of the steps followed in the development of the model follow the problem description and also takes into account all other processing parameters that can affect generation of results though they were not highlighted as major areas of focus for the model building.

3.1.1 Model Characteristics

The characteristics of the model include the following:

- *Operating Hours:* 24 hours per day using three shifts, with a five day working week (Monday to Friday).
- *Machinery:* Five automatic exhaust dyevats of which any can be specified by the user.
- *Dedication*: Colours that dye better on one type of machine are “dedicated” to that machine group and cannot be processed on the other type. This applies for the machine that bleaches the raw yarn into the colour white which corresponds to shade code 102.
- *Colours*: It refers to the wavelength of the light for example blue, green and red. Colours in which a yarn fabric must be dyed are associated with the Knitted product use. Styles and associated colors are specified by the user. The model allows 91 colors and the shade of each color must be specified as light, medium, or dark.
- *Dye Lot:* is the amount of a specific fabric to be dyed to a given color and shade. The maximum size of a dye lot is machine-dependent. The economic batch quantity for this research is 282 kg.
- *Machine Cleaning:* There are three cleaning processes, as follows.
  - *Type 1* = Cleaning between dyelots of the same color; trivial downtime.
  - *Type 2* = Cleaning between dyelots of different colors if either the colors are the same shade, or a lighter shade is followed by a darker shade downtime is relatively short.
  - *Type 3* = Cleaning between dyelots of different colors when a darker shade is followed by a lighter shade. Cleaning time in this case is in the order of 3.5 hours.
- *Processing time* (Dyeing time): light shade takes 3.0 hours while medium shade takes 4.0 hours and a dark colour takes 4.5 hours.
- *Customer Orders: These* Received by the dyehouse on weekdays in quantities which must be multiples of 5kgs as the packaging
- *Shade and Tone:* The shade is how light or dark the colour is, and tone refers to the blueness of the blue, or the redness of the red, that is you can get pure blue, or a mixture of say blue and yellow, the more of one colour you add to the first, the more it alters the tone.

3.1.2 The Database

All the information relevant for the model is captured in a database in Access. The database captures information about the processing parameters like cleaning times between different colours, processing times of all the colours within the product range, setup time between batches, colour families and the ranking of the colour within the colour families. The database and VB programme are connected by a *data control string ADODB*. The flow diagram of the system developed is shown in Figure 1 below.

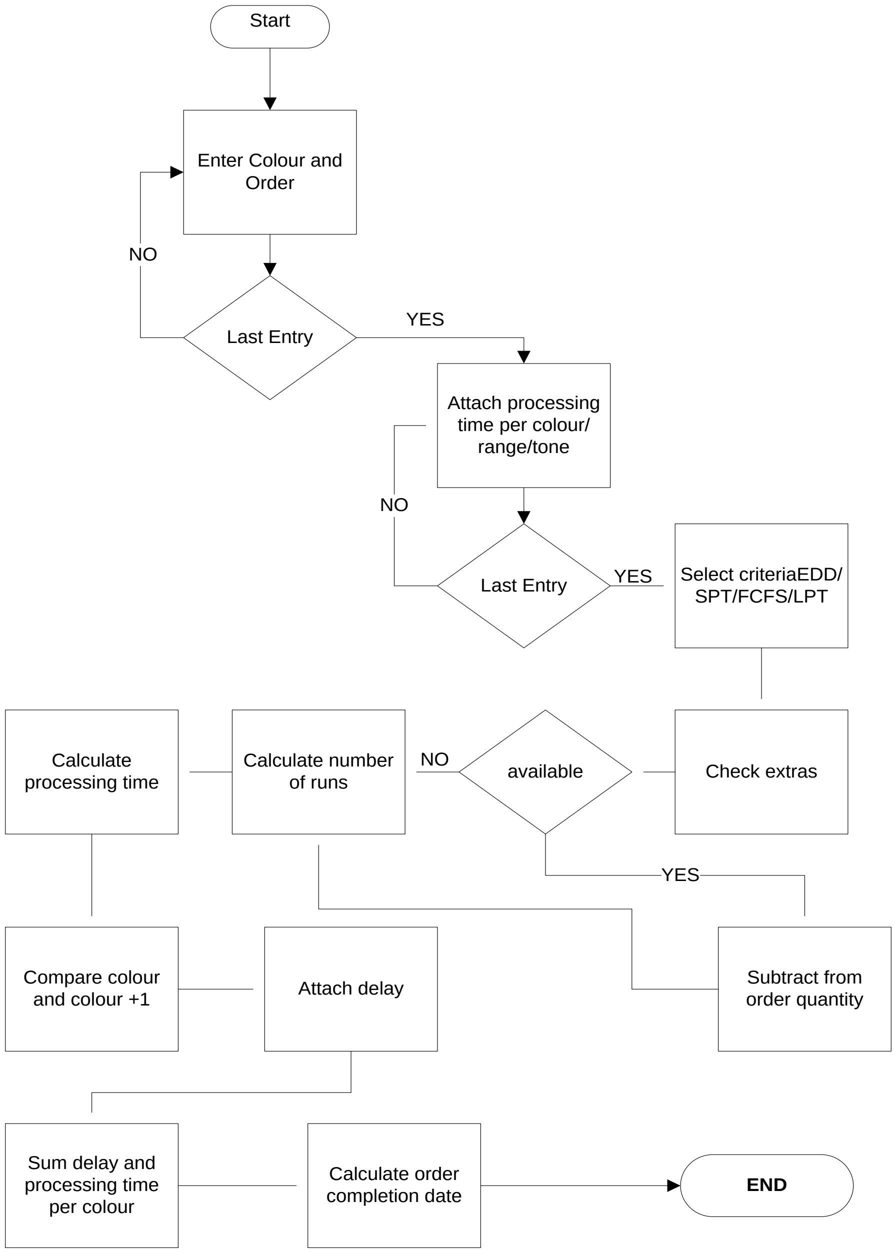

Figure 1: Flow chart of the model developed in VB

4 Results and Discussion

The model was used to obtain scheduling results for a complete order month of May for TN Textiles (Pvt) Ltd. Confirmed orders from the Sales Department were used together with outstanding orders from the previous month. The test-run could not be matched to the plant for the full period as operations stopped midway due to logistical problems concerning raw materials. Since the scheduling could be done by using the rules of jobs and orders, two types of scheduling methodologies were used namely job-based rule (EDD and SPT) and order-based rule (FCFS and Random)**.**

It was found that job-based rules (EDD and SPT) always gave better results than order-based rules. The results shown below give a summary after running the orders with information as given in Table 1 below. The constituting colours for each particular order are entered into the system so that results show orders completed on-time, the setup time (delay) between colour ranges and shades.

Table 1: Orders for the month of May

Customer Name	**Order Number**	**Order quantity (kg)**	**Order due date**
A	01	2000	05/03/2011
B	02	8000	05/05/2011
C	03	7150	05/06/2011
D	04	6550	05/09/2011
E	05	9200	05/10/2011
F	06	1500	05/16/2011
G	07	14500	05/20/2011
H	08	5420	05/17/2011
I	09	2300	05/07/2011

4.1 Analysis of results

Results obtained from the processed orders for each scheduling rule are shown in Tables 2 to 5.

4.1.1 Processing time using the Earliest Due Date (EDD)

Table 2 shows scheduling results using the EDD method. The total processing time is 54630 minutes with a delay of 4500 minutes giving a total of 59130 minutes.

Table 2: Scheduling results showing Earliest Due Date (EDD)

Order No	**Quantity**	**Processing Time**	**Delay**	**Total Delay**	**On Time**
1	2000	1710	460	2170	8
2	8000	6480	500	6980	19
3	7150	6390	710	7100	4
4	6550	4950	520	5470	5
5	9200	8220	560	8780	0
6	1500	2880	210	3090	0
7	14500	14670	710	15380	0
8	5420	7380	560	7940	0
9	2300	1950	270	2220	3
Totals		**54630**	**4500**	**59130**	

4.1.2 Processing time using the Shortest Processing Time (SPT)

Table 3 shows scheduling results using the Shortest Processing Time (SPT). The total processing time is 53790 minutes with a delay of 710 minutes, giving a total of 54500 minutes.

Table 3: Scheduling results showing Shortest Processing Time (SPT)

Order No	**Quantity**	**Pro Time**	**Delay**	**Total Delay**	**On Time**
1	2000	1350	0	1350	9
2	8000	7470	220	7690	15
3	7150	7500	150	7650	11
4	6550	5910	0	5910	1
5	9200	8880	0	8880	0
6	1500	2400	220	2620	0
7	14500	14610	120	14730	0

8	5420	4590	0	4590	0
9	2300	1080	0	1080	3
Totals		**53790**	**710**	**54500**	

4.1.3 Processing time using First Come First Serve

Table 4 shows the scheduling Results for First Come First Serve method. The total processing time using the FCFS is 60340 minutes broken into 54780 minutes for processing time and 5560 minutes for delay.

Table 4: Scheduling results showing First Come First Serve (FCFS)/ Random

Order No	Quantity	Pro Time	Delay	Total Delay	On Time
1	2000	3210	180	3390	6
2	8000	8700	830	9530	19
3	7150	6780	610	7390	9
4	6550	6000	380	6380	4
5	9200	9540	520	10060	3
6	1500	2310	330	2640	0
7	14500	12300	970	13270	0
8	5420	4680	1210	5890	0
9	2300	1260	530	1790	10
Totals		**54780**	**5560**	**60340**	

4.1.4 Processing time using Longest Processing Time (LPT)

Table 5 shows scheduling results using the Longest Processing Time method. The processing time using LPT is 55500 minutes and a delay of 4650 minutes giving a total of 60120 minutes.

Table 5: Scheduling results showing Longest Processing Time (LPT)

Order No	Quantity	Pro Time	Delay	Total Delay	On Time
1	2000	3210	460	3670	6
2	8000	8700	500	9200	18
3	7150	6780	710	7490	8
4	6550	5310	520	5830	4
5	9200	9540	560	10100	2
6	1500	2310	330	2640	0
7	14500	12030	710	12740	0
8	5420	5040	560	5600	0
9	2300	2580	270	2850	10
Totals		**55500**	**4620**	**60120**	

4.1.5 Scheduling rules comparison

Results above show that job-based rule methodology gives better average completion. The delay used during the execution of the programme refers to the cleaning time required in between colours. SPT uses the algorithm that first selects the colours requiring less processing time and this reduces the need to clean the machine hence minimizing sequence dependant setups.

4.2 Setup Time or Delay

Further, with the use of the average completion time and utilization percentage as the measures. Table 6 shows that SPT is the best method, followed by EDD. LPT and FCFS give the worst results. The programme also calculates colours that are completed on-time. This is a very important criterion in choosing the best rule to use for the scheduling as any major deviation from the promised delivery dates results in lost business.

Table 6: Summary of Setup costs

	SPT	EDD	LPT	FCFS
Delay(minutes)	710	4500	4620	5560
Total colours off schedule	39	39	48	51
Production loss (kg)	910	5768	5922	7127
Monetary loss($)	$12 286.23	$77 870.50	$79 947.00	$96 213.27

The production loss was calculated using processing time of an average shade that is 220 minutes for a medium shade using Equation (1). The monetary value lost due to the delay in setup between shade ranges using the different rule is also a function of the production lost as shown in Equation (2).

$$\boldsymbol{production\ \ loss\ (kg) = \frac{\sum \text{delay}}{220} \times 282} \tag{1}$$

$$\boldsymbol{Monetary\ value\ loss = production\ loss\ (kg) \times US\$13.5} \tag{2}$$

Satisfying all the objectives of the Accountant, the Dye house manager, the Marketing manager and the Plant manager can result in conflict on what to produce but the ambiguity can be solved by having a standard procedure on processing orders when received in dye house which they all agree upon**.**

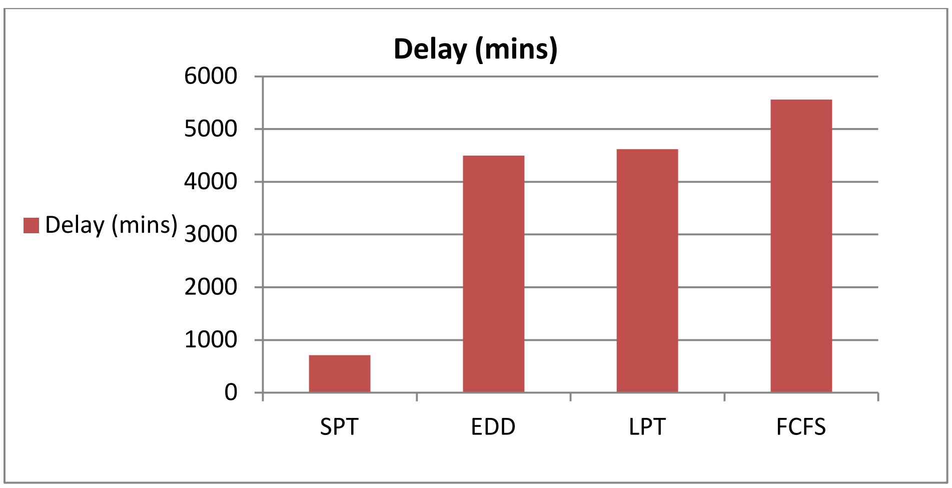

Figure 2: Delay (sequence dependant setup)

The sequencing of colours using SPT followed the rankings of colours within their colour families thereby resulting in less time lost between changes. The colours with shortest processing time are also the lighter range colours and the time required for cleaning the machine from a dark range to a lighter range is also the highest, therefore this rule is more preferable especially given there is less chances of spoiling of the next colour to be run. Using the other rules results in the delay or cleaning time being higher as shown in Figure 2 above.

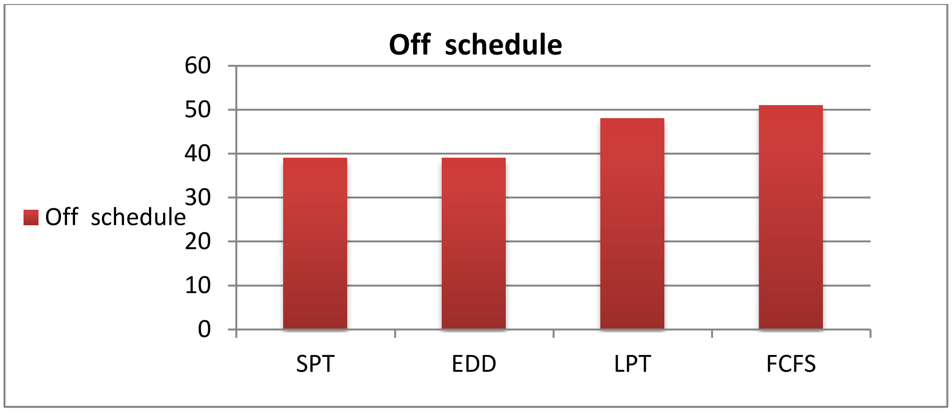

Figure 3: Number of Colours off-schedule

Using the earliest due date and shortest processing time for the specific orders for May gives same results but change of order quantities can result in notable differences between these two rules. The first come first serve has the worst results as 51 colours showed that they will not be on time.

All the rules used dependant more on the order requirements as determined by the sales department but in general all have been modeled to try and minimize setup time lost through cleaning of the machine and also uses the colour families as grouped in the database so that like colours are processed in preference to random choosing of colours.

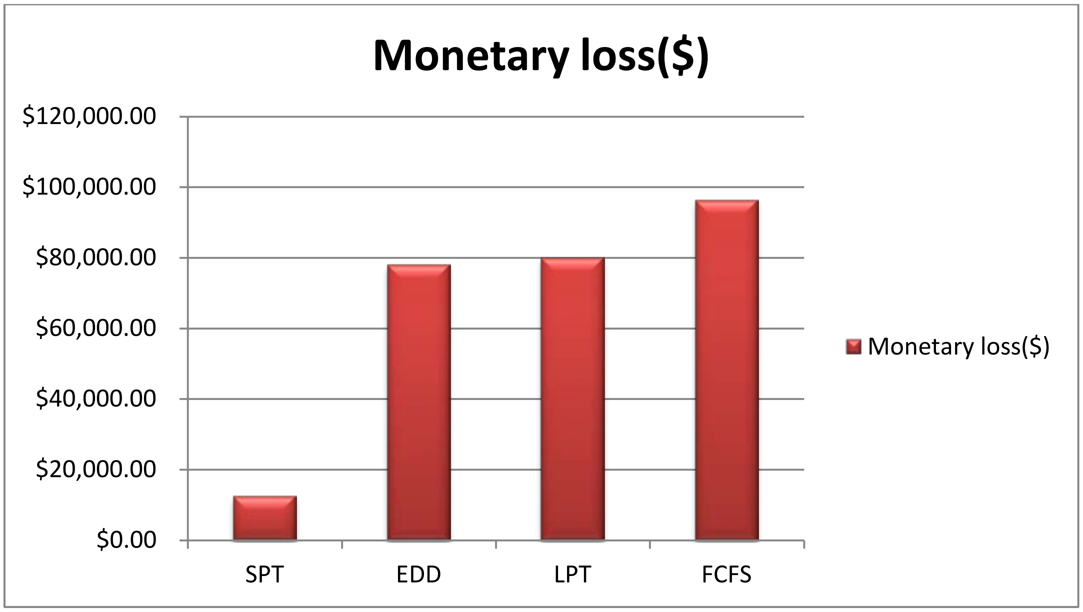

Figure 4: Monetary value loss US$

The loss shown above in Figure 4 shows the lost business due to setup and sequence dependant time losses. The loss will be expected to increase given the other process challenges that can be faced like power cuts and machine failures resulting in failure to meet promised delivery dates. Failure to meet promised delivery dates results in loss of business. A balance of the two methods that is SPT and EDD can be used as they both showed they can perform fairly the same with respect to number of outstanding colours. Considering the costs of not meeting the due dates the conflict between the different stakeholders can be resolved after analyzing the opportunity cost.

Therefore, based on this case study, utilizing SPT or EDD may be a better idea. However, choosing between SPT and EDD methodology may be ambiguous. It depends highly on the company objectives and their costs.

5 Conclusion

We have presented that sequence dependent times during manufacturing especially in a colour shop can be greatly reduced by employing different scheduling rules that can result in better allocation of resources at the same time fulfilling customer orders. We solved a scheduling problem that can be faced within a particular month for nine orders with different requirements. The results show a print-out from the database of the scheduling of colours on the machines that is qualified as the best compromise.

This paper discussed the results as obtained from the model developed in Visual Basic linked to the colour database. All the parameters are related to each particular colour. Orders for the month of May were run to obtain results for identifying the total processing time and hence the tardiness of each rule based on the received orders. A balance between satisfying promised dates to customers, reducing the overhead costs and other process related cost deviations is also important. However, there is always conflict among different stakeholders. This model helps to establish an optimum schedule that strives to attain a reasonable balance of orders.

In this highly competitive global market, manufacturing companies need to implement sustainable solutions to challenges. Production scheduling presents one such challenge that causes delays in meeting customer demand in terms of quality and quantity. As such the developed computer program can aid in order scheduling with emphasis to colour mixes and sequence.

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