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SIMULATING PRIMARY MANUFACTURING AREA (PMA) ACTIVITIES OF FIXED TRAILING EDGE PANELS PRODUCTION

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ABSTRACT

Simulation clearly has the potential to play an important role in manufacturing decision-making at many levels. This simulation study is conducted at the local manufacturing plant that manufactures fixed trailing edge panels for the aerospace industry. The model focused on operational activities at the primary manufacturing area of cutting and laminating of aircraft's composite parts. The model built was used to investigate a variety of issues, for example to determine the impact of a proposed change, without affecting production. The result shows that when production rate was increased by 20% to investigate the current plant capacity, the current resources capacity was unable to tolerate this increment. From the model experimentation, an increase of 60 minutes working time for ply cutter machines and 75 minutes of lay up operators found to be the best design to meet the expected production throughput and increase resources utilisation.

***Keywords**: Simulation, Modelling, Manufacturing, Planning, Aircraft*

ABSTRAK

Teknik simulasi berkeupayaan memainkan peranan penting dalam proses pembuatan keputusan dalam sektor perkilangan. Kajian ini dilakukan di sebuah loji pembuatan 'fixed trailing edge panels' untuk industri penerbangan. Fokus model yang dibina ialah aktiviti memotong dan melaminasi bahagian komposit kapal terbang. Model dibina bagi mengkaji pelbagai isu seperti menentukan kesan perubahan ke atas sistem tanpa mengganggu proses pengeluaran kilang. Hasil kajian mendapati apabila kadar pengeluaran ditingkatkan 20%, kapasiti sumber di kilang tidak mampu menangani pertambahan ini. Hasil ujikaji model mendapati kombinasi tambahan 60 minit

waktu bekerja bagi 'ply cutter machine' dan 75 minit bagi 'lay up operator' adalah paling sesuai menampung keperluan jangkaan pengeluaran di kilang.

***Kata kunci**: Simulasi, Pemodelan, Pembuatan, Perancangan, Kapal Terbang*

INTRODUCTION

Simulation technology is currently being used by many manufacturing companies in the developed countries such as the U.S. and many European countries with much success. The opportunities to cut costs and to improve service levels in this sector are tremendous by applying this technology.

It has become the main agenda of the manufacturing sectors to produce a cost effective product so as to stay competitive in business. In today's highly competitive marketplace, manufacturers use the latest technology to reduce time-off production cycles, ramp up production and speed up time-to-market. One-way companies can save time and cost by using factory-simulation software, which enable test production line activity before it is implemented.

It has then become normal practice by the management to conduct an experiment by setting the machines at certain speed and record the system performance. However, this experimental approach of studying a manufacturing system may not be economically feasible (Grabau, Maurer & Ott, 1997). Can also become costly, time consuming and not productive. Moreover, it is difficult to comprehend and anticipate the reaction of the system to certain experimental conditions on the spot. Many expensive errors can be avoided if simulation technology is used.

The design of new manufacturing systems or improving the existing system can be immensely supported by simulation as the designer is given an opportunity to assess the proposed system via properly designed experiments without the cost and time associated with physically building the system. A real-life system enviably contains randomness or variability and simulation is able to closely mimic these characteristics (Banks & Gibson, 1996).

This study focuses on applying a simulation technology to a manufacturing system of the aerospace industry in Malaysia. The manufacturing plant is located in a northern state of Malaysia and is a joint venture between the two Malaysian companies and two American companies. The plant is involved in the production of advanced composite materials for the aerospace industry.

The plant started its production with one production line, producing fixed trailing edge parts for the wings of the Type A aircraft. At present, the company has four production lines used to build parts for Type A, Type B, Type C and Type D aircrafts. The company also plans to expand its business by producing parts for Type E in the future and may even venture into other industries where there are demands for composite based components (Sime Darby Group News, 2000).

Schwetman (1998) described three types of situations where the simulation project is usually initiated; first when a new system is being designed, second when an existing system is delivering unsatisfactory performance, and lastly when the workload for an existing system is predicted to change. Simulation study at this plant is initiated based on the last case where the workload for the existing system is predicted to change. The managers need to understand the impact of such changes on system performance. The simulation model offers practical information to the management to make informed decision performance in these situations.

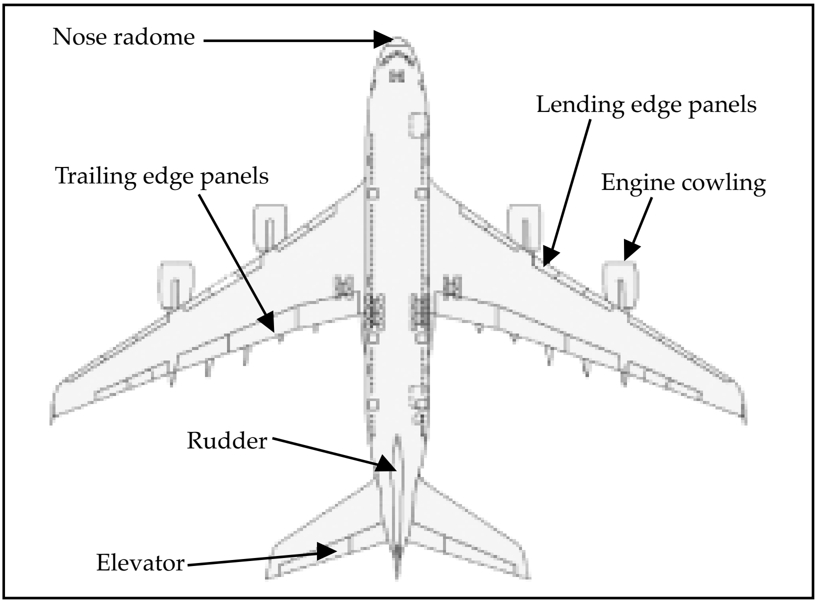


Figure 1
Plan view of a typical aircraft body.

Figure 1 shows a plan view of a typical aircraft body where composite materials are used at various parts of an aircraft. The parts that are currently being manufactured at the plant are trailing edge panels.

PRIOR STUDIES

Computer simulation has become an increasingly important operation research technique in recent years. It is the act of reproducing the behaviour of a system using a model that describes the processes of the system. Simulation has been applied to manufacturing problems for more than 40 years (Law & McComas, 1998). Simulation technology holds tremendous promise for reducing costs, improving quality, and shortening time-to-market for manufactured goods (McLean & Leong, 2001).

According to Kelton, Sadowski and Sadowski (2002), the main reason for the simulation's popularity is its ability to deal with very complicated models of correspondingly complicated systems. This makes it a versatile and powerful tool. Besides, the continual reduction in cost of computers and simulation software, emergence of more user-friendly and powerful simulation software, increase in the speed of model building and delivery, and acceptance of an established set of guidelines for simulation model building (Ülgen & Williams, 2001) make it all the more appealing.
The concept of simulation is both simple and intuitively appealing. Simulation is defined as the process of designing a model of a system and conducting experiments with this model for the purpose of either understanding the behaviour of the system and/or evaluating various strategies for the operation of the system (Carrie, 1988). The introduction of newer, user-friendlier simulation in recent times has made the task of simulation much simpler and less time consuming.

As computer hardware becomes more powerful, so does computer software too. The number of businesses using simulation is increasing rapidly. Many managers are realising the benefits of utilising simulation for more than just the one-time remodelling of a facility. The benefits of simulation modelling and analysis are discussed by many authors (Banks, Carson, Nelson & Nicol, 2000; Law & Kelton, 2000; Maria, 1997; Shannon, 1998) and are covered in the following:

1. Basic concept of simulation is easy to comprehend and hence often easier to justify to management and customers than some of the analytical models.
2. Simulation model captures more of the true characteristics of the system under study. It requires fewer simplifying assumptions and its behaviour has been compared to that of real system.

3. Simulation lets one tests every aspects of design and proposed change or addition without committing resources to their acquisition. In a simulation one can maintain much better control over experimental conditions than would generally be possible when experimenting with the system itself.
4. Simulation allows one to control time, either by speeding up phenomena over long periods or slowing down complex phenomena in detail.

Alternative proposed system designs or alternative operating policies can be compared via simulation to see which best meets a specified requirement.

Manufacturing simulation focuses on modelling the behaviour of manufacturing organisations, processes, and systems. Simulation models are built to support decisions regarding investment in new technology, expansion of production capabilities, modelling of supplier relationships, materials management, human resources, and so forth.

For many manufacturers, implementing a change in their real system can be very risky. Therefore, simulation can be used as the test bed for evaluation of new manufacturing strategies. Some of performance measures commonly estimated by simulation in manufacturing (Law & McComas, 1998; Rohrer, 1998) includes production throughput, cycle time, time parts spend in queues, queue sizes, work in process (WIP), timeliness of deliveries and utilisation of resources.

Recent illustrative uses of simulation in the manufacturing industry are in a continuous improvement process for the aerospace manufacturer (Adams, Componation, Carnecki & Schroer, 1999), implementation of moving line technology concept at Boeing factory (Lu & Sundaram, 2002), study on production capacity of Mercedes-Benz All Activity Vehicle (AAV) facility (Park, Matson & Miller, 1998), prediction of system performance of an electro-phoretic deposition plant (Chan 1995), and in business process re-engineering project (Irani, Hlupic, Baldwin & Love, 2000).

SYSTEM DESCRIPTION

The plant produces fixed trailing edge panels of aircraft. Current production rate is 110 parts per day. The parts flow in a single part order along moving lines in lay up cells through autoclave, water-jet trim, test, paint, inspection and finally to shipping. Batch processing is also applied at a few workstations. This paper only focuses on the operation at Primary Manufacturing Area (PMA), which involves the ply cutting and lay up (lamination) processes. The complete process of the activities is depicted in Figure 2.

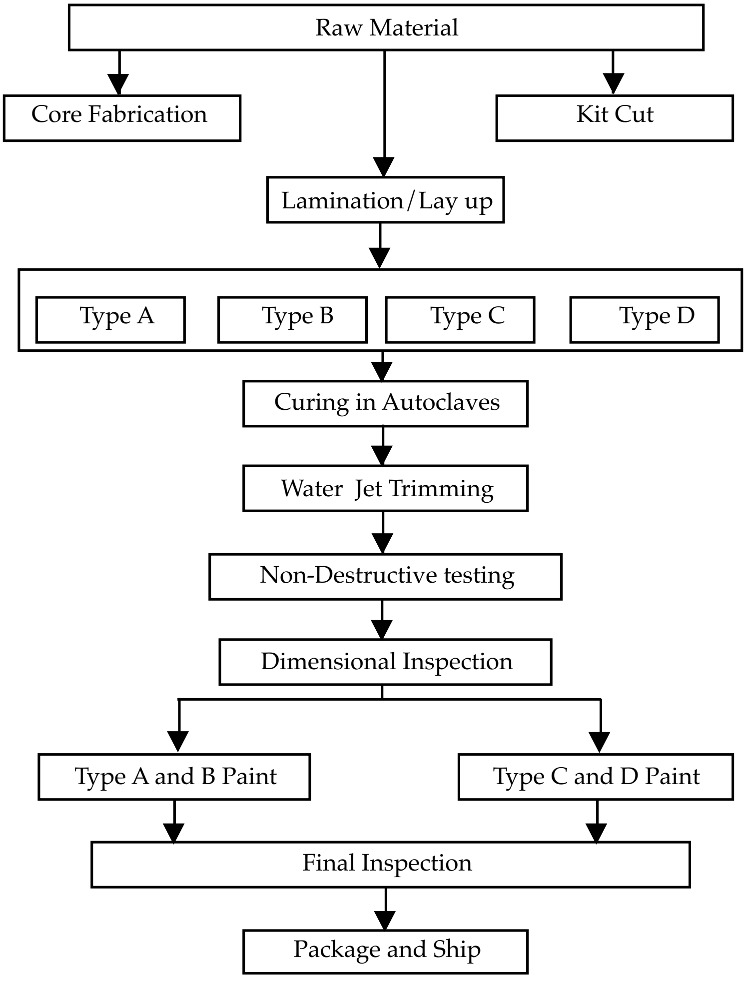


Figure 2
Schematic of production flows

Production process begins when a production planner issues a shop p-copy (manufacturing plan), which describes the process routing. Once the p-copy is issued to the production line, ply cutting process starts. It is a simple process where an operator firstly verifies the raw material and records tractability.

Then, a technician will operate an automatic cutting machine (kit-cutter) to cut the ply patterns. There are two identical cutting machines (c/w tables). One machine serves for Type A and Type B models, and another one for Type C and Type D models. The machines are driven by a personal computer (PC) and all patterns templates are retrieved from files in the PC. There is one technician assigned to operate each machine. After the cutting process, an operator will issue a part mark label as an identification label for a particular part and send the plies to the next process, that is lamination.

There are four lay up lines, one line for each model. This process consists of several steps and mostly is done manually. There are six stations for each line. The stations are connected to each other by a non-accumulating conveyor. The semi-finished part at the sixth station will then be sent to the staging (waiting) area for the next process that is curing in autoclave.

OBJECTIVES

The main objective of the study is to model and simulate the design and operational policies of the production process, which can be used to improve the performance of the different activities at the factory. The focused activities of modelling study are the operations at the Primary Manufacturing Area (PMA).

The following objectives were identified and pursued in order to achieve and realise the stated main objective:

1. To model the existing production system.
2. To understand existing operations and capability of the plant resources.
3. To find an alternative design of optimum production system.

The main objectives of this study were to provide information on machine utilisation, part flow time, and information on bottlenecks. The simulation was also used to test “what if ” scenarios such as increased production requirements, resources utilisation and other effects of operating variables on production.

MODEL DEVELOPMENT

The actual production process was studied and modelled into a computer simulation programme. Arena simulation language was used to model the activities at the plant under study. Arena is a Windows-based platform that is popular and widely used due to its tremendous flexibility and ease of use. Models can be constructed without any programming knowledge due to its use of dialog we boxes. The model then was simulated and analysed to investigate several alternative designs.

The model development is the most visible part of the simulation study. The model development will adhere to the goals and objectives and will be completed in phases of increasing complexity. The model will first capture the basic logic of the system and the logic flow. Part movement and elements will be added and verified as the model is developed. As soon as basic model function has been encoded, more detail can be added for each location until the desired function is achieved.

The Model Concept

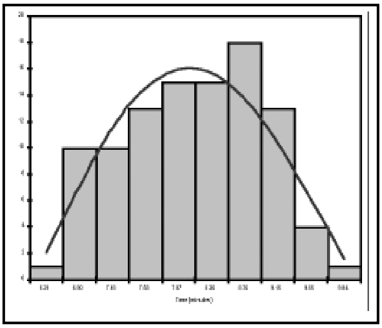
Arena simulation software was selected to construct the model. Arena is a general-purpose simulation package and is very powerful for many manufacturing applications (Kelton *et al.,* 2002). The Input Analyzer incorporated with Arena allows the user to input raw data and fit a statistical distribution to the given data. It provides excellent tools to fit input probability distributions based on actual data. Animation of the operations of activities at the plant provides a visual representation without the technical understanding of a simulation modelling language.

Table 1
Distribution of Process Times

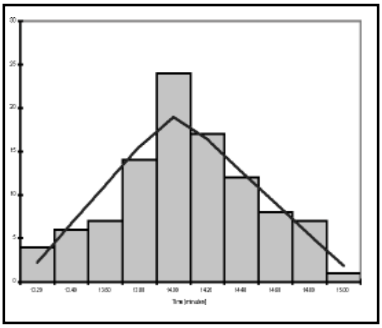
Process	Distribution	Expression
Ply Cutting	Beta	6 + 3.94 * BETA(2.28, 2.38)
Lay up Type A	Triangular	TRIA(13, 13.9, 15)
Lay up Type B	Weibull	13 + WEIB(3.38, 2.84)
Lay up Type C	Weibull	13 + WEIB(1.05, 2.46)
Lay up Type D	Weibull	14 + WEIB(2.11, 2.61)

Input Data

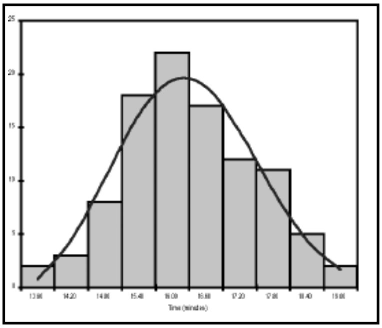
The distribution of process times at ply cutting machines and 4 lay up stations were fitted, using 100 samples of actual data (for each of the process) and the Arena Input Analyzer. Figure 3 (a-e) shows the generated histogram of distributed process times and Table 1 summarises the appropriate distribution for each of them.



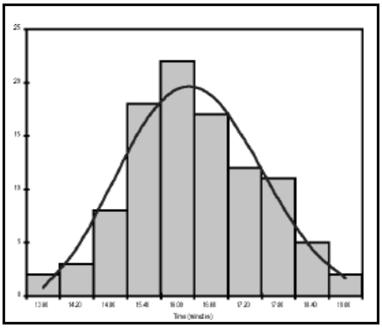
(a) Ply Cutting



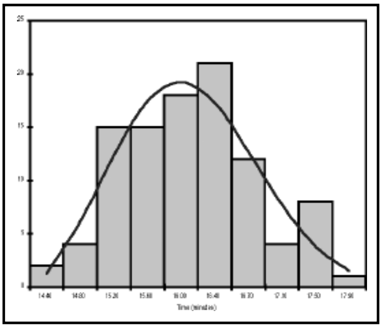
(b) Lay up Type A



(c) Lay up Type B



(d) Lay up Type C



(e) Lay up Type D

Figure 3

Histogram of process time distributions at five stations.

SIMULATION RESULTS

The statistics collected from the simulation model include parts throughput, parts flow times, utilisation of resources (ply cutter and lay up operators) and work-in-process quantity (WIP). The simulation model was run for 5 replications and the average was recorded.

Parts Throughput

Throughput represents the number of parts for the period of one-week study. Table 2 shows the output of the throughput using the simulation compared to the actual plant data and it seems that they are in good agreement.

Table 2
Number of Predicted Parts Compared to Historical Data

Part Type	Average Simulation	Historical Data	% Difference
Type A	121.0	120	0.83
Type B	99.8	100	0.20
Type C	119.4	120	0.50
Type D	100.6	100	0.60

Parts Flow Time

This is the total time that a part spends in the system to complete all the activities of cutting and laminating. The flow time should be kept to a minimum to reduce work-in-process inventories, which carry hidden cost. The average parts flow time is compared with the actual data together with calculated error is given in Table 3.

Table 3
Flow Time of Parts

Part Type	Average Simulation (min)	Actual Data (min)	% Difference
Type A	521.04	540	3.51
Type B	569.12	545	4.43
Type C	506.65	550	7.88
Type D	519.45	545	4.69

Resource Utilisation

Resource utilisation is the ratio of the average resource number busy to the average resource number scheduled. Resource utilisation is a common indicator of measuring how busy the machines and operators are. Table 4 exhibits the average of five replications scheduled utilisation for all resources. The output data indicate that the resource utilisations range from 82.87% to 91.29%, which are in agreement with actual average value claimed by the plant process engineer, that is 85%.

Table 4
Scheduled Utilisation Values for Resources

Resource	Average	Resource	Average
Ply Cutter 1	0.9129	Operator Type C 1	0.8659
Ply Cutter 2	0.9121	Operator Type C 2	0.8653
Operator Type A 1	0.8805	Operator Type C 3	0.8649
Operator Type A 2	0.8802	Operator Type C 4	0.8661
Operator Type A 3	0.8809	Operator Type C 5	0.8666
Operator Type A 4	0.879	Operator Type C 6	0.8667
Operator Type A 5	0.8815	Operator Type D 1	0.8298
Operator Type A 6	0.8831	Operator Type D 2	0.8318
Operator Type B 1	0.8337	Operator Type D 3	0.8318
Operator Type B 2	0.8345	Operator Type D 4	0.8287
Operator Type B 3	0.8304	Operator Type D 5	0.8294
Operator Type B 4	0.8316	Operator Type D 6	0.8311
Operator Type B 5	0.8314	Operator Type B 6	0.8348

High utilisation value of resources reflects that the resources are consistently busy but not necessarily mean a queue is present since the conveyor used is of the non-accumulating type.

Work-In-Process (WIP)

The WIP for each type of parts was also computed from the model. The output from the simulation model was then compared with the historical data. The results are shown in Table 5.

Table 5
WIP for Each Type of Parts

Part Type	Average Simulation(min)	Actual Data (min)	% Difference
Type A	16.1804	15	7.87
Type B	14.8433	16	7.23
Type C	15.8996	17	6.47
Type D	13.4634	14	3.83

MODEL EXPERIMENTATION

In line with the plan of company to expand its business by producing more parts, an increase of 20% of production capacity was experimented. The number of daily arrival was increased from 110 parts to 132 parts to investigate whether the present resource capacity can tolerate. Also, an additional two alternative scenarios were experimented with. One of the scenarios is a 20% increase of all resources working time (0.2 x 480 min = 96 min). The other scenario is an increase of 60 minutes for ply cutting machines, and 75 min for lay up processes. The simulation model was run for 5 replications and the average was recorded for each of the scenarios.

Parts Throughput

Table 6 shows and explains that present resource capacity (Scenario 1) was unable to cater the production increase. However, Scenario 2 and 3 seem that they are in good agreement with 20% expected increase of throughput.

Table 6
Number of Predicted Parts Throughput

Part Type	Expected Result	Scenario 1	Scenario 2	Scenario 3
Type A	144	123.8	143.6	142.4
Type B	120	124	119.8	119.2
Type C	144	103.8	143.6	142.8
Type D	120	107.4	120.2	119.2

Parts Flow Time

Parts flow time of the three scenarios is given in Table 7. Scenario 1 shows that the parts will spend more than 60% extra time compared to other scenarios.

Table 7
Flow Time of Parts

Part Type	Scenario 1	Scenario 2	Scenario 3
Type A	1051.4	529.87	561.81
Type B	1112.88	565.69	611.73
Type C	1054.83	515.95	576.55
Type D	957.68	533.76	562.1

Resource Utilisation

Table 8 exhibits the resource utilisation for the three cases. Ply Cutter 1 and 2 seem to be fully utilised in Scenario 1. However, for the other two scenarios, resource utilisations in Scenario 3 are higher than in Scenario 2.

Table 8
Resources Utilisation Three Scenarios

Resource	Scenario 1	Scenario 2	Scenario 3
Ply Cutter 1	1.0000	0.9111	0.9660
Ply Cutter 2	1.0000	0.9060	0.9689
Operator Type A 1	0.8998	0.8719	0.8992
Operator Type A 2	0.9013	0.8711	0.8940
Operator Type A 3	0.9016	0.8689	0.8969
Operator Type A 4	0.9003	0.8696	0.8953
Operator Type A 5	0.9023	0.8702	0.8954
Operator Type A 6	0.9013	0.8699	0.8949
Operator Type B 1	0.8651	0.8328	0.8642
Operator Type B 2	0.8678	0.8338	0.8617
Operator Type B 3	0.8651	0.8310	0.8599
Operator Type B 4	0.8636	0.8337	0.8629
Operator Type B 5	0.8677	0.8340	0.8619
Operator Type B 6	0.8642	0.8361	0.8588
Operator Type C 1	0.9006	0.8675	0.8946
Operator Type C 2	0.8984	0.8692	0.8944
Operator Type C 3	0.8985	0.8683	0.8949
Operator Type C 4	0.8977	0.8675	0.8961
Operator Type C 5	0.8986	0.8668	0.8950
Operator Type C 6	0.9005	0.8678	0.8945
Operator Type D 1	0.8899	0.8227	0.8520
Operator Type D 2	0.8855	0.8256	0.8543
Operator Type D 3	0.8865	0.8246	0.8540
Operator Type D 4	0.8900	0.8261	0.8507
Operator Type D 5	0.8871	0.8267	0.8511
Operator Type D 6	0.8862	0.8246	0.8535

Work-In-Process (WIP)

Parts WIP of the three scenarios is given in Table 9. Scenario 1 shows that WIP value is much higher compared to other scenarios.

Table 9
WIP for Each of Scenario

Part Type	Scenario 1	Scenario 2	Scenario 3
Type A	39.3473	19.9182	21.2324
Type B	34.9353	17.699	19.1944
Type C	39.4624	219.393	21.2055
Type D	29.934	16.659	18.0951

CONCLUSION

This paper presents the results of a case study that involved the use of a computer simulation technique for the production planning process in the aerospace industry. The model built was used to investigate a variety of issues, for example to determine the impact of a proposed change without affecting production. The model is also able to determine the plant capacity under various situations. This enhances the ability to manage the system, control its capacity, and make better decisions regarding its operation, which in turn improves the ability to deliver quality product to customers.

When production rate was increased by 20% to investigate the current plant capacity, the current resources capacity was unable to tolerate with this increment. From the model experimentation, an increase of 60 minutes working time for ply cutter machines and 75 minutes for lay up operators was found to be the best design to meet the expected production throughput and increased resources utilisation.

The research and the simulation model developed have improved understanding of the inter-relationship of the several physical components of the plant. The process of constructing the simulation model and reviewing the interaction of these components has given an insight into the different operational characteristics at the plant. The approach of system analysis is not only beneficial to the modeller, but it is also useful to the planner since it gives a thorough understanding on how the plant behaves and not how one thinks it behaves.

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