

# TABLE OF CONTENTS

Introduction . . . . .	vii
I. Basic Concepts of System Analysis . . . . .	I-1
1. The Purpose of System Analysis . . . . .	I-1
2. Definition of a System . . . . .	I-3
3. Analytical Approaches . . . . .	I-7
4. Perils and Pitfalls . . . . .	I-9
II. Overview of Inductive Methods . . . . .	II-1
1. Introduction . . . . .	II-1
2. The "Parts Count" Approach . . . . .	II-1
3. Failure Mode and Effect Analysis (FMEA) . . . . .	II-2
4. Failure Mode Effect and Criticality Analysis (FMECA) . . . . .	II-4
5. Preliminary Hazard Analysis (PHA) . . . . .	II-4
6. Fault Hazard Analysis (FHA) . . . . .	II-5
7. Double Failure Matrix (DFM) . . . . .	II-5
8. Success Path Models . . . . .	II-10
9. Conclusions . . . . .	II-12
III. Fault Tree Analysis—Basic Concepts . . . . .	III-1
1. Orientation . . . . .	III-1
2. Failure vs. Success Models . . . . .	III-1
3. The Undesired Event Concept . . . . .	III-3
4. Summary . . . . .	III-4
IV. The Basic Elements of a Fault Tree . . . . .	IV-1
1. The Fault Tree Model . . . . .	IV-1
2. Symbology—The Building Blocks of the Fault Tree . . . . .	IV-1
V. Fault Tree Construction Fundamentals . . . . .	V-1
1. Faults vs. Failures . . . . .	V-1
2. Fault Occurrence vs. Fault Existence . . . . .	V-1
3. Passive vs. Active Components . . . . .	V-2
4. Component Fault Categories: Primary, Secondary, and Command . . . . .	V-3
5. Failure Mechanism, Failure Mode, and Failure Effect . . . . .	V-3
6. The "Immediate Cause" Concept . . . . .	V-6
7. Basic Rules for Fault Tree Construction . . . . .	V-8

VI.	Probability Theory—The Mathematical Description of Events . . . . .	VI-1
1.	Introduction . . . . .	VI-1
2.	Random Experiments and Outcomes of Random Experiments . . . . .	VI-1
3.	The Relative Frequency Definition of Probability . . . . .	VI-3
4.	Algebraic Operations with Probabilities . . . . .	VI-3
5.	Combinatorial Analysis . . . . .	VI-8
6.	Set Theory: Application to the Mathematical Treatment of Events . . . . .	VI-11
7.	Symbolism . . . . .	VI-16
8.	Additional Set Concepts . . . . .	VI-17
9.	Bayes' Theorem . . . . .	VI-19
VII.	Boolean Algebra and Application to Fault Tree Analysis . . . . .	VII-1
1.	Rules of Boolean Algebra . . . . .	VII-1
2.	Application to Fault Tree Analysis . . . . .	VII-4
3.	Shannon's Method for Expressing Boolean Functions in Standardized Forms . . . . .	VII-12
4.	Determining the Minimal Cut Sets or Minimal Path Sets of a Fault Tree . . . . .	VII-15
VIII.	The Pressure Tank Example . . . . .	VIII-1
1.	System Definition and Fault Tree Construction . . . . .	VIII-1
2.	Fault Tree Evaluation (Minimal Cut Sets) . . . . .	VIII-12
IX.	The Three Motor Example . . . . .	IX-1
1.	System Definition and Fault Tree Construction . . . . .	IX-1
2.	Fault Tree Evaluation (Minimal Cut Sets) . . . . .	IX-7
X.	Probabilistic and Statistical Analyses . . . . .	X-1
1.	Introduction . . . . .	X-1
2.	The Binomial Distribution . . . . .	X-1
3.	The Cumulative Distribution Function . . . . .	X-7
4.	The Probability Density Function . . . . .	X-9
5.	Distribution Parameters and Moments . . . . .	X-10
6.	Limiting Forms of the Binomial: Normal, Poisson . . . . .	X-15
7.	Application of the Poisson Distribution to System Failures— The So-Called Exponential Distribution . . . . .	X-19
8.	The Failure Rate Function . . . . .	X-22
9.	An Application Involving the Time-to-Failure Distribution . . . . .	X-25
10.	Statistical Estimation . . . . .	X-26
11.	Random Samples . . . . .	X-27
12.	Sampling Distributions . . . . .	X-27
13.	Point Estimates—General . . . . .	X-28

## TABLE OF CONTENTS

14.	Point Estimates—Maximum Likelihood . . . . .	X-30
15.	Interval Estimators . . . . .	X-35
16.	Bayesian Analyses . . . . .	X-39
XI.	Fault Tree Evaluation Techniques . . . . .	XI-1
1.	Introduction . . . . .	XI-1
2.	Qualitative Evaluations . . . . .	XI-2
3.	Quantitative Evaluations . . . . .	XI-7
XII.	Fault Tree Evaluation Computer Codes . . . . .	XII-1
1.	Overview of Available Codes . . . . .	XII-1
2.	Computer Codes for Qualitative Analyses of Fault Trees . . . . .	XII-2
3.	Computer Codes for Quantitative Analyses of Fault Trees . . . . .	XII-6
4.	Direct Evaluation Codes . . . . .	XII-8
5.	PL-MOD: A Dual Purpose Code . . . . .	XII-11
6.	Common Cause Failure Analysis Codes . . . . .	XII-12
	Bibliography . . . . .	BIB-1