IMPLEMENTATION THEORY OF CONSTRAINT ON CFM56-3 AIRCRAFT ENGINE MAINTENANCE

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ABSTRACT

This research aims to optimize the maintenance process of aircraft engines type CFM56-3 by applying the theory of constraints (TOC), with five focusing steps are performed on service provider company aircraft engine maintenance. The beginning problem is the 50% of the 20 project of engines maintenance, are of time spent grooming engines or turn around time (TAT) over, which agreed with the customer 60 days.

In the identification step, found the average TAT 205 days, the length of time the procurement of components repaired by outside vendors on average 108 days and procurement of replacement parts are damaged, it takes an average of 40 days. In step exploits constraints, through the evaluation review technique (PERT) obtained at 87 days' expectations, and the critical path and the critical period 82 days. Then it was decided to make the procurement process as a buffer component for component collector station (station drum). Next subordinated whole process station on drums. The impact, of 7 engines maintenance projects undertaken average can be completed within 79 days. Elevation step done by investing some new equipment, so that the procurement of components which repaired by outside vendors can be drawn for service on internal processes.

In evaluation step, the use TOC in the engine maintenance CFM56-3, shown success, namely reducing the TAT of engines maintenance CFM56-3 from 205 days to 79 days or 75.9% of the TAT targeted. The reduction in TAT delays on engine maintenance CFM56-3 on service provider company of aircraft engine maintenance are 61.5%. It was concluded that the TOC can be implemented in the service provider company's of aircraft engine maintenance to resolve maintenance issues CFM56-3 engines.

Key words: *TOC, Maintenance, PERT*

1. INTRODUCTION

Maintenance is a combination of several actions aimed at maintaining the performance of the facility or machine (British standard 3811, 1974; Pophaley & Vyas, 2010; Altuger & Chassapis, 2009). CFM56-3 engine treatment or so-called shop visit is based on the schedule and unscheduled. The engine must be undergoing scheduled maintenance, made to the engine components have been exhausted or nearly exhausted its operating life, so that the engine components must be replaced. While unscheduled maintenance, carried out on machines that can not function in accordance with the standards of operation or damage (Engine shop manual, 2011).

In carrying out maintenance of aircraft engines, the airline handed a provider of aircraft engine maintenance services. Where among the company's capabilities, one of which treat engine CFM56-3 type aircraft. The clientele is the airline that operates the B737 classic aircraft type Boeing Corporation's products and using the driving engine type CFM56-3.

CFM56-3 engine maintenance workscope has three (scope of work), the minor repair, restoration and overhaul performance. The scope of work is the repair minor repair work performed only on aircraft engine components that suffered little damage, because other components in serviceable condition, so that the implementation does not need to follow entire of the aircraft engine maintenance workflow. While the

ISSN : 1978-774X

scope of work the performance restoration and overhaul following entire of the engines maintenance workflow (Engine Shop Manual, 2011). Maintenance engines time or turn around time (TAT) a CFM56-3 engine with the work scope of restoration and overhaul performance target is 60 days (Shop Handling Guide, 2010).

1.1. Problem formulation

In conducting the CFM56-3 engine maintenance are problems of the working time engine maintenance exceeds the target time of 60 days. Based on the production year (2011), known TAT agreed with the customer can not be satisfied as much as 50% of 20 CFM56-3 engine that works.

This problem arises because of the time of procurement of replacement parts and components outside vendor components repaired or improved in other companies, can not support the engine treatment time target. The Company makes no buffer or buffer component provider. Thus, the process of collecting the components of each project, the time has gone backwards in setting up and configuring the engine components to supplying sub-station assembly process. Then it was time to retreat in sequence on subsequent processes.

Under these conditions, the aircraft engine maintenance service provider company's, take steps to reduce delays in processing CFM56-3 engines maintenance time by utilizing one of the concepts, namely theory of constraint or TOC (Goldratt & Cox, 2004).

1.2. Research objective

Research utilization Theory Of Constraint on issues CFM56-3 engine maintenance, in the aircraft engine maintenance service providers, aiming to get treatment processing time or turn around time (TAT) of treatment, according to a targeted under an agreement with a customer that is 60 days.

2. THEORETICAL BACKGROUND

2.1. Theory of Constraints

Theory of constraints or TOC, originally developed by Eliyahu Moshe Goldratt (1984) in his book, the goal. The performance of each company is limited by constraints, such as limited resources against its products. Companies that want to improve their performance, should be able to identify the constraints, exploiting constraints, then solve it (Goldratt & Cox, 2004).

There are several opinions about the TOC, such as TOC is a set of concepts, principles, and tools designed to help manage the system better (Zadry & Yusof, 2006). TOC is also defined as an example of a management philosophy built upon a number of assumptions and is designed to provide a process improvement continues over time (Qassim, 2000). TOC is a combination of philosophy, concepts, principles, and tools conceived to maximize the performance of any system to identify, manage and solve the most stringent limiting factor in the system. In summary the concept of TOC can be said that every system must have at least one obstacle, and the obstacle is an opportunity for improvement. The use of TOC in manufacturing can be divided into four categories: scheduling method, program improvement, project management and combination (Moss, 2007).

TOC combines the idea, purpose or mission of the organization is the existence of an organization. Only the owner of an organization that can determine the purpose or mission. To public shareholders, the goal is to maximize profits, because that owners of capital invested (Cox & Spencer, 1998). In Figure 1 Schematic TOC management system can be seen, that the TOC management system consists of elements such as logistics or scheduling methods, performance measurement, problem-solving or thinking process, project management, and market segmentation.

2.2. Five step focus TOC

In the TOC, there is a five-step procedure that allows for the overall planning process and focus attention on the work station that could potentially be affected by the changes in the system. The main principle of which is the basic philosophy of the TOC, that the performance of a system is limited by the constraints. In the process there is at least one constraint, and through the control

ISSN : 1978-774X

constraints will increase the flow of the process, so that the overall output can be increased (Mahapatra and Sahu, 2006).

There is a five-step framework for the implementation and utilization of TOC, where the steps are as follows:

1. Identify the system constraints (identifying the constraint). Identify the parts of the system where the weakest, with the data obtained is then displayed in the form of tables and Pareto diagrams.
2. Exploitation constraints (Exploiting the constraint). Determine how to eliminate or manage the constraints with the lowest cost. Through the depiction of the appearance of component procurement process is constrained by the exploitation of constraints.
3. Subordinated no constrained station (subordinating the remaining resources). After discovering the problem and have decided how to manage these constraints should then evaluate whether the constraint is a constraint on the performance of the system or not. If not it will go to the fifth step, but if it still happens constraints will be heading to the fourth step. By presenting the results of the station table subordination.
4. Elevation constraints (Elevating the constraint). This step is done with major changes in the system that new equipment investments.
5. Evaluation to repeat the entire process for different constraints. If the third and fourth steps have successfully done it will restart from the first step. This process will run as a cycle, because a solution can lead to new constraints need to be done.

3. RESEARCH METHOD

The research methodology consists of several phases, namely the initial stage, the stage of data collection, data processing stage, the stage of discussion, and conclusion stages, as in Figure 2 is a flow diagram of the study follows.

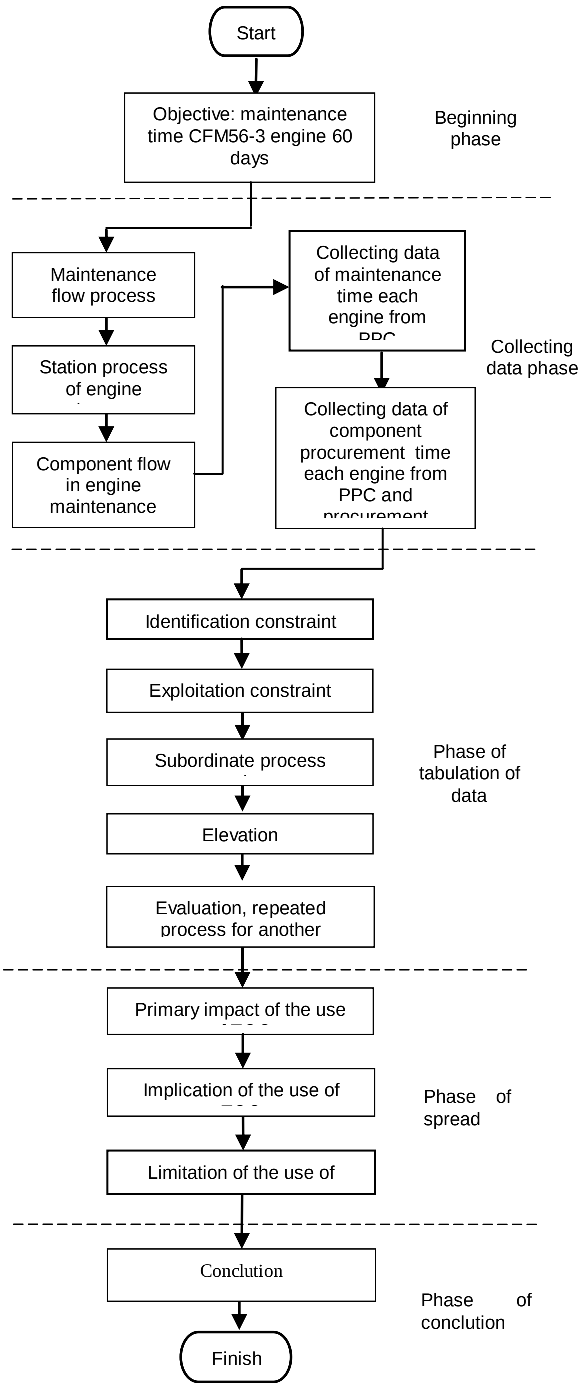

Figure 2. Flowchart of Research

4. RESULT AND DISCUSSION

4.1. Identification of Constraints

In this step begins with the collection of data drawn from the departments of production planning and control (PPC).

Based on production data in 2011, from January to October 2011, the company has completed the construction project as many as 20 engine (engine serial number). Among them there were 10 projects, see Table 1, undertaken with the scope of work overhauling and restoration performance as the data to be identified. The comparison of target and actual processing time of each engine can be seen in Figure 3.

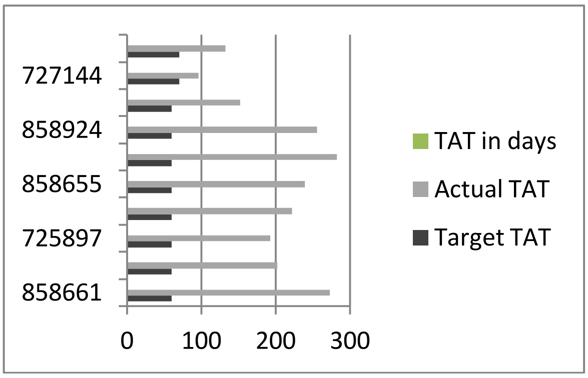

Figure 3. Comparison of target and actual processing time of each machine (unit day)

The next identification of constraints step to make the average time taken by each process station based on data from the 10 projects, see Figure 4.

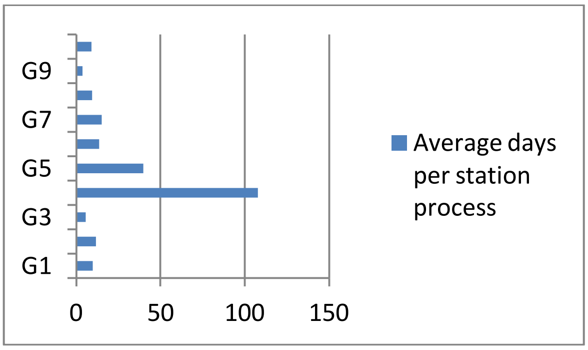

Figure 4. Average time per station in maintenance engine

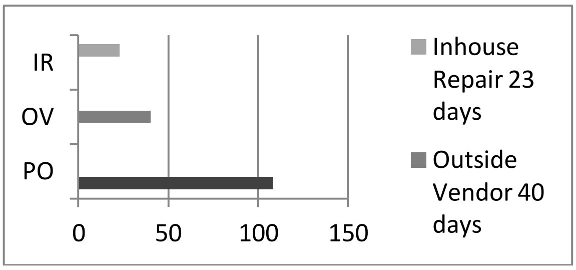

Figure 5. Average procurement component in days

The result of this identification step, inhouse repair 23 days, 108 days outside vendor repair and new purchase order for parts of 40 days, can be seen in the Figure 5.

4.2. Exploit Constraints

In step exploits constraints, expectations time calculated and critical path CFM56-3 engine maintenance by using a model of program evaluation review technique (PERT).

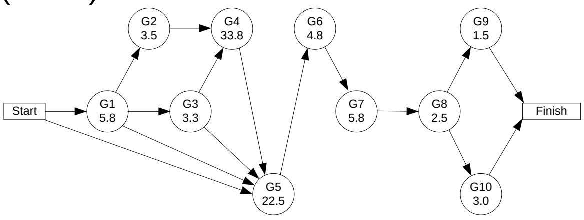

Figure 6. Network structure diagram

Activity care machine series, known expectations time and time critical 87 days 82 days, including component procurement process can be seen in Figure 6. Where the G5 as the train station work inhouse components repaired and is wary zone component procurement delays. On the components that need repair but the workshop did not have the capability, then start shipping to outside vendors G1 station immediately after completing the work. However, it is possible to outside vendor deliveries made after the G3 station, which at the time of inspection discovered components that require improvement. As for the procurement of new components as replacement parts operating life has expired, immediately started with the work station G1.

Activity station of maintenance									
G 1	G 2	G 3	G 4	G 5	G 6	G 7	G 8	G 9	G 10
					Inhouse repaired				
					Outside vendor repaired				
					Purchase order				

Start toaccount lateness

Start inhouse repaired and lateness on guard

Start outside vendor repaired process

Start purchase order

Figure 7.The process of procurement of components without changing work activity station

The reorganization of procurement of replacement parts and repairable components to balance production flow. Creating parallel work between the G4 and G5 component procurement with the demolition until the inspection process components. Changing G4 into the station-house components repaired, and G5 into component kitting. In the process of station maintenance engines activities put a buffer component procurement process as figure 8. Where the procurement department began working component procurement process since the engine maintenance contract with the customer approved. Thus the procurement department has enough spare parts procurement time freely.

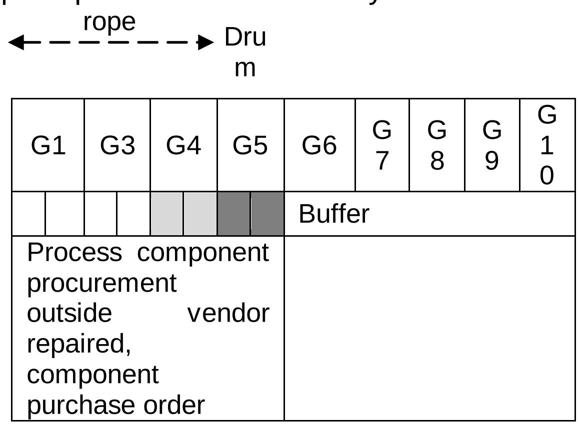

Figure 8. Activity of component procurement process into buffer

From these exploits constraints step, some of the results obtained, the expected time of 86.7 days ≈ 87 days, critical times 81.7 days ≈ 82 days. Activities G1, G2, G4, G5, G6, G7, G8, G9, G10 has a slack 1.5 days of work and activities G3 has a slack 35.5 days. Then make the decision making component procurement activities positioned as a buffer, while the G5 as a drum station.

4.3. Subordination Process Station

The subordinated step process station is not constrained to the station is constrains, the station intends to optimize the whole process to be a smooth flow of activities. Under the terms of the components procurement process work station that have taken on the steps of exploitation, the G5 activity stations serve as drum machines of the entire care process. Thus the whole of treatment following a schedule activity process G5 station.

Based on 2012 production data from the departments of production planning and control, that the timing of the completion of maintenance an average of 79 days. G4 Station outside vendor procurement process components repaired an average time of 17 days. G5 station time required for procurement of replacement parts an average of 14 days. And for inhouse components repaired settlement takes an average of 23 days calculated from the following G3 station.

4.4. Elevation Constraint

In an effort elevating constraints, this company has made new investments by buying some equipment. The goal is to attract outside vendor repaired so that components be repaired components inhouse. The equipment has been purchased, among others, fixtures, high speed grinding (HSG). However, this step has not been completed because the equipment can not be used. Because unresolved setup the equipment vendor. Equipment such as HSG, used to obtain dimensional flatness compressor, an equipment that has a high precision, resulting in the assembly is quite complicated. Similarly, operator training takes a long time.

4.5. Evaluation

The implementation of TOC with a 5 step focus, namely identification step, exploitation, subordination, elevation and evaluation, obtained some results as follows. At the time of identification of the difference between the actual targeted TAT. TAT obtained an average value of the difference 143 days. Where is the time required for procurement of replacement parts on average 40 days. As for the procurement of components outside vendor repaired it takes an average of 108 days and the time needed for the inhouse components repaired an average of 23 days.

From the steps of exploitation constraints, obtained some results, ie the time expectations ≈ 87 days 86.7 days, 81.7 days critical times ≈ 82 days. Activities G1, G2, G4, G5, G6, G7, G8, G9, G10 has a slack 1.5 days of work and activities G3 has a slack 35.5 days. Then make the decision making component procurement activities positioned as a buffer, while the G5 as a drum station.

After conducting exploitation and subordination constraints indicate a change. Components that require repair repaired outside vendor, the solution there is a change to an average of 16.1 days ≈ 17 days. The process of procurement of new components as replacement parts have been exhausted life operations, which are accelerating of the procurement on average 13.4 days ≈ 14 days. From 7 projects engine maintenance, machining results obtained with TAT 78.8 days on average ≈ 79 days.

The steps in the TOC produced some changes in time, where the working machine with original TAT average 204.7 ≈ 205 days to 78.8 days ≈ 79 days. The time change can be seen in the image below:

Table 2. Summary of time changes in maintenance engine in days

Sta siun	Activity	TAT before the use of TOC (days)	TAT after the use of TOC (days)
G1	Disassembly	9,7	11,3
G2	Shipping parts to outside vendor *repaired*	11,8	2,3
G3	Inspection complete	5,5	3,7
G4	All component include the parts O/V repaired, ready to assembly	108	16,1
G5	All component replacement was procure	39,7	13,4
G6	Subassembly	13,8	2,7
G7	Final assembly	15,1	11,3
G8	Engine test	9,3	6,6
G9	Engine was serviceable	3,8	2,4
G10	Invoice was ready	8,9	9
	Total	204,7	78.8

The evaluation steps, the use of TOC on maintenance issues CFM56-3 engine, showed the presence of a targeted approach at 60 days. Where the percentage of time spent on maintenance or turn around time (TAT) of treatment for a targeted, is achieved $= \frac{60}{79} x 100\ \% = 75{,}9\ \%$.

While the percentage of TAT reduction resulting from the use of TOC on maintenance issues CFM56-3 engine, is.$= \frac{205-79}{205} x\ 100\ \% = 61{,}5\ \%$.

4.6. Primary impact

Primary impact of the use of TOC in aircraft engine maintenance service provider corporate, processing time procurement of replacement parts and components repaired outside vendor becomes shorter. Initially, the time required to procure the components outside vendor repaired, sending up back in ready to be assembled on average 108 days, there is a change to an average of 17 days. While the process of procurement of new components as replacement parts have been exhausted life operations, initially it takes an average of 40 days to an average of 14 days. But to work inhouse components repaired, no changes in the average settlement of 23 days, before it takes on average 23 days.

From the change in the time of procurement of components, resulting in overall engine maintenance TAT. Where previously maintenance each engine TAT average 204.7 days ≈ 205 days, turned into an average of 78.8 days ≈ 79 days of each engine. This means that aircraft engine maintenance service providers, now has the ability to complete the treatment by CFM56-3 engine in an average of 79 days or 75.9% of the targeted time. While the percentage reduction in TAT delay of CFM56-3 engine maintenance on its aircraft engine maintenance service provider, 61.5%.

4.7. Implications of the use of TOC

In this implications theoretical presented studies that have been conducted relating to the use of TOC to improve the maintenance process. Exposure is intended as an overview of the study. In research conducted by Srinivasan, Jones, & Miller, (2002), on the use of TOC to improve maintenance processes at the maintenance center Marine Corps Logistics Base, Albany, Georgia, indicates success.

The root cause is the lack of consistent and high inventory levels by scheduling systems push the product out without regard status of resources, resulting in congestion. The invention uses a technique simplified drum buffer rope (S-DBR) to model and schedule of activities at the station processing components removed from the main product.

Similarly, in this study, the use of TOC on its aircraft engine maintenance service provider, moving procurement activities of outside vendor repaired parts and replacement components to be components procurement process, and makes the vendor or supplier as a buffer for the component. Here the buffer components makes both TCC and the NTCC. order activity component count and has a high dependence on vendors or suppliers.

4.8. Limitations in the use of TOC

Aircraft engine maintenance service provider corporate, are not implemented properly use of TOC with five step focus,. Five steps focus only applied to the third step. Exploitation step, buffer management is not done. That is, the aircraft engine maintenance service provider company's is currently no fundamental influence TOC utilization, resulting constraints have eased. Constraints will be eased if the buffer is appropriate as it is in theory do not just rely on the vendor.

5. CONCLUSION

Utilization TOC on issues CFM56-3 engine maintenance, as described in the chapter data and analysis, shows the success of the CFM56 engine maintenance lowers TAT-3 from 205 days to 79 days. Percentage TAT-3 CFM56 engine maintenance after TOC utilization is 75.9% of the TAT targeted. The percentage reduction in TAT delay of CFM56-3 engine maintenance on aircraft engine maintenance service provider company, at 61.5%. It can be concluded that the TOC can be implemented in the company's aircraft engine maintenance service provider to resolve the problem CFM56-3 engine maintenance.

6. REFERENCES

(a) Altuger, G., & Chassapis, C., (2009). Multi criteria preventive maintenance scheduling through arena based simulation modeling, Department of Mechanical Engineering Stevens Institute of Technology Castle Point on Hudson Hoboken, NJ, 07030, USA.
(b) Beale, D., (2008). Engine Condition Monitoring and Engine Trend Monitoring (ECM/ETM), Unpublished manuscript, MTU Maintenance Hannover, GMF AeroAsia
(c) Cox, J.F., & Spencer M., (1998). The constraints management handbook. Boca Raton, FL: St. Lucie Press.
(d) Engine Shop Manual for CFM56-3, (2011). Internal publication, CFMI. A joint Company Of Snecma, France and General Electric Co., U.S.A.
(e) Goldratt, E. M., & Cox, J., (2004). The Goal: A process of ongoing improvements, Third Revised Edition, North river press Publishing Corporation, P.O. Box 567 Great Barrington, MA 01230 United States of America.
(f) Gupta, A., Bhardwaj, A., & Kanda, A., (2011). Theory of Constraints- Lessons for Academicians and Practicing Managers from The Goal – II World Academy of Science, Engineering and Technology 75 2011
(g) Mahapatra, S. S., & Sahu, A., (2006). Application of Theory of Constraints on scheduling of Drum-Buffer-Rope system, Department of Mechanical Engineering, National Institute of Technology, Rourkela – 769008, India.
(h) Moss, H. K., (2007). Improving Service Quality with the Theory of Constraints, International Academy of Business and Economics. Published under license from the publisher through the Gale Group, Farmington Hills, Michigan.
(i) Pophaley, M., & Vyas R.K., (2010). Plant maintenance management practices in automobile industries: A retrospective and literature review. Journal of Industrial Engineering and Manajement. JIEM, 2010 – 3(3): 512-541.

(j) Qassim, R.Y., (2000). The Theory of Constraints in manufacturing, Department of Mechanical Engineering. School of Engineering and Program of Mechanical Engineering. COPPE Federal University of Rio de Janeiro. RJ. Brazil.
(k) Schragenheim, E., & Dettmer, H.W., (2000). Simplified drum buffer rope a whole system approach to high velocity manufacturing.
(l) Shop Handling Guide, (2011). Internal publication, Engine Maintenance PT. GMF AeroAsia.
(m) Srinivasan, M., Jones, D., & Miller, A., (2001). Applying Theory of Constraints principles and Lean Thinking at The Marine Corps Maintenance Center, The Maintenance Center for the Marine Corps Logistics Base, Albany, Georgia.
(n) Zadry, H.R., & Yusof, S.M., (2006). Total Quality Management and Theory of Constraints implementation in Malaysian automotive suppliers: a survey result. Faculty of Mechanical Engineering, Universiti Teknologi Malaysia.

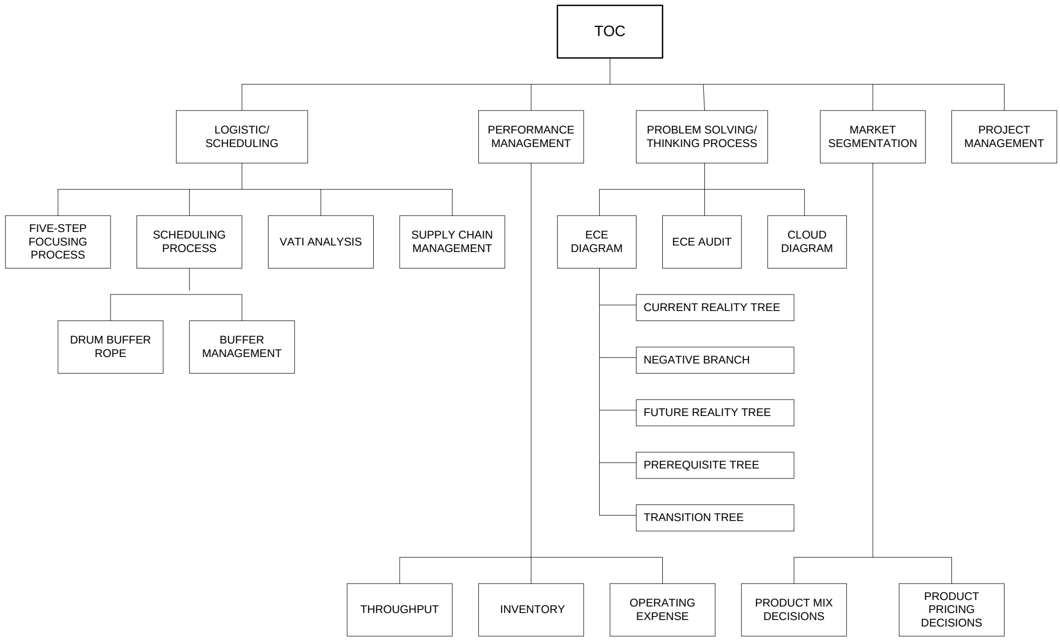

Figure 1. Schematic TOC management system (Cox & Spencer, 1998)

Table 4.1 Data production machine maintenance in units of days, in 2011 (Source: PPC, 2011)

Engine Serial Number	Contractual TAT	G1 Disassembly & Shipping	G2 parts shipped to Outside Vendor	G3 Inspections Complete	G4 All Rep, O/V and Scrap parts return	G5 All late parts are Purchased, Loaned	G6 Subassembly	G7 Final Assembly	G8 Test	G9 Serviceable	G10 Invoice Prepared
858661	60	10	32	8	102	103	19	12	7	3	9
858854	60	9	28	17	98	39	13	9	9	1	9
725897	60	9	16	4	53	93	12	12	6	4	9
856799	60	8	16	4	35	119	12	12	5	9	8
858655	60	9	2	4	173	5	7	13	24	3	9
858656	60	9	2	4	245	5	26	12	7	3	9
858924	60	9	2	2	211	5	4	43	7	3	9
858861	60	9	2	4	55	19	8	10	9	6	9
727144	70	11	12	7	52	4	5	16	12	3	9
725630	70	14	6	1	56	5	32	12	7	3	9