



## Overhaul maintenance of modern bulldozers with software-based management techniques (PERT/CPM)

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### ABSTRACT

Software programs on programme evaluation and review techniques (PERT) and critical path method (CPM) techniques have been developed to analyze the major overhauling of modern bulldozers. The knowledge of time and cost involved in a particular repair activity is essential to decide whether to continue the interrupted work and to assess whether or not it is possible to complete field operation within the stipulated time. These techniques identified forty two subsystems or activities. An analytical programme was subsequently worked out for the various operations related to major overhauling of bulldozer. The expected completion of all events required 192 hr with a variance of 8 hr. The analysis revealed that the probability of completing the overhauling ranged from 0.299 to 0.331 for completion duration of 185 to 200 hr respectively. The algorithms developed through software programs for major overhauling of bulldozer proved their superiority in the validation.

**Key words:** Breakdown, Bulldozer, Overhauling, Programme evaluation and review technique, Software

With the increase in agricultural mechanization, bulldozers have assumed an important role in Indian farming especially due to adoption of intensive cultivation. The bulldozer is used to fairly long periods for field operations. Due to change in terrain and other natural causes, repairs are invariably required in the bulldozer. There were as many as forty two systems in a bulldozer with each system having a number of components. Hence need for repair arose due to normal wear and tear of the components as well as due to unforeseen conditions in the field.

Due to sudden breakdown in a bulldozer, the work in the field gets adversely affected. The knowledge of time and cost involved in a particular repair activity is essential to decide whether to continue the interrupted work and to assess whether or not it is possible to complete the field operation within the stipulated time (Anil 2008, Anthony 2014). In the present paper, an analysis is done on the types of repairs, time required for each types of repair work and minimization of cost involved in the whole repair work, by applying Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM).

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Research work on maintenance of tractor and other farm machinery has focused mainly on the average life time and repair costs (Anne 2007). William *et al.* (1981) developed a method to accurately estimate the total cost of owning and operating farm machinery. The method adopts a depreciation schedule which is based on replacement price of the equipment. Ward *et al.* (1985) have estimated that the wear out life of tractor is 12 000 hours and that after 6000 hours of work a two wheel drive tractor has a accumulated repair cost equivalent to 70 per cent of the original purchase price. Dwarika Dhish *et al.* (1988) estimated that the life of a tractor is 10 to 12 years.

Wendl (1990) evaluated the repair costs for tractor to be 33000 DM after 9000 hours of work, without taking tyre replacements into account. He hypothesized that approximately 65% of total repair costs could be attributed to five different groups of components. Nosachinho (1990) developed a method for accounting of the operating time of tractors between repairs.

Recently operations research technique has been applied in the analysis of farm machinery (Kevin 2007, André 2008). Binder *et al.* (1990) have developed a post optimality algorithm which gives detailed information on the effects of a machinery change on all relevant tractor and labour resources. The information is useful for investigating complete machinery interactions.

Adam (1990) used reliability analysis to study tractor system failure. He employed a time between failure (TRF) analysis to estimate reliability levels. Using 120 tractors of

4 makes, he found out that the power drive was the more failed system in all makes.

### MATERIALS AND METHODS

The present study was carried out at the Tractor Workshop, Department Agricultural Engineering, Government of Tamilnadu, Coimbatore, India. The authors by their personal experience analysed the overhauling of the bulldozer of 100 units. First the entire bulldozer system was divided into 42 sub systems or activities.

For each activity three time estimate, viz. Optimistic ( $t_o$ ), pessimistic ( $t_p$ ) and most likely ( $t_m$ ) were estimated. The expected time of repair for each action was computed by using the following formula.

$$t_e = \frac{t_o + 4t_m + t_p}{6} \quad (1)$$

The PERT calculations and the critical path were identified as per the procedure suggested by Gillet (1976). The expected time of completion of the major overhauling was computed by the formula.

$$E(T) = \Sigma(T_i) \quad (2)$$

where,  $E(T_i)$  is the expected completion time of the 1th critical activity.

It is well known that PERT method takes into account the variability in the time duration of each activity. The variance of the completion time of an activity is estimated by the formula.

$$\sigma^2 = ((t_p - t_o)/6)^2 \quad (3)$$

The variance in the completion time of project (say  $\sigma^2$ ) is obtained by adding the variance of completion times of critical activities. The mean and the variance of the total time of completion, say, T can be used to find out the probability of several activities which can be assumed to be independent random variables, by Centre Limit Theorem (Hogg and Craig 1978, Nosachenko 1990). T will follow approximately normal distribution with mean T and variance  $\sigma^2$ . If ST is the scheduled time of completing the major overhauling than

$$P(T < ST) = P(T - T) / T < (ST - T) / \sigma T \\ = P(Z < Z_0) \quad (4)$$

where Z is the standard normal variable with mean 0 and variance 1 and  $Z_0$  is a known constant given by,

$$Z_0 = (ST - T) / \sigma T \quad (5)$$

In a similar manner the probability of completing a critical event I by a scheduled time  $ST_1$  can be worked out as

$$P(T < ST_1) = P(T_1 - T_1) / < (ST_1 - T_1) / \sigma T \\ = P(Z < Z_0) \quad (6)$$

where,  $T_1$  and  $\sigma T^2$  are respectively the sum of expected time duration and variance of the completion time of activities upto and including the 1<sup>th</sup> activity.

Computer programs have been developed using PERT and CPM techniques. These techniques have been utilized for the analysis of the major overhauling of modern bulldozers. The programs have been developed using C# with ASP.NET technology (Ender *et al.* 1990, Jeff 1999, Richter 1999).

The .NET Framework (Hart *et al.* 2007) is an environment from Microsoft which includes a large library of coded solutions to common programming problems and a virtual machine that manages the execution of programs written specifically for the framework. The framework's Base Class Library provides a large range of features including user interface, data and data access, database connectivity, cryptography, web application development, numeric algorithms, and network communications. The class library is used by programmers, who combine it with their own code to produce applications. Programs written for the .NET Framework execute in a software environment that manages the program's runtime requirements. The class library and the CLR together constitute the .NET Framework. There are several advantages of using .NET framework with C#:

- (i) Both the .net framework and C# are entirely based on object-oriented principles.
- (ii) While ASP offered a lot of flexibility, it was also inefficient because of its use of interpreted scripting languages, and lack of object-oriented design often resulted in messy ASP code. The .Net offers an integrated support for web pages using a new technology, i.e. ASP.NET.
- (iii) A set of .NET components, i.e. ADO.NET (Onion and Keith 2006) provides efficient access to relational databases and a variety of data sources. These components are also available to allow access to file-system and XML, which may be imported from or exported to non – windows platforms.

Microsoft Visual Studio 2010 is the development system for designing, developing, and testing next generation Microsoft Windows-based solutions, Web applications, and services. Visual Studio 2010 helps individuals and organizations rapidly create and deliver complete, connected, comprehensive, and compelling software solutions with breakthrough user experiences. Visual Studio 2010 offers organizations a robust, end-to-end platform for building, hosting, and exposing applications over the Web. The enhanced Web designer with both the design and source view provides a kind of ease in designing and development of programming. Microsoft Visual Studio Professional Edition, consists of the following various Microsoft development tools such as Microsoft Visual Basic, Microsoft Visual C++, Microsoft Visual C#, Visual Studio Tools for MS Office, Visual Web Developer and Crystal Reports. Various features such as Text Editor, Design View Editor, Supporting Windows, Integrated Debugger, Integrated MSDN Help, Windows Forms Controls and Web Forms Controls have been utilized (Kruglinski 1996, Smith Eric *et al.* 1998).

C# is an elegant and type-safe object-oriented language that enables developers to build a variety of secure and robust applications that run on the .NET Framework. One can use C# to create traditional Windows client applications, XML Web services, distributed components, client-server applications, database applications, and much, much more. Visual C# 2010 provides an advanced code editor, convenient user interface designers, integrated debugger, and many other tools to make it easier to develop applications based on C# language and the .NET Framework. C# programs run on the .NET Framework that includes a virtual execution system called the common language runtime (CLR) and a unified set of class libraries. The CLR is the commercial implementation by Microsoft of the common language infrastructure (CLI), an international standard that is the basis for creating execution and development environments in which languages and libraries work together seamlessly.

- (i) Source code written in C# is compiled into an intermediate language (IL) that conforms to the CLI specification. The IL code and resources, such as bitmaps and strings, are stored on disk in an executable file called an assembly, typically with an extension of .exe or .dll. An assembly contains a manifest that provides information about the assembly's types, version, culture, and security requirements (Balagurusamy 2000).
- (ii) When the C# program is executed, the assembly is loaded into the CLR, which might take various actions based on the information in the manifest. Then, if the security requirements are met, the CLR performs just in time (JIT) compilation to convert the IL code to native machine instructions. The CLR also provides other services related to automatic garbage collection, exception handling, and resource management. Code that is executed by the CLR is sometimes referred to as "managed code," in contrast to "unmanaged code" which is compiled into native machine language that targets a specific system.

ASP.NET is a unified Web development model that includes the services necessary for us to build enterprise-class Web applications with a minimum of coding. ASP.NET is part of the .NET Framework, and when coding using ASP.NET (Gittleman 2003) applications, one can access classes in the .NET Framework. One can code his/her applications in any language compatible with the common language runtime (CLR), including Microsoft Visual Basic.NET, C#, JScript.NET, and J#. An ASP.NET Web page presents information to the user in any browser or client device and implements application logic using server-side code. ASP.NET Web pages are based on Microsoft ASP.NET technology, in which code that runs on the server dynamically generates Web page output to the browser or client device. An ASP.NET Web page automatically renders the correct browser-compliant HTML for features such as styles, layout, and so on. Alternatively, one can design the ASP.NET Web pages to run on a specific browser such as Microsoft Internet Explorer and take advantage of browser

specific features. In ASP.NET Web pages, user interface programming component, viz. the visual component and the logic component have been used. An ASP.NET page consists of the various elements such as Directives, Code, declaration block Code render blocks, ASP.NET server controls, Server-side comments, Server-side include directives and Literal text and HTML tags. Java script has been utilized for various scripting functionalities (Esteve 2006, Krishnamunhy *et al.* 1986).

- (i) Read each activity.
- (ii) Estimate optimistic (to), pessimistic (tp) and most likely (tm) time estimates.
- (iii) Estimate expected time of repair (te) as

$$te = (t_0 + 4t_m + t_p) / 6 \tag{7}$$

- (iv) Compute PERT and Critical path analysis.
- (v) Determine expected time of computing each critical activity.
- (vi) Compute the variability in the time duration using PERT method.
- (vii) The variance of the completion time of an activity is estimated as

$$s^2 = (t_p - t_o) / 6)^2 \tag{8}$$

- (viii) Determine the probability of computing the critical events by using central limit theorem.

RESULTS AND DISCUSSION

The critical activities are as shown in Table 1. As clearly shown, the PERT technique identified 15 critical activities. The PERT chart for the major overhauling of a bulldozer was drawn (Shangyao 2009, Abbas 2011, Huang 2012). The critical path consists of the following activities.

A-F-H-L-AK-AL-AM-AN-AP-AQ

The expected completion time of overhauling is 192 hr. The total variance of completion time is 8 hours. The largest

Table 1 Major overhauling of a modern bulldozer

Description	Activity name	Activity duration, h	Preceding activity
Disconnect the U frame from the chassis	A	1	
Removal of the centre and corner blades	B	2	A
Reconditioning the centre and corner blades	C	16	B
Repairing the shovel and 'U' frame	D	24	A
Assembling the centre and corner blades in the shovel and 'U' frame	E	2	C,D
Disconnect the master pin of the track chain	F	1	A
Removal of the recoil spring assembly	H	6	F
Dismantling the idler wheels, welding, grinding and reassembling	I	24	O

Contd.

Table 1 (Continued)

Description	Activity name	Activity duration, h	Preceding activity
Removal of the carrier rollers	J	4	H
Dismantling, welding and turning the carrier rollers and roller shafts	K	24	J
Removal of the roller frame from the unit	L	8	H
Dismantling the track rollers and shaft	M	2	R
Inspection and reconditioning the shafts	N	32	M
Welding the track rollers, turning etc	O	56	M
Removing the sprocket wheel from the frame	P	8	Z
Welding and grinding the sprocket wheels	Q	24	P
Checking the bellow seal, bearing etc. and adjusting	R	8	P
Assembling carrier rollers and shaft	S	4	K,N
Assembling the track rollers and shaft	T	16	O
Welding and cleaning the roller frame	U	16	M
Assembling the rollers in the roller frame	V	6	T,U
Fitting the carrier rollers in the roller frame	W	2	N
Assembling the sprockets in the main frame	X	8	C,R
Fitting the roller frame in the unit	Y	8	V
Fitting the recoil spring, stand etc.	Z	6	Y
Fit the idler wheel in the frame and check the alignment	AA	8	I,Z
Removal of the grouser plates from the chain	AB	24	F
Dismantle the chain assembly	AC	16	AB
Welding and surface grinding of the chain links	AD	40	AC
welding the grouser plates and reconditioning	AE	24	AC
Assembling the chains	AF	16	AE, AD
Assembling the grouser plates	AG	24	AF
Assemble the chain assembly in the frame	AH	4	AG,AA,X
Removing and overhauling of fuel injection pump to Larson and Toubro and get back Dynamo, starter repairs etc.	AI	48	A
Dismantling cylinder head, cleaning, crack checking bottom surface checking, valve grinding lapping, etc. and assembling Head	AJ	32	AI
Removal of the radiator, oil cooler etc. and reconditioning	AK	16	L

Contd.

Table 1 (Concluded)

Description	Activity name	Activity duration, h	Preceding activity
Removal of the Block from the chassis and dismantling the piston, connecting rod, min and connecting rod bearing etc. and cleaning, removal of clutch and cleaning	AL	24	AK
Piston liner inserting, crank shaft grinding, main and connecting rod bearing setting, ring gap checking small end bush bearing etc.	AM	48	AL
Assembling the piston, connecting rod, main and connecting rod bearing etc. assembling the Head ad tightening etc.	AN	32	AN,AJ
Repairing the main clutch, steering clutch and assembling	AO	24	AL
Assemble the block to the chassis and fixing the radiator, oil cooler pump, injectors, Dynamo starters etc.	AP	24	AO, AN
Assembling the U frame with chassis alignment and adjustment, starting engine idle run, rectification of defects and final delivery	AQ	32	E,AH,AP

variance is associated with activity AD, viz. piston liners inserting, reboring, crankshaft balance and crack checking. The analysis reveals the probability of completing the overhauling ranges from 0.299 to 0.331 for completion duration of 185 to 200 hr.

Table 2 Expected completion time of overhauling

Activities in critical path	A	F	H	L	AK	AL	AM	AN	AP	AQ	Total
Duration, h	1	1	6	8	16	24	48	32	24	32	192

(i) The PERT technique has been applied to the major overhauling of modern bulldozers. The technique identified 10 critical activities and estimated that the overhauling work has an expected duration of 192 hr with a variance of 8 hr. The probability of completing activities in the critical path has to be properly watched. The analysis revealed that the probability of completing the overhauling ranged from 0.299 to 0.331 for completion duration of 185 to 200 hr.

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