भारतीय मानक

डिपेंडेबिलिटी प्रबंधन — अनुप्रयोग नियामिका — डिपेंडेबिलिटी विश्लेषण तकनीकें

Indian Standard

DEPENDABILITY MANAGEMENT — APPLICATION GUIDE ANALYSIS TECHNIQUES FOR DEPENDABILITY — GUIDE ON METHODOLOGY

ICS 03.100.40; 03.120.01

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Price Group 5

Reliability of Electronic and Electrical Components and Equipment Sectional Committee, LTD 3

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Reliability of Electronic and Electrical Components and Equipment Sectional Committee had been approved by the Electronic and Telecommunication Division Council.

Dependability analysis techniques are used for the review and prediction of the reliability, availability, maintainability and safety measures of a system. Dependability analyses are conducted mainly during the concept and definition phase, the design and development phase and the operation and maintenance phase at various system levels and degrees of detail to order to evaluate and determine the dependability measures of a system or an installation. They are also used to compare the results of the analysis with specified requirements.

While preparing this standard, assistance has been derived from IEC 60300-3-1 (1991) 'Dependability management – Part 3: Application guide – Section 1: Analysis techniques for dependability: Guide on methodology', published by International Electrotechnical Commission.

The technical Committee responsible for preparation of this standard has reviewed the provisions of following IEC publication and decided that it may be used in conjunction with this standard till Indian Standard on this subject is published:

IEC 1025(1990) Fault tree analysis (FTA)

The composition of the Committee responsible for formulation of this standard is given in Annex B.

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

DEPENDABILITY MANAGEMENT — APPLICATION GUIDE ANALYSIS TECHNIQUES FOR DEPENDABILITY — GUIDE ON METHODOLOGY

1 SCOPE

This standard gives a general overview of commonly used dependability analysis procedures. It describes the usual methodologies, the advantages and disadvantages, data input and other requirements for the various techniques.

This guide is an introduction to the available methodology and is intended to provide the analyst with the necessary information in order to choose the analysis method most appropriate to the system.

2 REFERENCES

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 DEFINITIONS

For the purpose of this standard, the terms and definitions given in IS 1885 (Part 39) shall apply in addition to the following.

3.1 System

Item on the highest level considered in the analysis.

3.2 Component

Item on the lowest level considered in the analysis.

3.3 Allocation

A procedure applied during the design of an item intended to apportion the requirements for performance measures for an item to its sub items according to given criteria.

NOTE — 'System' may be replaced by 'sub-system', etc, as applicable.

4 GENERAL

The analysis methods allow the evaluation of qualitative characteristics and estimation of measures (for example, failure rate, MTTF, MTBF, reliability, steady state availability) which describe the predicated long-term operating behaviour of a system. In order to perform a systematic and reproducible system analysis, use of a consistent procedure is essential.

However, no single dependability analysis method is sufficiently comprehensive and flexible to deal with all the possible model complexities required to evaluate the features of practical systems (hardware and software, complex functional structures, etc). It may be necessary to consider several additional analysis methods to ensure proper treatment of complex or multi-functional systems.

5 BASIC APPROACH TO SYSTEM DEPENDABILITY ANALYSIS

Specific procedures for analysis are contained in the standards describing each analysis method. General procedures, approaches and requirements are described hereinafter.

5.1 General Procedure

The procedure consists of the following steps (as applicable):

Step 1

List all system reliability and availability requirements, characteristics and features, together with environmental and operating conditions, and maintenance requirements. Define the system to be analyzed, its modes of operation, the functional relationships to higher levels and to interfacing systems of processes.

Step 2

Define system fault, fault criteria and conditions based on system functional requirements, expected operation and operating environment. Software performance should also be considered.

Step 3

When numerical results are required, it is recommended to carry out an allocation based on a preliminary design (assignment of a portion of the total permitted system failure rate or unavailability to each sub-system).

Step 4

Analysis of the system as follows:

4.1 *Qualitative analysis* (*deductive/inductive methodology*)

Analyze the functional system structure, determine system/component fault modes, failure mechanisms, effects and consequences of failures, consider item maintainability, construct reliability and/or availability models, determine possible maintenance and repair strategies, etc.

4.2 *Quantitative analysis* (*analytical or event simulation methods*)

Obtain or identify item reliability data (for example, failure rates), construct mathematical reliability and/or availability model, perform numerical evaluations of mathematical model, perform component criticality and sensitivity analyses, evaluate improvement of system performance due to redundant substructures and maintenance strategies, etc.

Step 5

Evaluation of results, comparison with requirements and/or alternative designs. Additional activities may include:

5.1 Reviewing system design, determining weaknesses, unbalances, critical/high risk fault modes and items, considering system interface problems, fail-safe features and mechanisms, etc.

5.2 Developing alternative ways for improving dependability (for example redundancy allocation, performance monitoring, fault detection, system reconfiguration procedures, maintainability, component replaceability, and repair procedures).

5.3 Performing trade-off studies and evaluating the cost of alternative designs.

The relationships between the general analysis procedure and the specific methods and procedures are given in Table 1 (note that Table 1 is not exhaustive). The methods are explained further in **5.2** to **5.5**.

5.2 Analysis of Functional Structure

In order to analyze the long-term operating behaviour of a system with confidence, the precise way a system is required to function, as well as its operational and environmental conditions should be determined and described in detail. A separate analysis of the functional system structure may be necessary to identify and departure from the required function.

The system function may be represented by functional block diagrams, signal flow diagrams, state-transition diagrams, event sequences, tables, etc.

Finally, the qualitative failure or success analysis may be conducted in accordance with either of the following two formal methods:

a) deductive methodology (top-down), for example fault tree analysis; and

b) inductive methodology (bottom-up), for example fault mode and effects analysis.

However, in practice, an iterative approach is more usual with deductive and inductive analysis complementing one another.

5.3 Deductive Analysis

The essence of the deductive approach is to proceed from the highest level of interest, that is, the system or sub-system level, to successively lower levels in order to identify undesirable system operation.

The analysis is performed at the next lower system level to identify, any fault and its associated fault mode which could result in the fault effect as originally identified. For each of these second level faults, the analysis is repeated by tracing back along the functional paths and relationships to the next lower level using logical gates. This process is continued as far as the lowest level desired.

The deductive method is an event-oriented method which is useful during the early conceptual phase of system design when the details of the system are not yet fully defined. It is also used for evaluating multiple failures including sequentially related failures, the existence of faults due to a common-cause, or wherever system complexity makes it more convenient to begin by listing system faults or system success.

In all cases the undesirable single event or system success at the highest level of interest (the top event), should be given. The contributory causes of that event at all levels are then identified and analyzed.

5.4 Inductive Analysis

The essence of the inductive method is to identify fault modes at the component level. For each fault mode the corresponding effect on performance is deduced for the next higher system level. The resulting fault effect becomes the fault mode at the next higher system level, and the fault effects of each fault mode are analyzed at this level. Successive iterations result in the eventual identification of the fault effects at all functional levels up to the system level. This 'bottom-up' method is rigorous in identifying all single fault modes. Because component fault modes must be identified. This method is normally used during the later stages of design where equipment has become mature.

5.5 Maintenance and Repair Analysis and Considerations

The long-term operating behaviour of a repairable system is greatly influenced by the system maintainability as well as the repair or maintenance strategies employed. An availability performance measure is the appropriate measure for evaluating the influence of maintenance and repair on system dependability.

Repair of a system during operation without interruption of its function is normally possible only for a redundant system structure with accessible redundant components. If so, then repair or replacement increase system reliability performance and availability performance.

It is usually necessary to perform a separate analysis to evaluate repair and maintenance aspects of a system (*see* IS 9692 series).

Table 1 Correspondence of Methods to General Analysis Procedure

(*Clause* 5.1)

Steps of General Procedure		Analysis Methods				
No.	Activity	FMEA/FWECA Fault mode and effects/critically analysis	FTA Fault tree analysis	RBD Reliability block diagram	MA Markov analysis	PC Parts count reliability
1	Requirements and system definitions	Component specification and operation	Functional system structure	System and sub-system operation	Component function, functional system structure	Component specification and failure data
2	Definition of system fault	Failure of first order functional level	Undesired (top) event	Criteria of system success (failure)	Criteria of system success and failure	Failure of first order functional level
3	Reliability apportionment	If applicable to components	If applicable to sub-systems	If applicable to sub-systems	If applicable to sub-systems	If applicable to components
4.1	Qualitative analysis, maintenance strategy	Inductive (table)	Deductive (fault tree)	Deductive (block diagram)	Inductive/deductive (state transition diagram)	Assume series system structure, list and evaluate components
4.2	Quantitative analysis (numerical evaluation)	Fault critically/probability analysis	Calculation of system reliability and availability measures	Calculation of system reliability and availability measures	Calculation of system reliability and availability measures	Calculation of components and system failure rates
5	Requirements met (terminate procedure)	Criticality of failures and failure probabilities within limits	Probability of undesired even within requirement	Reliability/availability requirement met?	Reliability/availability requirements met?	Does estimated system failure rate meet requirements?
5.1	Review design, determine weaknesses	Component failure modes, failure rates, etc	Sub-system/ component failure modes, failure rates, system structure, etc	Sub-system reliability/ availability, sub-system/ component failure rates, system structure, etc	Component/sub-system/system reliability and availability, maintenance and repair policy, system structure	Determine highest component failure rates
5.2	Develop alternative designs	Component selection and maintenance, etc	System structure, redundancy allocation, fault detection, maintenance, etc	System structure, redundancy allocation, component selection, maintenance, etc	System structure, redundancy allocation, component selection, repair policy, system reconfiguration, etc	Re-evaluate choke of weakest components
5.3	Perform trade-off studies and cost evaluation	Determine most economical solution	Determine most economical solution	Determine most economical solution	Determine most economical solution	Estimate cost

6 CHARACTERISTICS OF VARIOUS DEPENDABILITY ANALYSIS METHODS

6.1 Selecting the Appropriate Analysis Method

In order to enable a system dependability evaluation to be economically performed, an analysis method should be chosen which:

a) models and evaluates a wide range of dependability problems;

b) allows a straightforward, systematic, qualitative and quantitative analysis to be performed by trained design and dependability engineers; and

c) predicts measures of the dependability characteristics numerically, if data are available.

A dependability analysis method should be selected which will give the desired results and encompass all relevant attributes.

Table 2 gives an overview of various dependability analysis methods and their characteristics and features. More than one method may be required to provide a complete analysis of the system.

6.2 Short Descriptions of Analysis Methods

6.2.1 *Failure Mode and Effects Analysis*

Failure mode and effect analysis (FMEA) is an inductive (bottom-up), qualitative dependability analysis method, which is particularly suited to the study of material, component and equipment faults and their effects and mechanisms on the next higher functional system level. Iterations of the step (identification of single fault modes and the evaluation of their effects on the next higher system level) result in the eventual identification of all the system single fault modes. FMEA lends itself to the analysis of systems of different technologies (electrical, mechanical, hydraulic, software, etc) with simple functional structures.

FMECA extends the FMEA to include criticality analysis by quantifying fault effects in terms of probability of occurrence and the severity of any effects. Estimates of the probability of failure are calculated directly from a reliability prediction using the data assessed by the FMEA (probability of occurrence of a fault mode, failure rates, etc). The severity of effects is assessed by reference to a specified scale.

6.2.2 *Fault Tree Analysis*

Fault tree analysis (FTA) is a deductive (top-down) method for analyzing system dependability. It is concerned with the identification and analysis of conditions and factors which cause, or contribute to, the occurrence of a defined undesirable event and which significantly affect system performance, safety, economy or other specified characteristics.

Starting with the top event, the possible causes or fault modes on the next lowest functional system level are identified using logical gates. Following stepwise identification of undesirable system operation to successively lower system level will lead to the desired lowest system level. Causes at this level are usually the component fault modes. The results of the analysis are portrayed as a fault tree.

The quantitative analysis is performed on the basis of the fault tree. In order to estimate system reliability and availability, methods such as Boolean reduction and cut set analysis are employed. The basic data required are component failure rates, repair rates, probability of occurrence of fault modes, etc.

6.2.3 *Reliability Block Diagram Analysis*

Reliability block diagram (RBD) analysis is a deductive (top-down) system dependability analysis method. An RBD is the graphical representation of a system's logical structure in terms of sub-systems and/or components. This allows the system success paths to be represented by the way in which the blocks (sub-systems/components) are logically connected.

Various qualitative analysis techniques may be employed to construct an RBD. The first step is to establish the definition of system success. The next step is to divide the system in functional blocks appropriate to the purpose of the reliability analysis. Some blocks may represent system substructures, which in turn may be represented by other RBDs (system reduction).

For the quantitative evaluation of an RBD, various methods are available. Depending on the type of structure (reducible or irreducible) simple Boolean techniques, truth tables and/or path and cut set analysis may be employed for the prediction of system reliability and availability values calculated from basic component data.

6.2.4 *Markov Analysis*

Markov analysis is mainly an inductive (bottom-up) analysis method suitable for the evaluation of functionally complex system structures and complex repair and maintenance strategies.

The method is based on the theory of Markov chains. In principle the probabilities of system elements (components, sub-systems) being in a particular (functional) state, or events to occur, at specific points or intervals of time are evaluated by mathematical models.

Table 2 Characteristics of Analysis Methods

(*Clause* 6.1)

Analysis Method	Characteristics														
	Ability of method to handle model characteristics as:								Attributes						Indian Standard
	Number of components	Redundant structures	Irreducible structures	Failure/ event combinations and dependencies	Time varying failure/ event rates	Complex maintenance strategies	Simulation of functional process	Symbolic representation	Approach		Analysis		Analysis effort (cost)		
									deductive	inductive	quailtative	quantitative	quailtative	quantitative	
FMEA	Up to several thousands	(no)	no	(no)	yes	no	no	List	(nc)	c	c	nc	high	—	IS 11137 (Part 2)
FMECA	Up to several thousands	(no)	no	(no)	yes	no	no	List	nc	c	c	(c)	high	low	IS 11137 (Part 2)
Fault tree analysis	Up to several thousands	yes	(yes)[1)]	(yes)	yes	no	no	Fault tree	c	nc	c	c	high	medium	IEC 1025 (1990)
Reliability block diagram	Up to several thousands	yes	(yes)[1)]	(yes)	(yes)	no	no	Reliability block diagram	c	nc	(c)	c	medium	medium	IS 15037
Markov	2 to 100 [5)]	yes	yes	Yes[6)]	(no)[7)]	yes	(yes)	System state diagram	(nc)	c	c	c	high	medium	—
Parts count	1 to thousands	(no)	(yes)	no	(no)	—	—	List	nc	c	(nc)	c	low	low	—
Cause/consequence	Up to several hundreds	yes	yes	(yes)	(yes)	yes [2)]	no	Cause/consequence chart	(c)	c	c	c	high	low/ high [4)]	—
Event simulation	Up to several hundreds [8)]	yes	yes	yes	Yes	yes	yes	Any	c	c	c	c	high	high	—
System reduction	Up to several thousands [9)]	yes	no	(yes)	(yes)	(yes)	no	Reliability block diagram	nc	c	(nc) [10)]	c[10)]	medium	medium	—
Event tree	2 to 50	yes	yes	(yes)	yes	no	yes-	Event tree	c	c	(nc)	c	low	low	—
Truth table [3)]	2 to 50[5)]	yes	yes	yes [6)]	—	—	—	Table	nc	c	c	nc	high[5)]	—	—

NOTE — For abbreviations and remarks *see* **6.3.3**.

Initially all the states of interest shall be defined together with the probabilities of transition from one state to another (component failure or repair rates, event rates, etc). Transition rates (failure rates, event rates) are normally assumed to be constant, that is independent of time or previous history.

The qualitative analysis requires the determination of all the possible system states, preferably shown diagrammatically in a state-transition diagram. A major supporting analysis technique is the truth table.

The transition probabilities and the way in which the states are related, represented by the state-transition diagram, allow the construction of the desired transition matrix (mathematical model) for the purpose of system reliability/availability calculations. The evaluation of other measures of interest may also be accomplished.

6.2.5 *Parts Count Reliability Prediction*

Parts count reliability prediction is basically an inductive (bottom-up) method applicable mostly during the proposal and early design phases, to estimate an approximate system failure rate.

The components of the system need to be listed and the appropriate failure rates determined according to their stress levels.

The method is based upon the assumption that the components are logically connected in series. This is often a worst case estimate. Where redundancies at the higher levels of assembly are known, their effects may be taken into account.

A parts count reliability prediction of a system with a series type of structure will yield predictions at an acceptable precision level, provided a thorough 'Parts Stress Analysis' is carried out. Use of the parts stress analysis gives more realistic component failure rates.

6.3 Explanations to Table 2

6.3.1 *General*

On the left hand side of Table 2, the analysis methods are listed. In order to facilitate evaluation and comparison, their characteristics, attributes, flexibility, etc, are stated.

For each analysis method the matrix thus gives an indication as to which additional characteristics each method can handle as indicated by 'yes' and 'no' entries. Further, the analysis methods are distinguished by particular attributes or techniques. These are listed and rated on the right hand side of Table 2.

Table 2 indicates that there is no single, comprehensive dependability analysis method. The analyst should choose the method which best fits the particular system or analysis objective.

All these methods are capable of analyzing:

a) series structures;
b) reducible structures if redundant structures are applicable;
c) independent components (two-state model);
d) single faults;
e) exponential distribution of times to failure;
f) constant repair or event rates; and
g) independent component repair.

6.3.2 *Table 2 Headings*

6.3.2.1 *Number of components*

The number of components of the system which can be handled by a particular analysis method is basically limited by the number of combinations (system states) which arise from the possible component states or fault modes considered. The number of combinations is also heavily dependent on the specific system structure and maintenance considerations.

6.3.2.2 *Redundant structures*

The basis capability to handling redundant system structures.

6.3.2.3 *Irreducible structures*

A structure is called irreducible if straight forward reduction techniques are not possible.

6.3.2.4 *Failure/event combinations and dependencies*

The capability of the method to handle failure or event combinations. These include common cause or common mode failures, multiple failure effects and statistically dependent fault modes or sequential failure effects and mechanisms, or events caused by adverse environmental effects.

6.3.2.5 *Time varying failure/event rates*

Non-constant failure and event rates (or non-exponential distribution of times to failure).

6.3.2.6 *Complex maintenance strategies*

The capability of the method to handle statistically dependent repair and maintenance situations. These include cases where renewal processes (repair queues) should be considered, as compared to the assumption that, for each component failure, repair begins immediately after failure, independent of whether a component is accessible or not (independent repair).

6.3.2.7 *Simulation of functional process*

The capability of a method to simulate discrete events; that is, the failure and renewal processes are simulated and the particular system states evaluated according to the influence which they exert on any higher-level system or on the total environment (interrelation).

Therefore, it is also necessary to simulate the functional behaviour of the higher-level system along with processes within the total environment while analyzing the operating and failure processes of the system itself.

6.3.2.8 *Deductive/inductive approach*

See **5.3** and **5.4**.

6.3.2.9 *Qualitative/quantitative analysis*

The capability of a method to handle qualitative and/or quantitative analysis.

6.3.2.10 *Qualitative/quantitative analysis effort* (*cost*)

The entries give relative estimates of the cost of applying a particular analysis method to a particular problem. The effective analysis effort is dependent on the system complexity, the depth of analysis, the skill of the analyst, the availability of basic system and component data, and the availability of suitable computing resources.

6.3.3 *Remarks with reference to Table* 2

c Capable.

Nc Not capable, or not applicable

() With restrictions/exceptions

1) With cut sets or logical reduction.
2) By event simulation, numerical integration or renewal theory.
3) A basic, systematic method (combinatorics) to support qualitative system analysis, in particular for Markov and event simulation to determine the possible system states. Low for event rate, high for unavailability (diagrams with loops).
4) Low for event rate, high for unavailability (diagrams with loops).
5) Depends on system complexity (stochastic process to be simulated) and possible approximations (truncation of event sequences).
6) Especially dependent events, for example, parallel structures with passive (standby) components.
7) Special Erlang distribution (introduction of virtual – 'dummy' states) or semi-Markov process.
8) System size and complexity which can be handled are mainly dependent on available computing means, efficiency of event (Monte Carlo) simulation procedure and required accuracy of measures to be estimated.
9) Independent components at each reduction level are assumed. Therefore, any dependability analysis method may be employed for the evaluation of the relevant components.
10) Mainly calculation of system dependability measures by the reduction (substitution) method of a given reliability block diagram.

6.4 Advantages and Disadvantages of Methods

A comparison of some of the commonly used methods follows.

6.4.1 *Failure Mode and Effects Analysis*

6.4.1.1 *Advantages*

a) identifies systematically the cause and effect relationships;
b) gives an initial indication of those fault modes which are likely to be critical, especially single faults which may propagate;
c) searches for possible outcomes not previously or precisely known;
d) identifies outcomes arising from specific causes or initiating events which are believed to be important;
e) highlights spurious outcomes as well as deviations from normal functional performance; and
f) useful in the preliminary analysis of new or untried systems or components.

6.4.1.2 *Disadvantages*

a) the output data may be large even for relatively simple systems;
b) may become complicated and unmanageable unless there is a fairly direct (of 'single-chain') relationship between cause and effect, that is, cannot conveniently deal with parallel or complex relationship;
c) may not easily deal with time sequences, restoration processes, environmental conditions, maintenance aspects, etc;
d) does not, in itself, directly produce a model for quantitative evaluation; and
e) may not easily portray multiple dependencies or complex interactions between faults in different parts of the system.

6.4.2 *Fault Tree Analysis*

6.4.2.1 *Advantages*

a) identifies and records systematically the logical fault paths from a specific effect, back to the prime causes;
b) deals with parallel, redundant or alternative fault paths;

c) deals with most forms of combinatorial events and some forms of dependencies as well;
d) deals with systems which have several cross-linked sub-systems;
e) provide for fairly easy manipulation of the fault paths to give minimal logical models (for example by using Boolean algebra);
f) capable of sensitivity analysis to indicate the items dominantly contributing to overall system reliability;
g) capable of setting up models for the evaluation of overall system reliability and availability in probabilistic terms; and
h) results in compact and concise diagrams for a total system.

6.4.2.2 *Disadvantages*

a) does not, in itself, provide for a specific fault analysis – that is the cause-effect(s) paths or the effect-cause(s) paths are not specifically highlighted;
b) requires a probabilistic model of performance for each element in the diagram;
c) will not show spurious or unintended outputs unless the analyst takes deliberate steps to this end; and
d) is primarily directed towards success analysis and does not deal effectively with complex repair and maintenance strategies or general availability analysis.

6.4.3 *Reliability Block Diagram*

6.4.3.1 *Advantages*

a) Often constructed almost directly from the system functional diagram; this has the further advantages of reducing constructional errors and/or systematic depiction of functional paths relevant to system reliability;
b) deals with most types of system configuration including parallel, redundant, standby and alternative functional paths;
c) deals with most forms of combinational events and some forms of dependencies;
d) capable of complete analysis of variations and trade-offs with regard to changes in system performance parameters;
e) provide (in the two-state application) for fairly easy manipulation of functional or non-functional paths to give minimal logical models (for example, by using Boolean algebra);
f) capable of sensitivity analysis to indicate the items dominantly contributing to over-all system reliability;
g) capable of setting up models for the evaluation of overall system reliability and availability in probabilistic terms; and
h) results in compact and concise diagrams for a total system.

6.4.3.2 *Disadvantages*

a) does not, in inself, provide for a specific fault analysis – that is the cause-effect(s) paths or the effect-cause(s) paths are not specifically highlighted;
b) requires a probabilistic model of performance for each element in the diagram;
c) will not show spurious or unintended outputs unless the analyst takes deliberate steps to this end; and
d) is primarily directed towards success analysis and does not deal effectively with complex repair and maintenance strategies or general availability analysis.

6.4.4 *Markov Analysis*

6.4.4.1 *Advantages*

a) provides a direct probabilistic model for system state behaviour based on the system logic;
b) provides the probabilistic solutions for sub-sets of other models such as logic diagrams and fault trees;
c) deals readily with multi-state situations and outcomes, right down to the component level;
d) represents event sequences with a specific pattern or order of occurrence;
e) valuable in computing availability performance measures of the system; and
f) deals with complex, dependent repair situations.

6.4.4.2 *Disadvantages*

a) may become very complex for models involving a large number of system states;
b) may not help in the logical solution of a problem;
c) depends normally upon the assumption that transition rates are constant; and
d) can only represent combinatorial events by creating a new state for each combination.

6.4.5 *Parts Count Reliability Prediction*

6.4.5.1 *Advantages*

a) time and cost of analysis are very low;

b) the necessary input information and data are small and suiting to the situation in the early design and development phase;
c) basic information on component reliability is gained in the early design and development phase;
d) adapted to computerized calculations;
e) little training is necessary;
f) applied to parts of any complexity, provided reliability data are available.

6.4.5.2 *Disadvantages*

a) the functional structure (for example lower level redundancies) of a system cannot be considered, and therefore only simple structures lend themselves to parts count analysis;
b) the precision level of the predictions is normally low, especially for small sub-systems, due to the wide spread in values of most published data;
c) repair and maintenance cannot be considered;
d) the evaluation of fault modes and mechanisms and their effects is not possible; and
e) time-sequential failure and event behaviour cannot be considered.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
1885 (Part 39) : 1999	Electrotechnical vocabulary: Part 39 Reliability of electronic and electrical items (*second revision*)
9692	Guide on maintainability of equipment:
(Part 1) : 1980	Introduction to maintainability
(Part 2) : 1980	Maintainability requirements in specifications and contracts
(Part 3) : 1981	Maintainability programme
(Part 4) : 1987	Test and diagnostic procedures
(Part 5) : 1985	Maintainability studies during the design phase
(Part 6) : 1983	Maintainability verification
(Part 7) : 1984	Collection, analysis and presentation of data related to maintainability
(Part 8/Sec 1) : 1988	Maintenance and maintenance support planning, Section 1 General
(Part 8/Sec 2) : 1988	Maintenance and maintenance support planning, Section 2 Maintenance support analysis
(Part 8/Sec 3) : 1988	Maintenance — maintenance support support planning, Section 3 Maintenance planning analysis
(Part 8/Sec 4) : 1988	Maintenance and maintenance supporting planning, Section 4 Maintenance support resources requirements
11137 (Part 2) : 1984	Analysis techniques for system reliability: Part 2 Procedure for failure mode and effects analysis (FMEA) and failure modes, effects and criticality analysis (FMECA)
15037: 2001	Analysis techniques for dependability — Reliability block diagram method

ANNEX B

(Foreword)

COMMITTEE COMPOSITION

Reliability of Electronic and Electrical Components and Equipment Sectional Committee, LTD 3

Organization	*Representative(s)*
Indian Institute of Technology, Kharagpur	PROF K. B. MISRA (***Chairman***)
All India Radio, New Delhi	SHRI A. B. MATHUR SHRI J. P. THAKUR (*Alternate*)
Bhabha Atomic Research Centre, Mumbai	SHRI D. KIRO SHRI R. K. SARAF (*Alternate*)
Bharat Electronics Ltd, Bangalore	SHRI RUDRA MANUEL SHRIMATI MEENA PARAMESHWARAN (*Alternate*)
Central Electricity Authority, New Delhi	DIRECTOR (TELECOMMUNICATION) DEPUTY DIRECTOR (Tele) PTCC (*Alternate*)
Centre for Development of Telematics (C-DOT), New Delhi	SHRI Y. K. PANDEY SHRI A. K. AHUJA (*Alternate*)
Consumer Electronics & TV Manufacturers Association, New Delhi	SHRI N. G. NANDA
Department of Electronics (STQC), New Delhi	SHRI A. K. SINHA SHRI S. K. KIMOTHI (*Alternate*)
Department of Telecommunication (TEC), New Delhi	SHRI V. A. RAMA RAO DIRECTOR (*Alternate*)
Electronic Components Industries Association, New Delhi	SHRI V. K. SEKHRI
Electronics Corporation of India Ltd, Hyderabad	SHRI R. RAMDEV SHRI B. BHASKAR RAO (*Alternate*)
Hindustan Aeronautics Ltd, Hyderabad	SHRI V. RAM MOHAN RAO SHRI S. C. H. JAGNANATHA RAO (*Alternate*)
IETE, New Delhi	MAJOR GEN YASHWANT DEVA MAJOR GEN K. B. JHALDIYAL (*Alternate*)
Instrumentation Ltd, Kota	SHRI A. P. PADARHA SHRI RAJIV SRIVASTAVA (*Alternate*)
ISRO (Department of Space), Bangalore	SHRI S. SATISH SHRI G. LAKSHMIPATHI (*Alternate*)
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