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DEFINING THE PRODUCT MIX BASED ON STRATEGIC CAPACITY MAPPING IN WOVEN TEXTILE MANUFACTURE

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Abstract—This work is aimed at optimizing the operational management by deciding upon articles composition to be made on different process flow and capacity within an industrial situation. More specifically: matching the quantity and arrangement of order variation to assign appropriate tasks to applicable production units. The problem arises due to various process flows and task time necessary to produce different articles. Appropriate product composition is expected to minimize set up time, and increase overall machine utilization and efficiency. Similar issue have a strong importance in textile industries, eminently in filament woven textile manufacture in which the process load varies dynamically upon fabrics construction. To present the solution, an MRP model is constructed as a preliminary analysis on process and raw material requirement for each order. The MRP model's output will be mapped into a capacity map that is constructed based on real life machines capacities and task times. Subsequently, product mix combination is derived through application of linear programming simulation to minimize capacity waste.

Keywords: textile, MRP, linear programming, production planning, strategic capacity mapping

I. INTRODUCTION

In After the signing of CAFTA Agreement in 2008, textile companies in Indonesia have been facing fierce competition to survive. With ever increasing labor and electricity cost and auxiliary price, Textile companies have to survive with very thin margin. Thus make continuous effort to increase efficiency, effectiveness and innovation extremely important.

As the ground base of fashion industry, appropriate machine composition is crucial to increase the survival rate of a mill upon shift in fashion trend. Thus, suitable product to machine capacity mapping needs to be applied to accommodate the machine composition to achieve high utilization and production output rate. A strategy in choosing the right *product mix* to increase machine utilization and diversify risk has to be derived to increase competitiveness.

II. BUSINESS ISSUE EXPLORATION

A. Conceptual Framework

Surviving in oligopoly competition, it is crucial for textile companies to maximize their output to reduce fixed cost per unit fabrics. In order to boost its competitive advantage, the company has *to find appropriate product mix that maximizes its machine utilization rate and productivity*. Inappropriate capacity mapping causes waste of resources, stacking up inventory in buffer of each process, and machine down time due to raw material unavailability.

Based on the commonly run fabrics construction in the market, the research tries to propose a generic solution/formulation of the correct product mix for the installed capacity in a weaving mill through *strategic capacity management* and *line balancing approach*.

Since similarity to real problem is crucial, this analysis is conducted in a weaving mill that performs in house pre-weaving treatment.

Aside from repackaging of the yarn, sizing, twisting, interlacing and process will be taken into account to add complexity to mimic real life situation. Sizing of warp yarn is required except for twisted and highly interlaced yarn.

Based on the process flow, the product can be categorized into three:

- Fabrics made of Twisted Warp and Twisted Weft Yarn
  Both warp and weft have to undergo twisting process
- Fabrics made of Sized Warp and Twisted Weft Yarn
  Warp yarn will be repackage in sizing machine prior to application of sizing agent, while weft yarn has to undergo twisting process
- Fabrics made of Sized Warp and Non-Twisted Weft Yarn.

The complete process flow is described in the figure below:

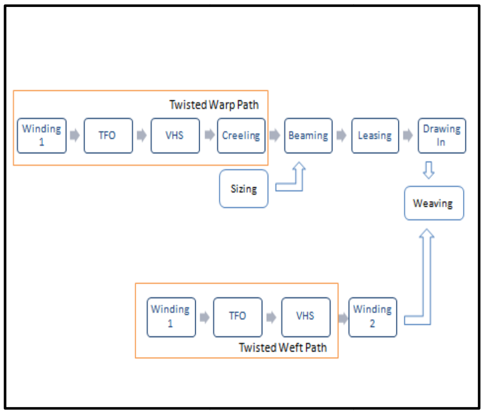

Figure 1. Process Flow

B. The Method of Data Collection and Analysis

Divergence of several hours in the task time has little impact in the overall performance due to the average task time of a weaving beam is around 20-30 days. Thus, the use of primary data analysis is not suitable due to the lengthy period of data collection.

Hence, the project will use secondary data based on pre existing daily, weekly and monthly report to calculate the efficiency, productivity and utilization rate of the machines.

C. Analysis of Business Situation

For each order, the number of machine run will gradually increase depending on the number of mechanics available. A normal production curve and machine allocated for an order should increase gradually until it reach its targeted production rate, and then gradually decrease until the end of the beam.

On ideal situation, the graph of machine run for each order should follow trapezium like shape. Irregularity of the pattern indicates overtime of mechanics or machine downtime due to change in scheduling policy or unavailability of raw material. Figure 2 shows the comparison between ideal graphs of machine run as compare to real life situation.

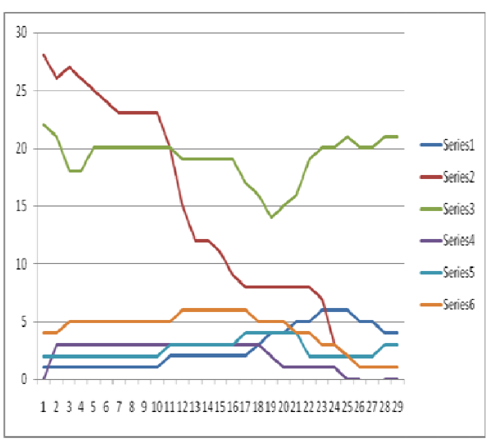

Figure 2. Machine Running Chart

Irregularities was observed in series 3, showing that there is lack of coordination or sudden change in production planning.

Such changes are observed to be the main cause of machine downtime due to set up time and waiting time.

The problem arises due to the variety of process flows required to fabricate different articles. Failure in recognizing the capacity mapping might lead to starvation and stocking up buffer in certain process.

III. BUSINESS SOLUTION

In order to determine the business solution, a strategic capacity map is constructed to simulate real order and define the ideal quantity that should be produced. Prior to the capacity map , an MRP model has to be constructed to define the required resources for each order quantity.

A. Defining product mix through machine to product mapping

In order to construct the mapping table, an MRP model needs to be generated to calculate the required resources and work hour to complete an order project.

The MRP Model

The MRP model takes up fabrics construction and quantity as input and calculates the necessary resources in a unit of work hour. The resources requirement is based on the batch size mapping and the work hour of each process. Due to the dynamic work load nature of the weaving process, the batch size and work hour varies according to the fabrics construction. The resources allocation and work hour based on fabrics construction is illustrated below:

Fabrics Construction

Filament based fabrics construction is defined as :

Warp Denier –Warp Twist x Weft Denier - Weft Twist;

Warp Density x Weft Density x Width

Or

$d_1\ T_1 \times d_2\ T_2$;

Wd x Pick X Inch

The tables below show the resource required to finish an order based on the fabrics construction.

Table 1. Warp Preparation

Process	Unit of Resources	Resources Needed
Pirn Winding	Spindles	Total end = Wd x Width Machines Required = ______
Two for One	Spindles	Machines Required = ______
Vacuum Heat Setter	Box 1 VHS Box = n Spindles	VHS Required = ______
Creeling/ Warping	Machine 1 Creeling Machine = n Spindles/ Cones	Machines Required = ______
Beaming	Machine Weaving Beam = M meters	Process Required = ______
Leasing	Machine	Process Required = # of Beam
Drawing In	Rack / Operator	Process Required = # of weaving machine allocated

Table 2. Weft Preparation

Process	Unit of Resources	Resources Needed
Pirn Winding	Spindles	Spindles Required = $\frac{Total\ Weft\ Lenght}{Pirn\ Capacity}$
TFO	Spindles	Spindles Required = $\frac{Total\ Weft\ Lenght}{Pirn\ Capacity}$
VHS	Box 1 VHS box = n Spindles	VHS Required = $\frac{Total\ \#\ of\ Pirn}{VHS\ Capacity}$
Winding 2	Spindles	Spindles Required = $\frac{Total\ Weft\ Lenght}{Bobbin\ Capacity}$

Defining the Task Time and Batch Size of Each Process

The task time of each process in weaving and weaving preparation is defined as follow:

- Weaving

The production task time in weaving machine is calculated as:

$$Fabrication\ Speed = \frac{RPM}{Pick}\ inch/minutes$$

$$Beam\ Task\ Time\ (\ Age) = \frac{Beam\ Capacity\ (lenght)}{Fabrication\ Speed}$$

- Drawing In and Leasing

The drawing in process tasks speed is defined as n/minutes while n equal to the number of warp yarn in a fabric construction.

- Beaming, Creeling/Warping and Sizing

The speed of beaming, creeling/warping and sizing process is defined in m/minutes unit.

- Vacuum Heat Setting

The VHS process task time is defined in T minutes.

- Twisting

The yarn speed of TFO process is defined as:

$$Yarn\ Speed = \frac{2\ x\ RPM}{Twist\ Per\ Meter}$$

And thus TFO task time =

$$Task\ Time = \frac{Yarn\ Lenght}{Yarn\ Speed}$$

- Winding Machine

Winding machine is used to repackage yarn and its task time is defined in m/minutes unit.

Strategic Capacity mapping and Linear Programming

Based on the MRP Model, an aggregate MRP model is constructed to forecast the amount of resources and work hour required to finish a variety of orders quantity and fabrics construction that comes simultaneously. The capacity used for a total order running is calculated by summating the entire working hour and resources needed by the total order.

Capacity Used

The Capacity Used on each 4 core processes is formulated as:

Weaving Capacity Used =

$$\frac{1}{RPM\ x\ 60\ x\ 39.37}\sum_{i=1}^{n} Pick_i\ x\ Quantity_i$$

Sizing/ Beaming/ Creeling Capacity Used =

$$\frac{1}{Speed}\sum_{i=1}^{n} Quantity_i$$

TFO Capacity Used for Warp =

$$\frac{1}{TFO\ Spindles}\left(\sum_{i=1}^{n}\frac{Quantity_i\ x\ Wd_i\ x\ Width_i\ x\ Warp\ TPM_i}{2\ x\ RPM_i}\right)$$

TFO Capacity Used for Weft =

$$\sum_{i=1}^{n}\frac{Quantity_i\ x\ Pick_i x\ (Width_i + 4)x\ Weft\ TPM_i}{2\ x\ RPM_i}$$

A linear programming approach will then be applied to modify the order quantity to seek the combination of order that minimize the capacity waste.

Minimize (Capacity Waste) = Total Capacity Available – Capacity Used

The Application of The Strategic Capacity Mapping Model

The Application of the strategic capacity mapping model is illustrated below

1. Input Field

a. Fabrics Construction

Fabrics and its construction should be inputted into the model since the workload of the machine is dynamic to the construction.

#	Quantity		Article Name	Construction						
	in Meter	in Inch		Warp	TPM	Weft	TPM	Warp D	Pick	Width
1			Faille I	75	0	150	2200	144	72	70
2			Chiffon Crepe	75	600	75	3200	98	70	70
3			Lining	75	0	75	0	88	72	69
4			Faille II	75	0	150	1600	152	74	64
5			Sateen	75	0	75	800	190	84	64
6			China de Crepe	75	0	75	2600	190	88	67
7			Faille III	135	0	150	1600	128	68	61
8			Wool Peach	130	1000	150	1500	170	78	65
9			Double Chiffon	80	2200	80	2200	108	96	69
10			Faille IV	80	0	150	1800	208	78	51
11			Chiffon - 22	75	2200	75	2200	190	100	67
12			Chiffon -27	75	2700	75	2700	98	70	69
13			Crepe 200	200	1000	200	1000	80	60	65
14			Suiting I	200	1000	300	600	145	56	65
15			Suiting II	200	1000	150	1000	160	64	65
16			Suiting III	200	1000	200	1000	130	64	65
17			Batik	80	0	150	1600	156	72	65
25										
	0.00	0.00								

Figure 3. Fabrics Construction

b. Available Machines and Machine’s Setting

The fields take up the number of available machines in a mill and their setting.

VARIABEL FOR CAPACITY MAPPING				
Weaving Machine RPM (on Average)	550			
Number of weaving machine	172			
Maximum Weaving Capacity	123,840	pick		
Cones Size	750	gram		
Number of TFO	80		57600	hours
Sizing Capacity			720	hours
Creeling Capacity			1440	hours
Beaming Capacity			720	hours
Weaving's Beam Capacity	177165	inch		

Figure 4. Machine Variables

c. Solver Variable

The solver variable is used in linear programming to calculate the excess capacity in the mill according to the order quantity available.

Solver Variable	Hour Capacity Waste	% Capacity Waste
Weaving Machine balancing	123840	100.00%
TFO Balancing	57,600	100.00%
Sizing Balancing	720	100.00%
Creeling Balancing	1440	100.00%
Beaming balancing	720	100.00%
Total Hour Capacity Waste	184320	

Figure 5. Solver Variables

2. MRP Cells

The MRP Cells will display the necessary resources according to the fabrics construction and quantity.

Warp Preparation					Weft Preparation	#Weaving's Beam	Weaving's Speed (m/hour)	Beam's Task Time	Total Weaving
#Creeling	Sizing T Time	∑ TFO TT	Creeling Task	Beaming TT	∑ TFO TT				
0.00	0.00	0.00	0.00	0.00	0.00	0.00	458.33	387	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	471.43	376	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	458.33	387	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	445.95	397	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	392.86	451	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	375.00	472	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	485.29	365	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	423.08	419	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	343.75	515	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	423.08	419	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	330.00	537	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	471.43	376	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	550.00	322	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	589.29	301	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	515.63	344	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	515.63	344	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	458.33	387	0
	0.00	0.00	0.00	0.00	0.00	0.00			0

Figure 6. MRP Cells

3. Result

The result of the application of linear programming to the strategic capacity mapping model for the product mix problem is illustrated in the table below:

Table 3. Product Mix Problem Solution

Adjustable Cells

Cell	In meter	Fabrics
E23	69,992.34	Faille I
E24	77,344.89	Chiffon Crepe
E25	58,927.07	Lining
E26	69,711.69	Faille II
E27	76,982.66	Sateen
E28	86,592.77	China de Crepe
E29	62,958.56	Faille III
E30	84,216.70	Wool Peach
E31	103,866.06	Double Chiffon
E32	71,517.52	Faille IV
E33	118,724.41	Chiffon - 22
E34	83,867.76	Chiffon -27
E35	58,199.72	Crepe 200
E36	60,801.60	Suiting I
E37	68,775.83	Suiting II
E38	66,374.53	Suiting III
E39	68,029.53	Batik

B. Analysis of Business Solution

The model was constructed to derive the machine-product composition mapping as an improved production strategy.

Run on forecasted fabrics construction, the model has shown that a mixture of the three products will be able to increase production output by 30% as compare to running of all sized warp or all twisted warp on a mill consisting of 80 twisting machine, 1 sizing machine, 1 creeling machine and 172 weaving machines. Different machine combination and fabrics construction will yield different result though the same algorithm applies.

Without taking into account the scheduling policy and the time of order placing, strategic capacity mapping and linear programming can be used to increase efficiency and machine utilization rate through suitable product composition. The application of the strategic capacity mapping model has shown that machine-product composition and quantity affect the total output of the mill to a great extend.

The model should also be taken into account upon deciding the bottleneck process that requires capacity addition.

It can also be applied on new investment planning to formulate twisting –sizing to weaving capacity ratio based on forecasted market strategy.

IV. CONCLUSION AND IMPLEMENTATION PLAN

A. Conclusion

Based on the research, it is concluded that strategic capacity mapping can be used to formulate generic product mix solution.

Implementing strategic capacity mapping through the excel model, minimum capacity waste can be achieved by mixing twisted warp and sized warp order. Inputting regular market items on the excel model generate a guideline for the factory to decide upon which order to choose to improve their efficiency.

Based on the scheduling data, bottleneck process can also be detected. Running the strategic capacity map, the necessary capacity addition can be detected in order to achieve higher overall utilization rate.

B. Implementation Plan

The action plan for the product mix solution is define as follow:

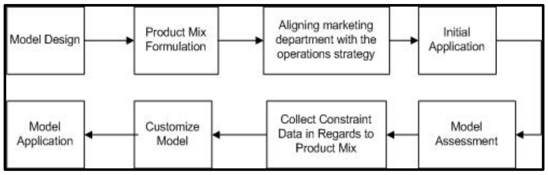

Figure 7. Implementation Plan

After the model design and the product mix formulation have been defined, the new product mix strategy is introduced to marketing department to align the order with the product mix. The production performance will then be assessed to analyze the impact of the new strategy to the utilization and efficiency rate.

Afterwards, the data and constraint in regards to the product mix solution should be collected to perform model customization before the final application of the model. Since the mill takes up order around 1 month prior to the production, the product mix formulation can only be assessed in two months after aligning with marketing department.

The constraint and downfall of the product mix solution will be collected as daily report upon the application of the product mix solution. Model customization will be done if necessary before the final application of the strategy.

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