Maintenance Resource Prioritization in a Production System Using Cost-effective Importance Measure

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ABSTRACT

For a long time now different importance measures are put to use in reliability literature for importance ranking of events/components, an integral part of reliability analysis. Commonly used importance measures account the probability of occurrence of faults and systems structure, and ignore the effect or severity of failures which is an important factor in engineering decision making. Here a new approach is proposed by evaluating an indicator, called cost-effective indicator that accounts both the component's performance and economic aspects. The cost-effective indicator is useful in production systems where operational reliability and cost of break down are of paramount importance. Basic events/components in a fault tree are ranked as per the decreasing value of this indicator to indicate the favourable area for improvement. It is observed in the analysis that cost-effective indicator can be a handy and effective tool for inspection, maintenance and failure detection and these activities can be carried out as per the rank of the components. Upgradation of system's performance can also be done by improving components performance with relatively large values cost-effective indicator.

Keywords

Fault Tree, Importance Ranking, Birnbaum Importance, Cost-effective Importance.

1. INTRODUCTION

There are many quantities estimated in probabilistic reliability analysis to index the level of reliability of a system. If the reliability analysis is to be used as a maintenance management tool to assist the efficient operation of the system, it is essential that those components or subsystems have the greatest impact on the system reliability/availability must be identified. This may be done by performing ranking of components. Although Xie et al. [1] used a procedure for ranking of basic events by adding up the number of AND gates leading up to the top event, but ranking of events by importance measures (IMs) has gain popularity due to their added advantages. A component's or event's contribution to the top-event occurrence may be regarded as its importance measure (IM). The prime aim of an IM is to prepare an importance rank list. The basic event which contributes maximum to the change in top event probability due to a change in that basic event's probability leads the preference list. Ranking has an extensive application in categorization of high failure prone parts and helps to take appropriate measures in improving system performance. It guides the decision makers in lessening the unavailability or increasing the availability of their system/plant. Therefore a handful number of IMs like, risk achievement worth (RAW), risk reduction worth (RRW), Birnbaum importance (BI), criticality importance (CI), Fussell-Vesely (F-V) importance and generalized importance measure (GI) are used to prepare a priority list of basics events. BI, RAW and RRW of an event (x_i) consider only two probability values for x_i. These IMs assume event x_i has failed, i.e., probability of failure = 1.0 or it is perfectly reliable, i.e., probability of failure = 0.0 and study its impact on the overall system reliability/availability. CI ranks the basic events accounting the system's and basic events' present failure probabilities. Actually, CI measures the ratio of percentage change in system's failure probability with the percentage change in basic event's failure probability. On the other hand GI is the ratio of change in system's probability with its reference probability importance measures.

Above mentioned IMs are risk based and consider safety is of paramount importance as in risk informed systems. However the economics plays vital role in production systems and therefore an importance measure based on probability coupled with economics may be a better choice. Importance of cost in operation of safety related systems have been duly accounted to optimize total plant-level cost through cost/risk sensitivity ratio [2]. Vesely [3] has measured the resource-effectiveness of an activity by burden to importance ratio (BIR) which is the relative resources spent on the activity divided by the relative importance of the activity. Ebeling [4] used marginal analysis technique for reliability optimization problem which calculates the increase in the logarithm of component reliability per unit investment in that component. Keeping the economic aspect in view, a cost effective indicator (CEI) is proposed in this paper for ranking of basic events in a fault tree (FT) to chalk out a preference list for inspection, maintenance and repair of components or design improvement.

The outline of the paper is as follows. In sections 2 and 3, reported recent works on IMs and maintenance were revised in order to identify the proposed techniques of importance ranking and maintenance prioritization applied in diverse fields. In section 4 the proposed new IM has been defined. Use of this proposed CEI has been discussed in section 5. A case study was conducted in a coal conveying system as enumerated in section 6. Finally section 7 offers conclusion and future research direction.

2. DEVELOPMENT OF IMPORTANCE MEASURES PHILOSOPHIES

IMs are defined for system components or individual basic events of the plant logic model like FT of the plant. An IM is commonly a function of time, failure and repair characteristics, and system

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structure. In literature numerous IMs have been defined and each contains different information and has its own uses. On the basis of the applied situations and purposes, IMs can be grouped as reliability importance, risk and safety importance and uncertainty importance. Risk significant IMs deal with the basic event's contribution to system failure probability when safety significant IMs refer to system success probability [5]. The primary objective of risk-based IMs is to reduce overall system risk by prioritizing inspection and maintenance procedures or by allocating redundancies [6]. Schmidt et al [7], Sutton [8] and Cheok et al [9] have discussed various IMs and their inter-relationships, like RAW, RRW, BI, CI, F-V importance and GI. F-V and RAW are widely used as risk significant IM when RRW and prevention worth (PW), introduced by Youngblood [5], are safety significant.

BI studies the change in the system unavailability given that the component goes down when the F-V importance gives the likelihood of the component being down given the system is down [10]. BI does not depend on the present probability of the component and this limits it applicability. To increase its domain of applicability Natvig et al [11-12] have presented a standardized version of BI to be used in repairable systems by incorporating the availability term into its expression. This extended version of Birnbaum measure has been applied to a real world oil and gas production system and the results have been obtained by discrete event simulation [13]. F-V and CI measures are increasing in present/reference probability of the non-repeated and independent events connected by OR gate and are independent of the present/reference probability when events are connected through AND gate. Traditional importance measures like BI, F-V, CI or RAW, frequently used in probabilistic safety assessment (PSA) are based on the basic or initiating events probabilities and not on the parameters values like, failure rate of components, maintenance intervals, etc. changes of which may affect a number of components at the same time. Borgonovo et al [14] have solve this problem by introducing a parameter based differential importance measure (DIM) having additivity property that helps to calculate DIM of a group of components, much need to study the effect of proposed change over multiple components. A more recent work by Van et al [15] have suggested a multi-directional sensitivity measure (MDSM) for measuring the change in system performance with changes in parameters like transition rates of a Markov process.

All the above IMs are based on the point estimates of the probability values which are subjected to uncertainty arise due to lack of historical data. Therefore the concept of uncertainty importance measure of a basic event (UIMB) was developed to asses the contribution of the uncertainty of each basic event to the uncertainty of the top event and is expressed in terms of the change in the variance of the top-event probability with respect to the change in the variance of that basic event probability [16-17]. However, variance based IMs are not sufficient to identify the parameter that reduces variance the most and hence the decision-maker state of knowledge of the output the most. To overcome the above limitations of variance-based uncertainty measures, Borgonovo [18] have introduced a moment independent uncertainty measure that looks at the entire input/output distribution and holds the presence of correlation among parameters. In a recent work, Aven [19] has suggested a holistic approach through the unification of uncertainty, probability, expected value and risk perspectives into the IM to be applied in risk critical systems.

3. USE OF IMPORTANCE MEASURE IN MAINTENANCE

System or equipment, how well is developed, will soon becomes unreliable unless maintain properly. The basic objective of maintenance is to maintain a high reliability of the system at the lowest possible cost making use of the past knowledge. This process is carried out by improving system component one by one through prioritizing components by reliability importance or structural importance depending on the availability of probabilistic data [20-21]. Determination of test and maintenance interval on the basis of failure rate only, may likely to stress components having high failure rate with little cost/production significant. Vaurio [2] suggested minimizing the total plant level cost while limiting risk to its acceptable value. Estes et al [22] have given a lifetime cost optimized maintenance model for deteriorating structures using the best available information at the time of decision regarding expected life, costs of inspection and repairs, expected level of deterioration with time, etc.

Many a times, poor availability results from faulty design and maintenance will be in vain to enhance it. Modeling of aging from operational feedback will be decisive to frame maintenance program [23]. But high availability does not necessarily guarantee low risk from premature failures, specially of critical components involving high cost of failure and the concept of warranty servicing contract upto a certain length of useful life [24], minimum failure free operating period (MFFOP) [25] were developed as a reliability measure that may be enhanced economically through life cycle cost based maintenance policy. Nourelfath et al [26] have optimized multi-state system configuration with minimum maintenance cost while maintaining system availability to an acceptable level. Jung et al [27] have given a replacement model to determine the optimal maintenance period based on minimizing the overall value function developed from weighted aggregation of the expected downtime per unit time and the expected cost rate per unit time. Majority of these developed maintenance program is minimum cost based and optimized the cost function in risk or availability constraints, e.g. Munoz et al [28] have used genetic algorithm approach for optimization of surveillance and maintenance intervals of components based on risk and cost criteria simultaneously. However, an IM based test and maintenance programs are most stressed upon nowadays [29].

Importance analysis acts as sensitivity analysis or significance analysis in essence and useful to identify weakness in a system, and to aid system control, failure diagnosis, inspection, test and maintenance, optimal configuration design, and system improvement through upgradation of components. Decisions related to resource prioritization in maintenance, to upgrade or replace old components and to allocate component redundancy for improving system availability or reliability, requires ranking of components. Commonly used IMs like, BI, F-V, RRW and RAW, are mono-parametric and used for binary-states systems. Recently a number of IMs, e.g, unsatisfied demand index (UDI), multi-state failure frequency index (MFFI), multi-state redundancy importance (MRI) [30] and dynamic reliability indices (DRIs) [31] have been reported for multi-states systems to identify the most important component and state in a multi-state system from availability and safety aspects. IMs for a system with mutually exclusive events or components are well established when Vaurio [32] has defined an IM for dependent events based on the intensity contribution to failures. These reliability parameters based importance measures lack in one very important aspects of system operation, i.e., financial impact or effect of failures. Ideally a suitable importance measure, to be used as a maintenance management tool, should place at higher rank to the component/s resulting higher benefits in terms of increased MTTF or reduced MTTR with the expense of equal amount of resources over other components. An IM that considers a trade-off between the improvement of system availability or reliability and cost may guide the decision making, i.e., a two-parameters IM is sought for. Isaksen [33] has suggested weighting the results of IM with costs to incorporate the cost parameter in resource prioritization. Here, a bi-parametric IM, termed as cost-effective importance measure (CEI) has been proposed incorporating the failure probability (reliability parameter) and cost of failure (economic parameter) simultaneously into the expression for CEI calculation.

4. PROPOSED COST-EFFECTIVE INDICATOR

The rank of an event in a FT mainly depends on its failure probability which in turn varies with time, failure and repair characteristic. It is also related with the event's location in the FT diagram. Existing reliability based IMs are based on reliability/availability value and structure of the system. Although reliability/availability is a good indicator of system/equipment performance but it is also important to consider at what cost it has been achieved. If a component has high probability of failure but low cost of failure whereas another component has low probability of failure but high cost of failure then the cost of failure should be incorporated in the ranking function. Ranking by proposed CEI is an endeavour to combine these two aspects. An event/component that gives maximum benefit with minimum investment or in other words event/component offering the highest increase in system reliability/availability for same expenditure will be termed as the most cost effective event/component and would possess the highest rank in priority list. Symbolically,

Cost effective indicator $I_i^{CEI}(t) = \dfrac{I_i^{GI}(t)}{C_{f,i}}$ ... ... (1)

Where, $I_i^{GI}(t)$ is the generalized importance of the event i at time 't' and $C_{f,i}$ is cost factor for i-th event. Mathematically, GI of an event 'i' is calculated as a ratio of the change in the system probability due to a change in probability of this basic event with the base probability of the system and expressed for the i-th basic event at time 't' as:

$$I_i^{GI}(t) = \frac{\Delta g_i(Q(t))}{g(Q(t))} \quad \text{... ... ... (2)}$$

Where,

$\Delta g_i(Q) = \mathit{changein\ top\ event\ probability\ due\ to\ change\ in\ i^{th}\ basic\ event\ probability}$

The cost factor for i-th event ($C_{f,i}$) is calculated as the ratio of sum of the expected cost of failure of all the components and the expected cost of failure for i-th component, i. e., $\dfrac{\sum_{i=1}^{n} E(C_i)}{E(C_i)}$ where $E(C_i)$ is expected cost of failure for i-th component. This cost of failure is the sum total of the cost for manpower, cost of spare and materials, cost due to loss of production and any other direct or indirect losses/expenses due to that failure.

5. USE OF CEI FOR RELIABILITY/AVAILABILITY ENHANCEMENT

Often it becomes hard for the policy makers to take decision regarding the enhancement of plant's reliability/availability. CEI can be helpful to choose the favourable area for enhancement from both performance and economic point of view. Following sections demonstrate the use of proposed CEI with numerical examples.

5.1 Use of CEI for Resource Allocation in Reliability Optimization

Resource is limited and the best way to spend it is to gain maximum benefit from it, i.e., allocating it for optimizing the system reliability. The proposed method can be used in reliability optimization problem with an objective to maximize the decrease in the system unavailability using available resources and CEI is bounded by the following assumptions:

- Reliability improvement is only possible by adding units in parallel.
- Parallely connected units are identical to the existing one having same failure characteristics.
- Units are statistically independent and act as an active or hot redundancy with full load.

The change in system probability $\Delta g_i(Q)$ for i-th component is calculated as the difference between the reference system unavailability and changed system unavailability when an identical unit of i-th component is connected in parallel with the existing unit. Here the cost factor for i-th component is calculated as a ratio of the sum of the expected cost for all the components and the cost of one unit of i-th component. CEI for reliability optimization are calculated for the basic events in Figure-1 and tabulated in Table-1 with GI. Column 2 of Table - 1 presents the failure probabilities of the events at time't', point of interest. As per the CEI values of different basic events D would get topmost priority in reliability improvement of the system and the next choice should be B followed by C when the basic event A has the least priority.

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Table 1. Basic events with failure probabilities and various importance measures

Basic Event	Failure Probability	Cost Of One Unit	New Failure Probability	Generalized Importance	CEI Values	Rank by CEI
A	0.4	05	0.16	0.048	0.00471	4
B	0.3	30	0.09	0.056	0.03294	2
C	0.4	06	0.16	0.235	0.02765	3
D	0.3	10	0.09	0.176	0.03451	1

5.2 Use of CEI in Case of Standby System Model

In case of a two-component cold standby system, a unit similar to the first one is placed in parallel with the original unit. Unlike in a parallel system a unit is active in the circuit only when the original one fails. As long as the first one is operative the other unit remains as reserve or standby. CEI ranking based cold standby unit allocation is done on the basis of following assumptions.

- Decision of system improvement through allocation of cold standby unit is opted for.
- Standby components are identical to the existing one (having same failure rate, λ and repair rate, μ) and do not age at all during standby (failure rate λ = 0).

The steady state unavailability of a repairable component is [4]:

$$\text{Steady state}\left(\text{inherent}\right)\text{unavailability} = \frac{\lambda}{\lambda+\mu} \qquad \cdots\ \cdots\ (3)$$

Steady state unavailability of a two-component (identical units) cold standby system is estimated from the following equation:

$$\text{Steady state unavailability of cold standby system} = \frac{\lambda^2}{\lambda^2 + 2\lambda\mu + \mu^2} \qquad \cdots\ (4)$$

Here the change in system probability, $\Delta g_i(Q)$ for i-th component is calculated as the difference between the reference system unavailability and changed system unavailability due to the inclusion of a stand by unit of i-th component in the system. The cost factor is calculated in a similar line of the above optimization model. For a four components system, as given in Figure-1, CEI values are calculated and presented in Table-2. The result indicates as per the CEI ranking, event C heads the priority list and is followed by D, B and A respectively for allocation of standby unit.

5.3 Use of CEI in Repairable System Model

The CEI can be successfully used to choose the correct repair and maintenance policy. The CEI as well as the CEI ranking of basic event change with time. This rank may prove to be helpful to schedule repair and maintenance activities. CEI values are calculated assuming that

- System components have constant failure and repair rates.
- Expected cost of failure is constant irrespective of the time when it is repaired.

Table-2 Rank of basic events with standby units by CEI

Basic Event	Failure rate (λ)	Repair rate (μ)	Cost Of standby Unit	Steady state unavailability	Steady state unavailability with an identical standby unit	Cost Effective Indicator	Rank by CEI
A	0.01/h	0.025/h	05	0.28571	0.05405	0.004813	4
B	0.005/h	0.03/h	30	0.14286	0.01176	0.032682	3
C	0.01/h	0.025/h	06	0.28571	0.05405	0.054286	1
D	0.005/h	0.03/h	10	0.14286	0.01176	0.042671	2

The failure probability (P_f) of a single component at time t, with constant failure rate (λ) can be calculated by the expression [34]:

$$P_f = 1 - e^{-\lambda t} \qquad \dots\ \dots\ \dots\ (5)$$

If the component is a repairable one then the non-availability of the component at time t can be found out by the expression [34]:

$$Non-availability = 1 - \left(\frac{\mu}{\lambda+\mu} + \frac{\lambda}{\lambda+\mu} e^{-(\lambda+\mu)t}\right) \qquad \dots\ \dots\ (6)$$

Here, the component has a constant repair rate (μ). Table-3 gives the GI and CEI for the basic events A, B, C and D of Figure-1 at different operating time with $\lambda_A=\lambda_C=0.01/h$, $\lambda_B=\lambda_D=0.004/h$; $\mu_A=\mu_C=0.025/h$ and $\mu_B=\mu_D=0.01/h$. Table-3 presents the ranking of components at different time. The cost of repair includes the cost of spare, cost of maintenance, cost incurred due to production losses during repair and other related expenses and losses. Component having maximum CEI requires resource and maintenance priority.

6. CASE STUDY

A belt conveyor system in an underground mine of Singareni Coal Company Ltd. was studied in India. This belt conveyor was transporting coal from a longwall face. To understand the failure logic of the system an FT is constructed by dividing the system into manageable components. Figure-2 represents the FT of the belt conveyor system consisting of 10 basic events. Quantification of FT requires probability values for basic events that can be estimated from performance data like, time between failures (TBF). For the present study various failures and maintenance information were collected from the records kept in the mine and TBF data for all the components were calculated from these records. TBF data were analyze using a popular statistical software package (*STASTICA*) to estimate the reliability parameters like scale (α) and shape (β) parameters of Weibull distribution. The scale and shape parameters for all components are found out and listed in Table-4. Failure probability at time 't' is estimated from equation (7).

$$Q(t) = 1 - \exp\left[-\left(\frac{t}{\alpha}\right)^{\beta}\right] \qquad \dots\ \dots\ \dots\ (7)$$

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Table-3 Change of importance of repairable basic events with time

Basic event	Expected cost of repair	Attribute list	Time interval					
			50hrs	100hrs	150hrs	200hrs	250hrs	300hrs
A	5	Failure probability	0.3934694	0.6321205	0.7768698	0.8646647	0.9179150	0.9502129
		Unavailability	0.2360646	0.2770865	0.284215	0.2854538	0.2856691	0.2857065
		GI	0.0262953	0.0358644	0.0295714	0.0200337	0.0122235	0.0069985
		CEI	0.0025780	0.0035161	0.0028992	0.0019641	0.0011984	0.0006861
		Ranking by CEI	4	4	4	4	4	4
B	30	Failure probability	0.1812692	0.3296799	0.4511883	0.5506710	0.6321205	0.6988057
		Unavailability	0.1438328	0.2152581	0.2507268	0.26834	0.2770865	0.2814299
		GI	0.0135749	0.022162	0.0207181	0.0153334	0.0099673	0.0059771
		CEI	0.0079852	0.0130365	0.0121871	0.0090196	0.0058631	0.0035159
		Ranking by CEI	2	2	2	2	2	2
C	6	Failure probability	0.3934694	0.6321205	0.7768698	0.8646647	0.9179150	0.9502129
		Unavailability	0.2360646	0.2770865	0.284215	0.2854538	0.2856691	0.2857065
		GI	0.2221104	0.2340857	0.1907776	0.1408223	0.0988872	0.0615864
		CEI	0.0261306	0.0275395	0.0224444	0.0165673	0.0116338	0.0072455
		Ranking by CEI	1	1	1	1	1	1
D	10	Failure probability	0.1812692	0.3296799	0.4511883	0.5506710	0.6321205	0.6988057
		Unavailability	0.1438328	0.2152581	0.2507268	0.26834	0.2770865	0.2814299
		GI	0.0391342	0.0414034	0.0315609	0.0206747	0.0123902	0.0070170
		CEI	0.0076734	0.0081183	0.0061884	0.0040539	0.0024295	0.0013759
		Ranking by CEI	3	3	3	3	3	3

Repair times and spares & materials consumption were collected from the case study mine. Cost of each failure is estimated by adding up the cost of lost production due to failure (@ INR. 108000/hours taking production rate 155T/hour and selling price of coal INR. 700/T), cost of spare, material and manpower cost. Cost of each failure and total cost for each type of failure for the financial year 2005-06 are given in Table-4. The mine follows four shifts working per day with first shift as pre-maintenance shift and the expected operating time per day is 16.5 hours. $\Delta g_i(Q)(t)$ for i-th component is calculated as the difference between the system failure probability at time 't' and changed system failure probability when i-th component is maintained at time 't'. The failure probability of each component at a time is calculated taking 't' for it as the actual operating time after its previous maintenance. Proposed CEI is calculated on the following assumptions:

- Basic events of the FT are independent to each other. Failures of components are considered as basic events in the FT.
- Expected cost of failure is fixed irrespective of the time when repair is actually carried out.
- Repair/maintenance of one component is done at a time and immediately after repair/maintenance its failure probability is zero, i.e., it is as good as a new one.

Table-4 List of reliability parameters and cost of failure for components of belt conveyor

Basic Event	Scale Parameter (hrs.)	Shape Parameter	Cost of failure in Rs.	Total cost of failure for the session 2005-06in Rs.
Adjustable Unit (CCAU)	1799.25	0.992493	142500	860000
Belt (CBEL)	1049.78	0.619651	702090	10530000
Belt Scraper (CBSC)	688.829	1.456	1392000	15310000
Drive Drum (CDDR)	1048.572	0.88379	1827000	20110000
Electrical Motor (CEMO)	795.585	1.255	2296800	25260000
Fixed Drum (CCFD)	1052.76	0.991558	780100	8580000
Fluid coupling (CFCP)	2318.343	0.7983	548100	3840000
Gear Box (CGBX)	4661.71	0.709478	9604800	48000000
Idler (CIDA)	2341.764	1.0345	170700	690000
Winch Section (CCWS)	7871.672	1.2777	50000	53500

Ranking of various components of the system are done according to CEI at time t = 16.5 hours, 33.0 hours, 49.5 hours, 66.0 hours, 82.5 hours, 99.0 hours, 115.5 hours, 132.0

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hours as listed in Table-5. CEI ranking indicates mostly gear box (CGBX) should get the first priority in inspection and maintenance and is supported by the maximum value of the cost of failure for the year 2000-01 (ref. column 5 of Table-4). Occasionally, e.g., drive drum (CDDR) and electrical motor (CEMO) head the priority list when belt (CBEL) constantly deserves good importance in maintenance scheduling. Result shows that winch section (CCWS) is least important from maintenance aspect. CEI ranks are mostly supported by total cost of failure. Disagreeing of a few components may be due to collection of cost of failure for relatively short duration.

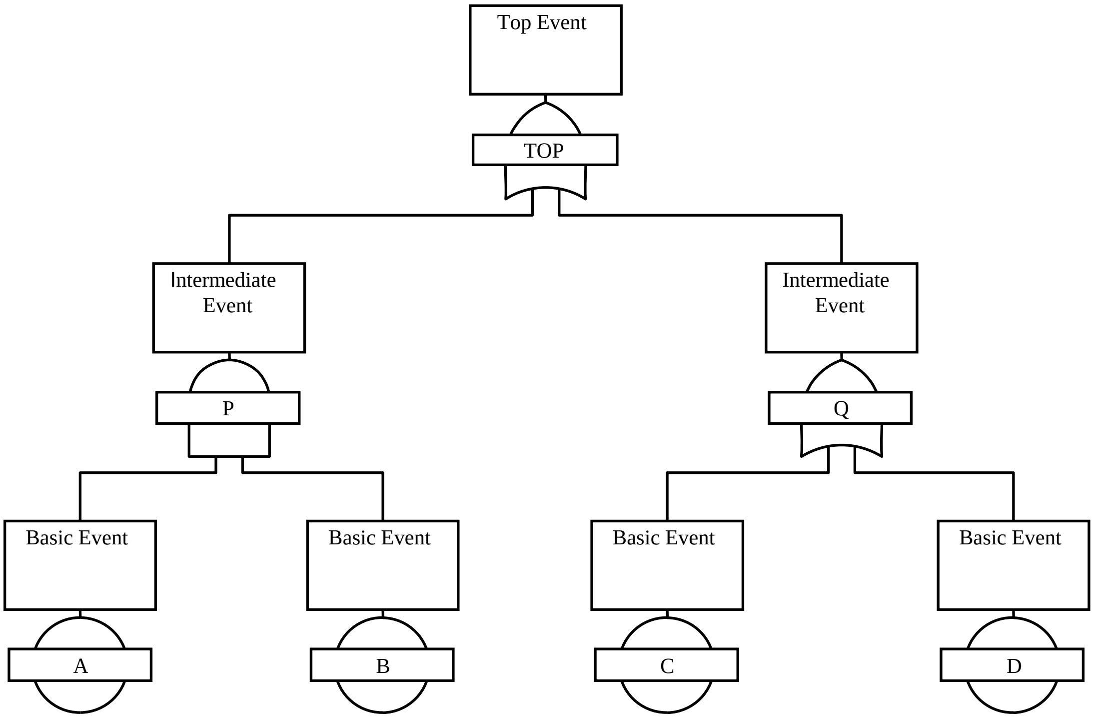

Figure-1 An example fault tree having both AND & OR gates

7. CONCLUSION

The paper shows that ranking of basic events as per the CEI is a very simple and effective method to make a preference list of basic events for new investment, allocation of inspection, repair and maintenance gangs. CEI not only includes fractional change in top event probability but also takes into account the other factors directly or indirectly in terms of cost. It has higher sensitivity, as it is a multi-parameter indicator. When improvement in performance of a couple of basic events in an FT gives equal amount of improvement in system performance then naturally economy is the deciding factor and CEI is appropriate. For allocation of maintenance and repair workers in a production system particularly when there is an acute shortage of men, CEI can guide the management to engage the people in activities which are performance-effective and at the same time cost-effective. In design improvement programme the CEI points out the favourable area from both the performance and economic aspects. Therefore CEI can be an effective tool to the management where the aspects of reliability and the cost of repair are equally important. Ranking of component/subsystem/module by CEI should be a continuous process before allocation of maintenance resources to identify cost-effective maintenance critical component. CEI may be incorporated as an integral part in reliability centred maintenance.

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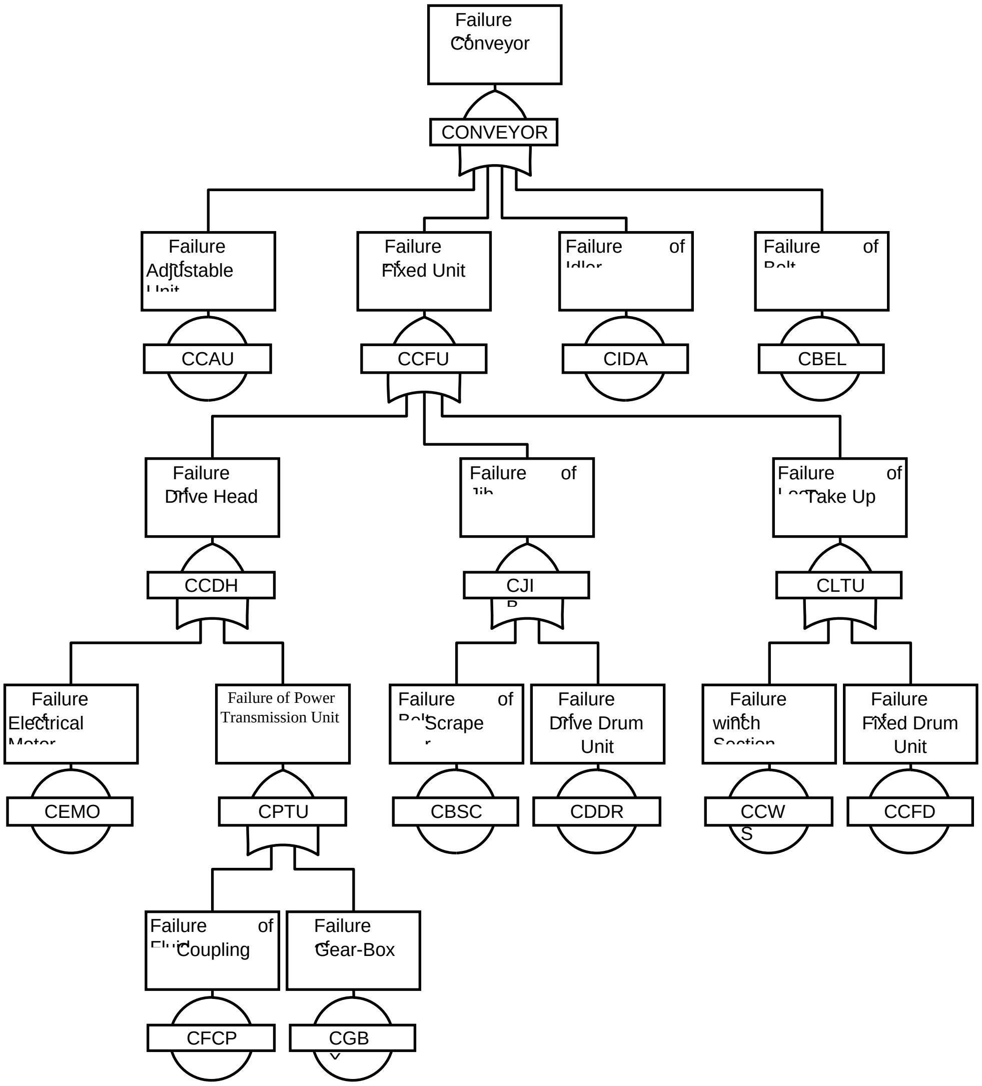

Figure-2 Fault tree of the belt conveyor system

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Table-5 Priority ranking of belt conveyor components for maintenance scheduling at different time

Basic Event	Ranking by CEI at 't' = 16.5 hrs.	Ranking by CEI at 't' = 33.0 hrs.	Ranking by CEI at 't' = 49.5 hrs.	Ranking by CEI at 't' = 66.0 hrs.	Ranking by CEI at 't' = 82.5 hrs.	Ranking by CEI at 't' = 99.0 hrs.	Ranking by CEI at 't' = 115.5 hrs.	Ranking by CEI at 't' = 132.0 hrs.
Adjustable Unit (CCAU)	8	8	8	8	9	8	9	8
Belt (CBEL)	2	3	3	3	3	2	2	2
Belt Scraper (CBSC)	7	7	6	6	6	4	4	3
Drive Drum (CDDR)	3	2	2	2	1	7	6	4
Electrical Motor (CEMO)	4	4	4	4	4	3	1	7
Fixed Drum (CCFD)	5	5	5	5	5	5	5	5
Fluid coupling (CFCP)	6	6	7	7	7	6	7	6
Gear Box (CGBX)	1	1	1	1	2	1	3	1
Idler (CIDA)	9	9	9	9	8	9	8	9
Winch Section (CCWS)	10	10	10	10	10	10	10	10

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