

# Comparative Evaluation of Power Supply System Maintenance in Railway Coaches

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## Abstract

India is one of the countries with the largest network of railways spread over every nook & corner of the country. Needless to say, it requires a large resource of man power for every sector of its operations. Recently a major shift was seen where by the railways have a taken a decision to shift from their self-generating cars to End-on-generation cars, to reduce both cost & time. A major time saving is claimed with respect to maintenance & also the number of times maintenance would be required for each car & equipment. Railways generally faces a lot of problem regarding time consumed for maintenance & which is an unavoidable part of the process. This paper is an attempt to show a comparative analysis regarding the time saved in maintenance between two similar equipment of these cars. This analysis also brings about the fact about how railways now requires only a fourth of the time to complete their maintenance process & help gear things faster & smoother, by increasing quality & efficiency.

*Keywords:* Railways, Maintenance, PERT

## Comparative Evaluation of Power Supply System Maintenance in Railway Coaches

Indian Railways (IR) is India's national railway system. By size it manages the world's fourth largest railway network, with 121,407 kilometres (75,439 mi) of total track over a 67,368-kilometre (41,861 mi) route. Forty nine percent of the routes are electrified with 25 KV AC electric traction while thirty three percent of them are double or multi-tracked. IR runs more than 13,000 passenger trains daily, on both long distance & suburban routes, from 7,349 stations across India. As of March 2017, Indian Railway's consisted of 70,937 passenger coaches & 11,452 locomotives<sup>1</sup>. Development & maintenance of such a huge network requires immense time & highly skilled & efficient planning. Asset management is of great importance to any business of which maintenance, or the maintaining & monitoring of assets, is an integral & important part. The purpose of maintenance is to maximise an asset's useful lifetime & minimise cost. Decisions are regularly made about how to sustain assets – from servicing intervals & frequency to a responsibility hierarchy. If an asset is maintained more often than necessary, valuable time & resources are wasted. It is also self-evident that well maintained machinery will be more efficient & less 'power hungry'. A greener environment will therefore result. Whether the saved power involves electricity or the more direct burning of fossil fuels, the energy consumed in operating the terminal will be reduced & emissions will be cut down.<sup>2</sup>

The following work has been taken from TL-AC notes written by various employees & senior section engineers published by central railway itself where it elaborates about the different systems that will be relating to the study & comparison of equipment maintenance timings. There are two types of AC coaches namely Self-generated (Conventional coaches) & End on Generation (RMPU type coaches).

In Self generating system the power supply for AC equipments is met from axle driven transom mounted brushless alternator rated 110v DC supply. Various Equipment in a self-generating coach include 2 X 18 kw alternator running at > MFO 800 Ah cells, 200A cap battery charger, 415 v, 50 Hz, 3 phase pre-cooling plug- 2 numbers, RRU- 18 kw at 130V. Some of the drawbacks of the self-generation system are that these systems use open type of

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<sup>1</sup> Indian Railways. (2018, October 10). Retrieved October 16, 2018, from [https://en.wikipedia.org/wiki/Indian\\_Railways](https://en.wikipedia.org/wiki/Indian_Railways)

<sup>2</sup> Jones, L. (2015, May 01). Importance of Planned Maintenance. Retrieved October, from <https://www.ttclub.com/news-events/articles/article/importance-of-planned-maintenance-132573/>

compressor system & hence are more spacious, heavy in weight & incur higher maintenance costs. It requires higher man power & also has a lot of leakage problems from pipes & joints. In addition to these coaches consume more energy & very less energy efficient.

In coaches of an End-on – generation system power supply is derived from DG set 415 V/ 750v, 3 phase, 50 Hz. Power is distributed to entire rake through 2 sets of 3 phase, 415/ 750 v feeders. Each coach is provided with control, distribution & feeder arrangement on control panel. The AC equipment work on 415 v supply & lighting equipment on 110 v AC obtained from 3 KVA, 415 / 190 V, 4 wire step down transformer. Key Features of RMPU type AC coaches include they being very light in weight. This gets a low cost of installation, no water leakage. Hermetically sealed compressor is installed so no outside fittings. Use of 3 phase induction motor, less maintenance cost. No chance of damage by CRO & flash flood etc. More energy efficient, modern technology & excellent performance.<sup>3</sup>

CPM (Critical Path Method) & PERT (Programme Evaluation Review Technique) models will be used for making comparisons & finding out the optimal time to finish a given task. Basically, CPM & PERT are project management techniques, which have been created out of the need of Western industrial & military establishments to plan, schedule & control complex projects.

Essentially, there are six steps which are common to both the techniques. The procedure that follows is first we define the Project & all of its significant activities or tasks. The Project (made up of several tasks) should have only a single start activity & a single finish activity. Then we develop the relationships among the activities. Decide which activities must precede & which must follow others. Followed by it, we draw the "Network" connecting all the activities. Each Activity should have unique event numbers. Dummy arrows are used where required to avoid giving the same numbering to two activities.

We assign time &/or cost estimates to each activity & then we compute the longest time path through the network which is called the critical path. We use the Network to help plan, schedule, monitor & control the project.

The Key Concept used by CPM/PERT is that a small set of activities, which make up the longest path through the activity network control the entire project. If these "critical" activities could be identified & assigned to responsible persons, management resources could

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<sup>3</sup> Notes on TL AC. (2015, January 01). Retrieved October, from <http://www.cr.railnet.gov.in/department/elect/CETITHK/Notes%20on%20OHE.htm>

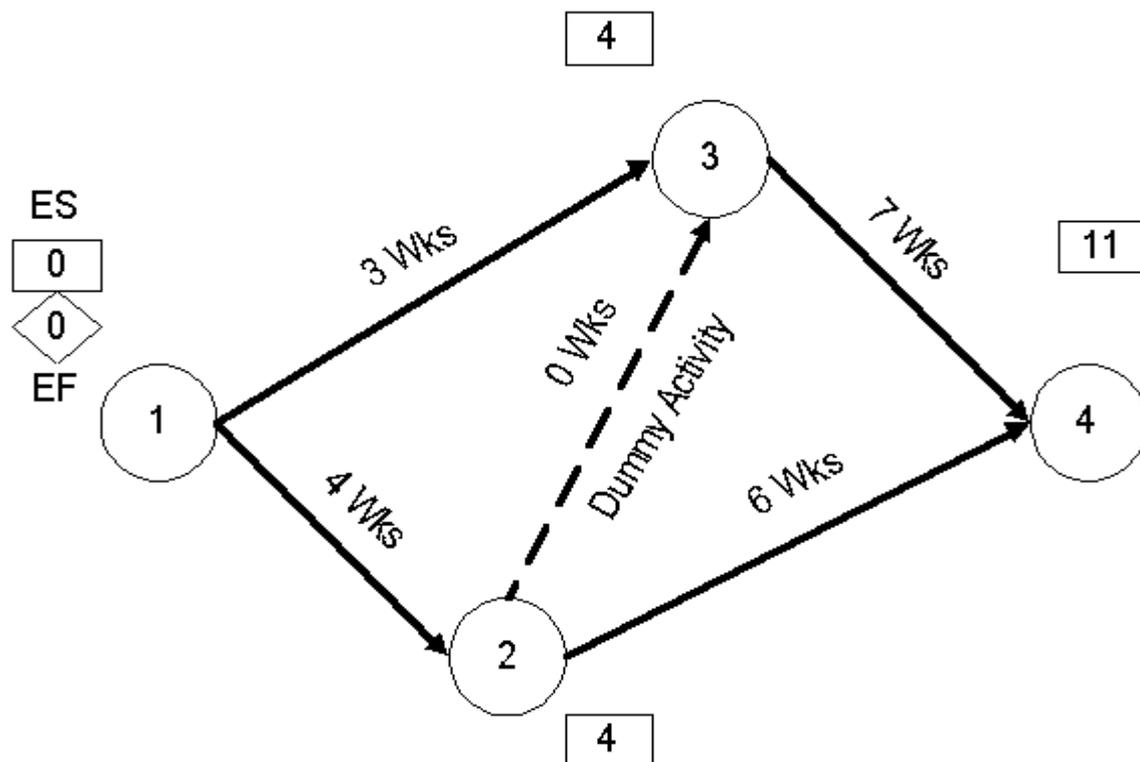
be optimally used by concentrating on the few activities which determine the fate of the entire project.

Non-critical activities can be replanned, rescheduled & resources for them can be reallocated flexibly, without affecting the whole project.

We are majorly concerned with start activity, finish activity, activities which precedes them, activities, activities which they precede, activities which follows by & the concurrent activity.

Some activities are serially linked. The second activity can begin only after the first activity is completed. In certain cases, the activities are concurrent, because they are independent of each other & can start simultaneously. This is especially the case in organisations which have supervisory resources so that work can be delegated to various departments which will be responsible for the activities & their completion as planned.

When work is delegated like this, the need for constant feedback & co-ordination becomes an important senior management pre-occupation.



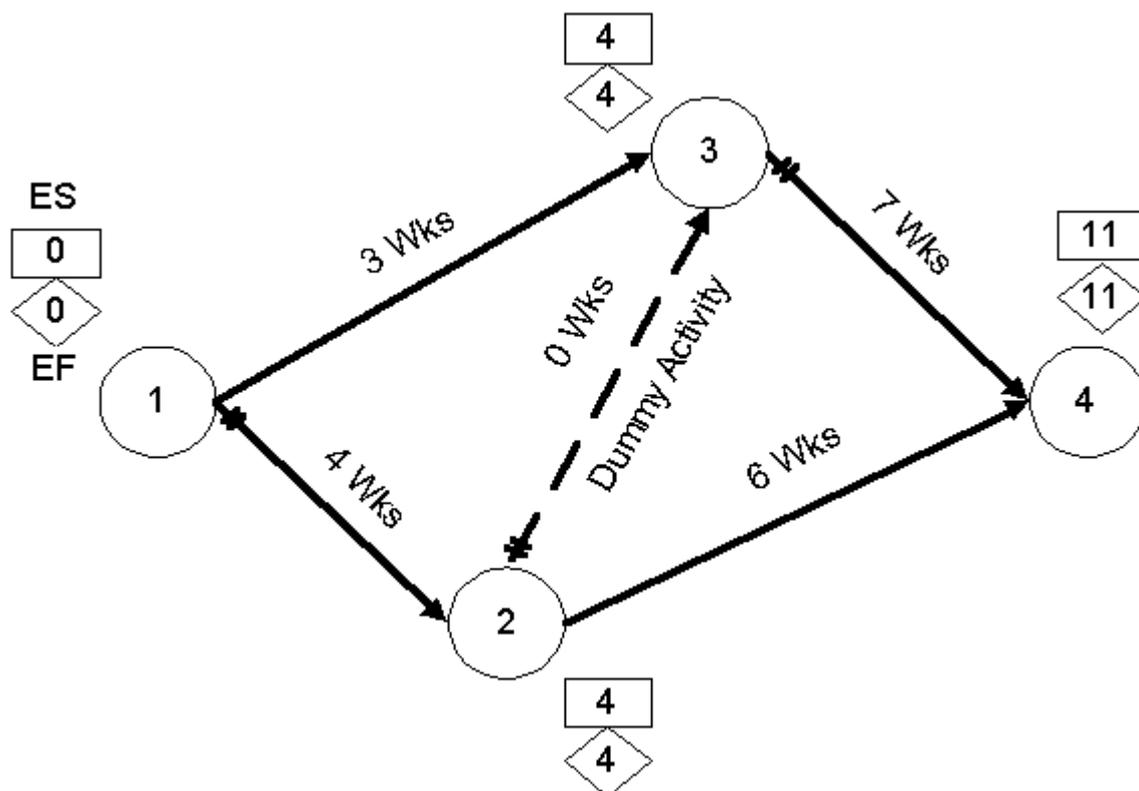
Each activity (or sub-project) in a PERT/CPM Network is represented by an arrow symbol. Each activity is preceded & succeeded by an event, represented as a circle & numbered.

At Event 3, we have to evaluate two predecessor activities – Activity 1-3 & Activity 2-3, both of which are predecessor activities. Activity 1-3 gives us an Earliest Start of 3 weeks at Event 3. However, Activity 2-3 also has to be completed before Event 3 can begin. Along this route,

the Earliest Start would be  $4+0=4$ . The rule is to take the longer (bigger) of the two Earliest Starts. So, the Earliest Start at event 3 is 4.

Similarly, at Event 4, we find we have to evaluate two predecessor activities – Activity 2-4 & Activity 3-4. Along Activity 2-4, the Earliest Start at Event 4 would be 10 wks, but along Activity 3-4, the Earliest Start at Event 4 would be 11 wks. Since 11 wks is larger than 10 wks, we select it as the Earliest Start at Event 4. We have now found the longest path through the network. It will take 11 weeks along activities 1-2, 2-3 & 3-4. This is the Critical Path.

To make the Backward Pass, we begin at the sink or the final event & work backwards to the first event.



At Event 3 there is only one activity, Activity 3-4 in the backward pass, & we find that the value is  $11-7 = 4$  weeks. However, at Event 2 we have to evaluate 2 activities, 2-3 & 2-4. We find that the backward pass through 2-4 gives us a value of  $11-6 = 5$  while 2-3 gives us  $4-0 = 4$ . We take the smaller value of 4 on the backward pass.

PERT (Programme Evaluation Review Technique) model will be used for making comparisons & finding out the optimal time to finish a given task. Pert is project

management technique, which has been created out of the need of Western industrial & military establishments to plan, schedule & control complex projects.

Essentially, there are six steps in this techniques. The procedure that follows is first we define the Project & all of its significant activities or tasks. The Project (made up of several tasks) should have only a single start activity & a single finish activity. Then we develop the relationships among the activities. Decide which activities must precede & which must follow others. Followed by it, we draw the "Network" connecting all the activities. Each Activity should have unique event numbers. Dummy arrows are used where required to avoid giving the same numbering to two activities.

We assign time &/or cost estimates to each activity. We use this data to plan, schedule, monitor & control the project.

In the PERT (Program Evaluation & Research Technique) model for each activity, three-time estimates are taken- the most optimistic, the most likely, the most pessimistic

The Duration of an activity is calculated using the following formula:

$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

Where  $t_e$  is the Expected time,  $t_o$  is the Optimistic time,  $t_m$  is the most probable activity time &  $t_p$  is the Pessimistic time.

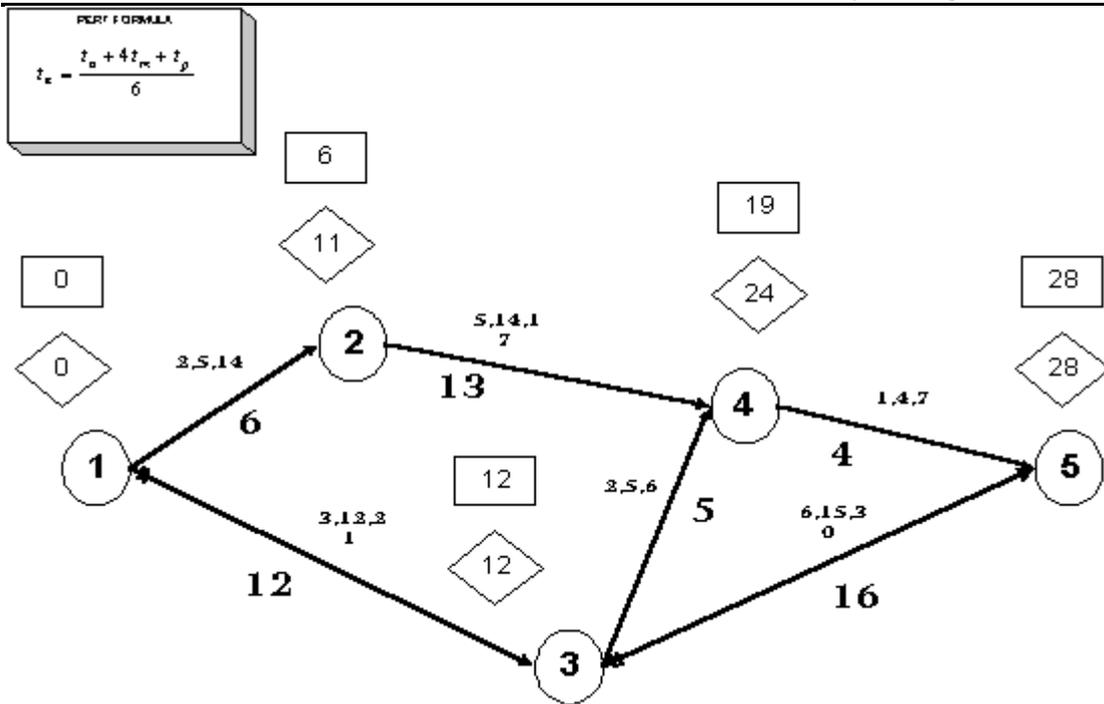
It is not necessary to go into the theory behind the formula. It is enough to know that the weights are based on an approximation of the Beta distribution.

The Standard Deviation, which is a good measure of the variability of each activity is calculated by the rather simplified formula:

$$s_1 = \frac{t_p - t_o}{6}$$

The Variance is the Square of the Standard Deviation.

In maintenance of Railway equipment's, the Project Manager is now not so certain that each activity will be completed on the basis of the single estimate he gave. There are many assumptions involved in each estimate, & these assumptions are illustrated in the three-time estimate he would prefer to give to each activity



In Activity 1-3, the time estimates are 3,12 & 21. Using our PERT formula, we get:

$$t_e = \frac{3 + (4 \times 12) + 21}{6} = \frac{72}{6} = 12$$

$$s_1 = \frac{(21-3)}{6} = \frac{18}{6} = 3$$

The Standard Deviation (s.d.) for this activity is also calculated using the PERT formula<sup>4</sup>

For comparison purpose the study includes a comparison between equipment maintenance times, one from self-generating (DC car) & another from End-on-Generation (AC car).

### Overhauling of DC motor 110V

Activity	Name of process	Preceded By	Time taken	Most optimistic	Most pessimistic
A	Initial Inspection	-	3	1	6
B	Dismantling	A	1	0.2	2
C	Rewinding	B	4	0.5	9
D	Overhauling	B	6	5	18
E	Assembling	C,D	3	1	4

<sup>4</sup> Freund, John E. "PERT/CPM for Project Scheduling & Management." *Intervention (India) Pvt. Ltd.*, 1979, [www.interventions.org/pertcpm/](http://www.interventions.org/pertcpm/).

F	Completion of job & handing over to R&D	E	0.5	0.2	1
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## Overhauling of brushless alternator AC motor

Activity	Name of process	Preceded By	Time taken	Most optimistic	Most pessimistic
A	Initial Inspection	-	2	0.5	4
B	Dismantling	A	1	0.5	2
C	Overhauling	B	3	1	6
D	Bearing	C	2	0.5	5
E	Rotor Assembly	D	2	1	3
F	Pulley	D	1	0.2	3
G	Assembling	E,F	2	1	4
H	Completion of job & handing over to R&D	G	0.5	0.2	1

## CPM of maintenance of time of compressor of Self Generating Car



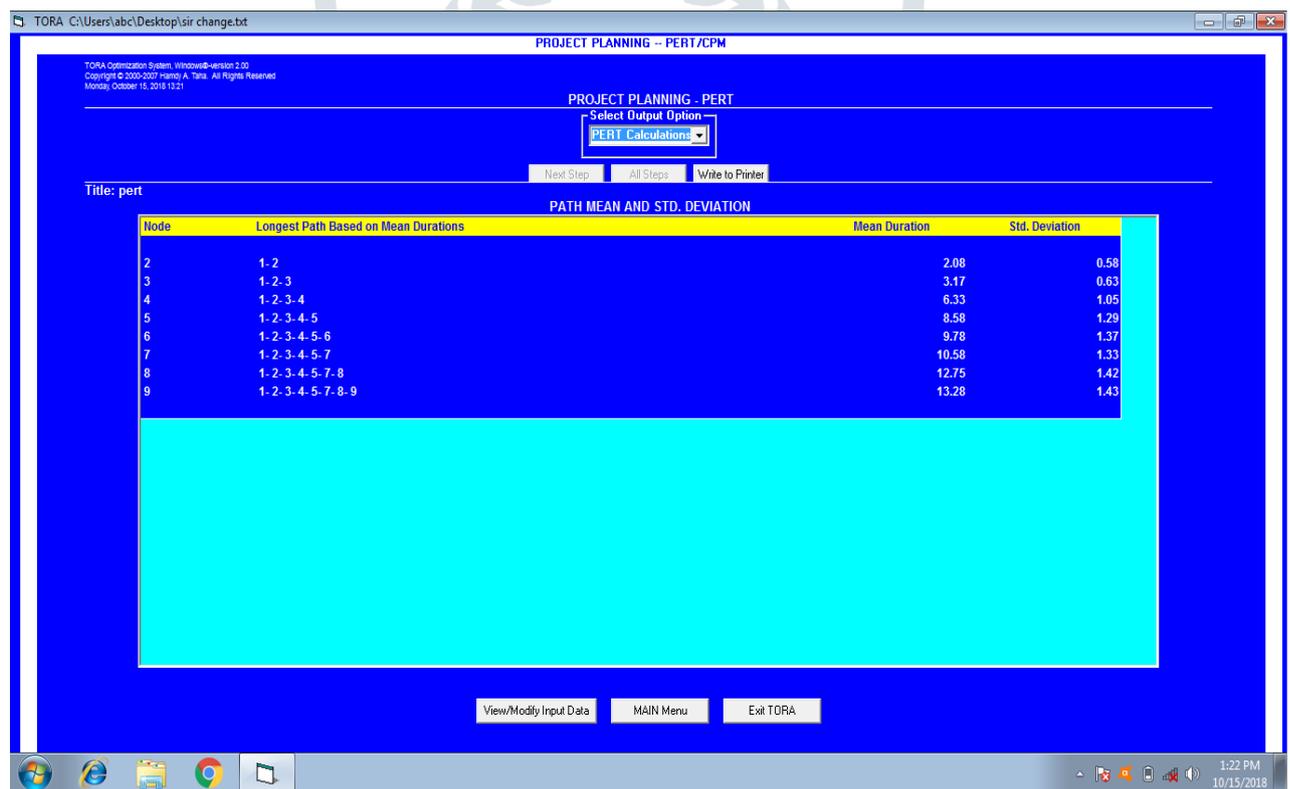
CPM of maintenance of time of Alternator of End on Generating Car



PERT of maintenance of time of compressor of Self Generating Car



PERT of maintenance of time of Alternator of End on Generating Car



The comparison between maintenance time of self-generating & EOG train cars is made using PERT through the TORA optimization software.

In the first process where CPM is run for both the maintenance schedules we can see that more time has been taken up for self-generating car as compared to the EOG car which is an hour more.

The data is run for both the process in the pert software & the analysis is done, time of each process is elaborated as to how much time is required considering the minimum & maximum time that is required for each process.

Also, the cost of maintenance & man power is reduced considerably because of the saving in the time. The quantum of time is also saved as the no of times maintenance required for EOG car is far less than the self-generating car by almost 4 times.

The findings of the research paper help us understand the difference between the maintenance time of two different types of railway coaches. The results determined by the PERT method analysis shows that Self-Generating car takes about 15.4 hrs for the entire process whereas the End on Generating car takes only 13.28 hrs which is a steady decrease of 2.12 hrs., approx. 128mins.

Also, the frequency is reduced as per which the maintenance needs to be done where earlier it required 9-10 times a year, with the new car it requires around 2-3 times a year which reduces the overall quantum of time by 21.2 hours per equipment. The overall time thereby reducing the overall cost of railways by 1/4<sup>th</sup> per year.

This helps railway save its time on the maintenance of cars/coaches which in turn increases the efficiency & reduces the frequency of maintenance required. This also helps in conserving the energy & thus paving way for greener environment.

Therefore, the research paper validates the decision of Indian Railway to replace Self-Generating car to End on Generating car as it bores fruitful results for the Railway & environment as whole.



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