QUANTITATIVE TECHNIQUES IN SAFETY MANAGEMENT

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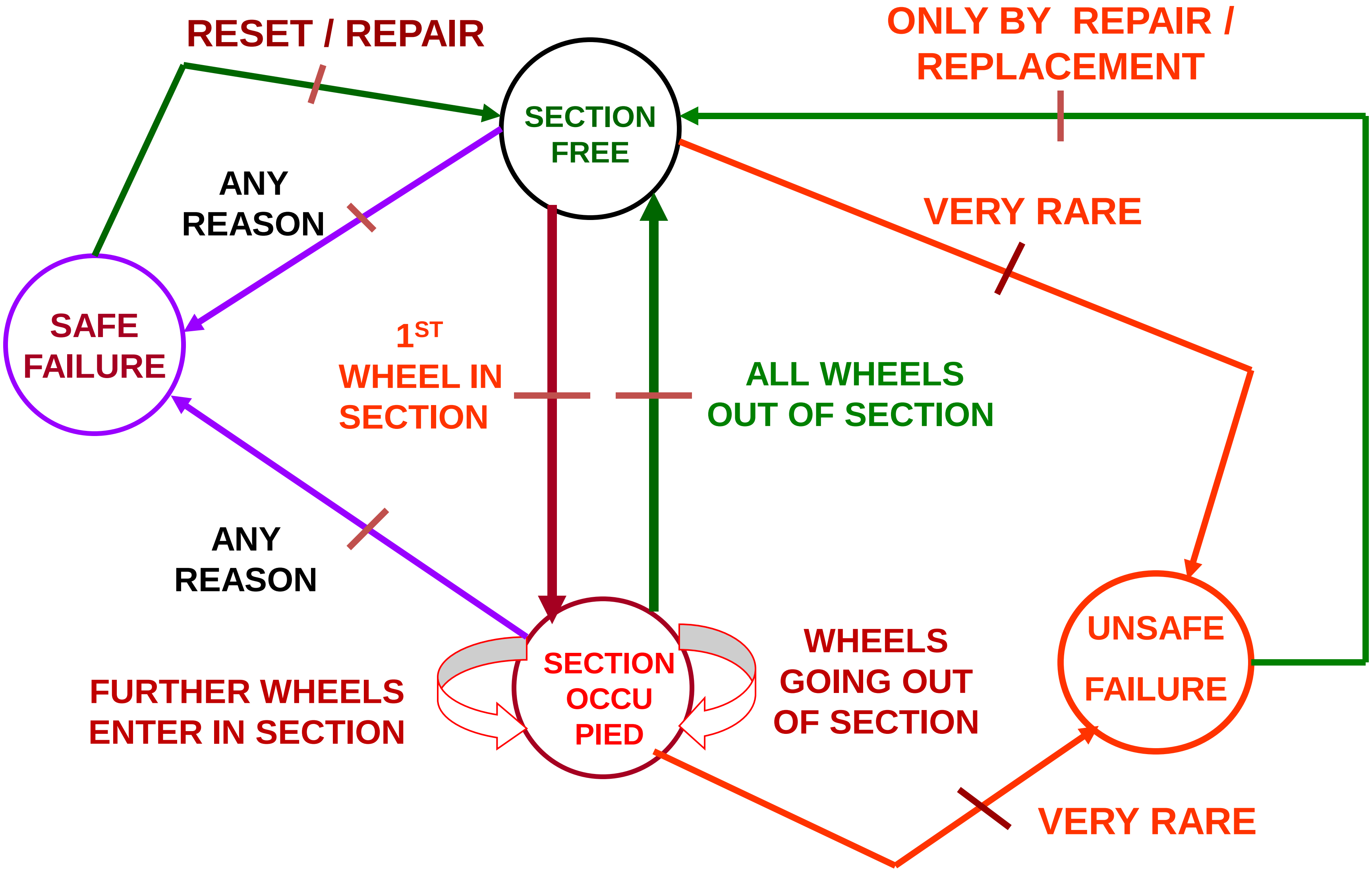
RAILWAY SIGNALING CAN BE DEFINED AS A STATE MACHINE.



SIGNAL FAILURES CAN BE SAFE OR UNSAFE (DANGEROUS).

FAILURES CAN BE DETECTED OR UNDETECTED.

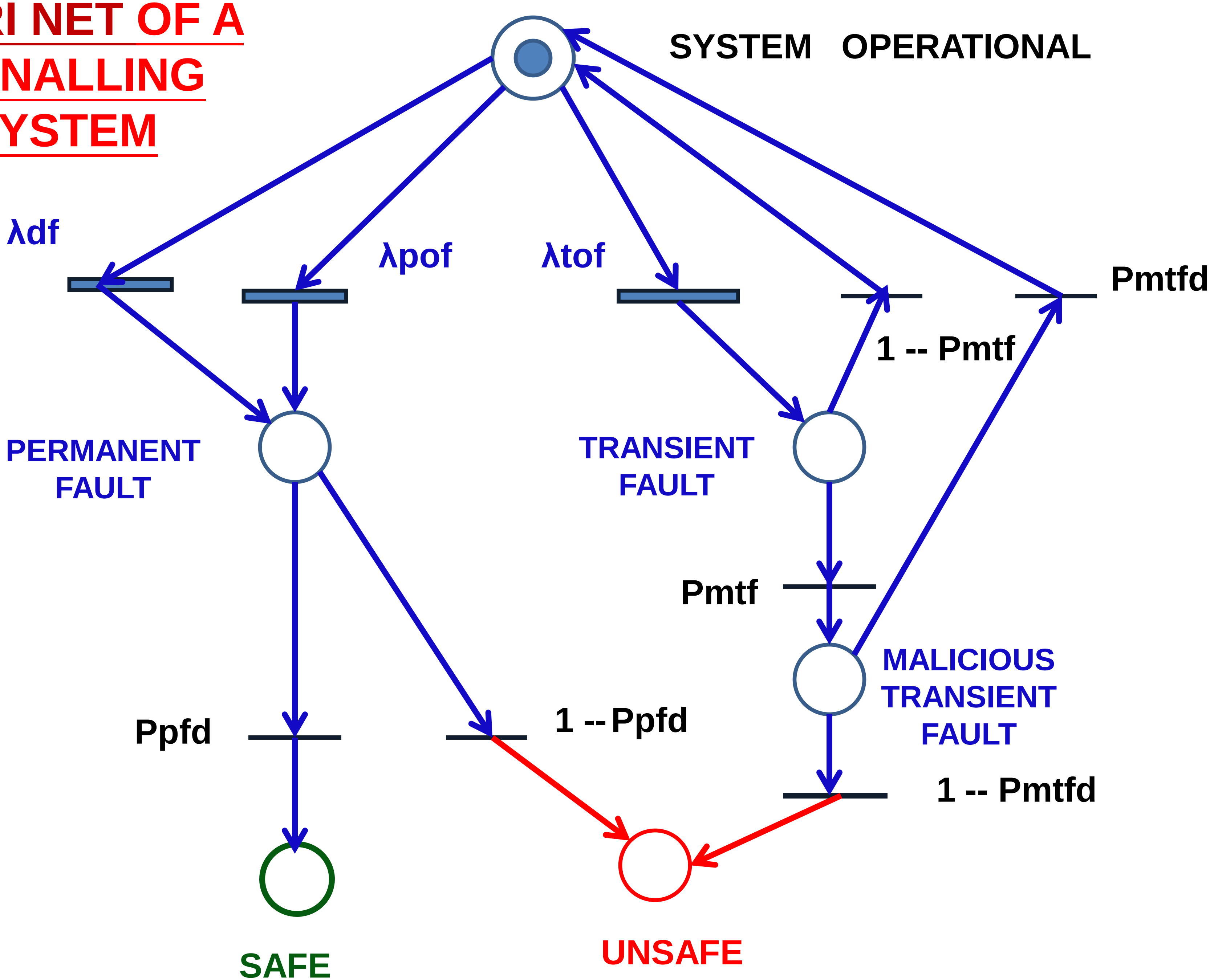
(UNDETECTED FAILURES ARE CONSIDERED AS DANGEROUS).

PROBABILITY OF FAILURE IS GIVEN BY

$$\lambda_{SYS} = \lambda_{SAFE} + \lambda_{DANGEROUS}$$

$$= (\lambda_{SD} + \lambda_{SU}) + (\lambda_{DD} + \lambda_{DU})$$

PETRI NET OF A SIGNALLING SYSTEM



A PROGRAMMABLE EQUIPMENT CAN HAVE FAILURES DUE TO BOTH HARDWARE AND SOFTWARE.

IF HARDWARE FAILURE RATE = λH AND SOFTWARE FAILURE RATE = λS

OVERALL UNSAFE FAILURE RATE CAN BE EXPRESSED BY

$$\lambda unsafe = (\lambda Hpof + \lambda Hdf + \lambda Spof + \lambda Sdf) \cdot (1 - Ppfd) + (\lambda Htof + \lambda Stof) \cdot Pmtf \cdot (1 - Pmtfd)$$

OR

$$\lambda unsafe = (\lambda Hpof + \lambda Hdf) \cdot (1 - Ppfd) + \lambda Htof \cdot Pmtf \, (1 - Pmtfd) + (\lambda Spof + \lambda Sdf) \cdot (1 - Ppfd) + \lambda Stof \cdot Pmtf \cdot (1 - Pmtfd)$$

FAILURE RATES FOR ELECTRONIC SIGNAL EQUIPMENT

ANALOG INPUT CIRCUIT FAILURE RATE	$= \lambda_{AI}$
NUMBER of ANALOG INPUT CIRCUITS	$= N_{AI}$
ANALOG OUTPUT CIRCUIT FAILURE RATE	$= \lambda_{AO}$
NUMBER of ANALOG OUTPUT CIRCUITS	$= N_{AO}$
COMMON CIRCUITRY ANALOG I/O MODULE FAILURE RATE	$= \lambda_{A}$
DIGITAL INPUT CIRCUIT FAILURE RATE	$= \lambda_{DI}$
NUMBER of DIGITAL INPUT CIRCUITS	$= N_{DI}$
DIGITAL OUTPUT CIRCUIT FAILURE RATE	$= \lambda_{DO}$
NUMBER of DIGITAL OUTPUT CIRCUITS	$= N_{DO}$
COMMON CIRCUITRY DIGITAL I/O MODULE FAILURE RATE	$= \lambda_{D}$
LOGIC SOLVER FAILURE RATE	$= \lambda_{MP}$
MODULE RACK FAILURE RATE	$= \lambda_{R}$
POWER SUPPLY FAILURE RATE	$= \lambda_{PS}$

SAFE AND UNSAFE FAILURE RATES

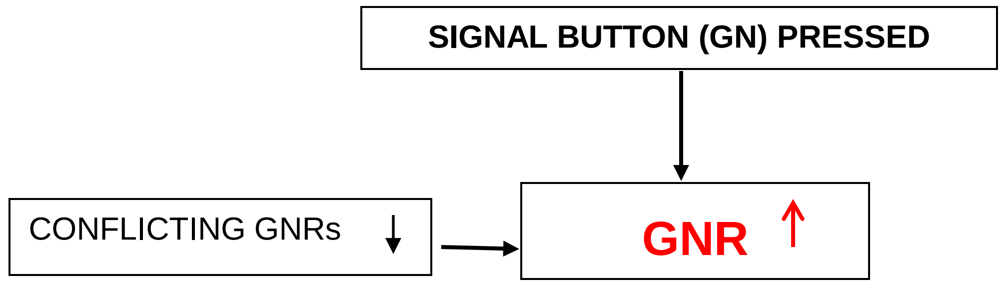
$$\lambda^{SD} = n_{DI}\lambda_{DI}^{SD} + n_{DO}\lambda_{DO}^{SD} + \lambda_{D}^{SD} + n_{AI}\lambda_{AI}^{SD} + n_{AO}\lambda_{AO}^{SD} + \lambda_{A}^{SD} + \lambda_{MP}^{SD} + \lambda_{R}^{SD} + \lambda_{PS}^{SD}$$

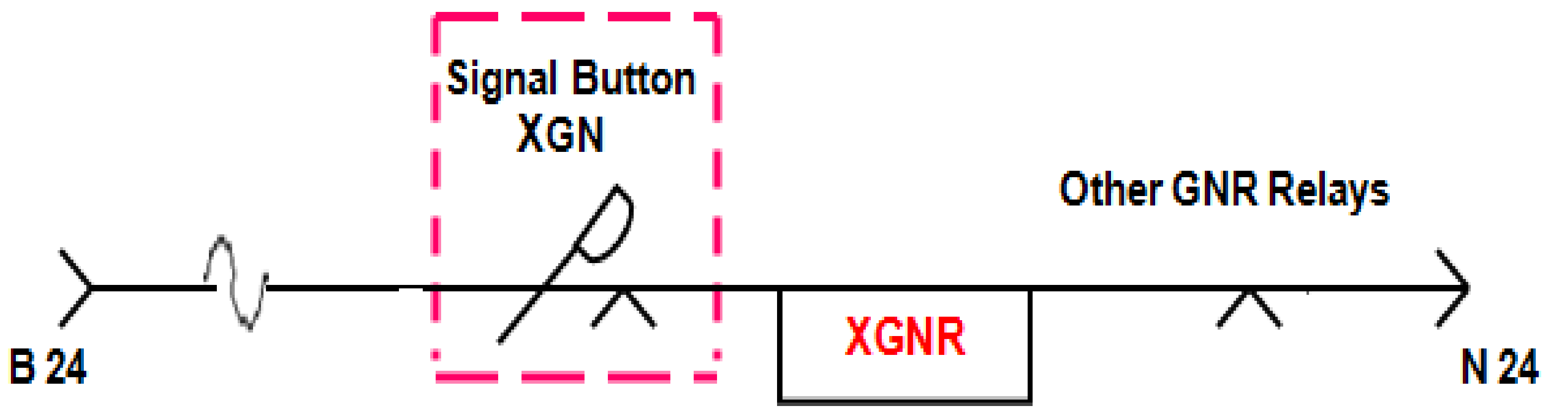
$$\lambda^{SU} = n_{DI}\lambda_{DI}^{SU} + n_{DO}\lambda_{DO}^{SU} + \lambda_{D}^{SU} + n_{AI}\lambda_{AI}^{SU} + n_{AO}\lambda_{AO}^{SU} + \lambda_{A}^{SU} + \lambda_{MP}^{SU} + \lambda_{R}^{SU} + \lambda_{PS}^{SU}$$

$$\lambda^{DD} = n_{DI}\lambda_{DI}^{DD} + n_{DO}\lambda_{DO}^{DD} + \lambda_{D}^{DD} + n_{AI}\lambda_{AI}^{DD} + n_{AO}\lambda_{AO}^{DD} + \lambda_{A}^{DD} + \lambda_{MP}^{DD} + \lambda_{R}^{DD} + \lambda_{PS}^{DD}$$

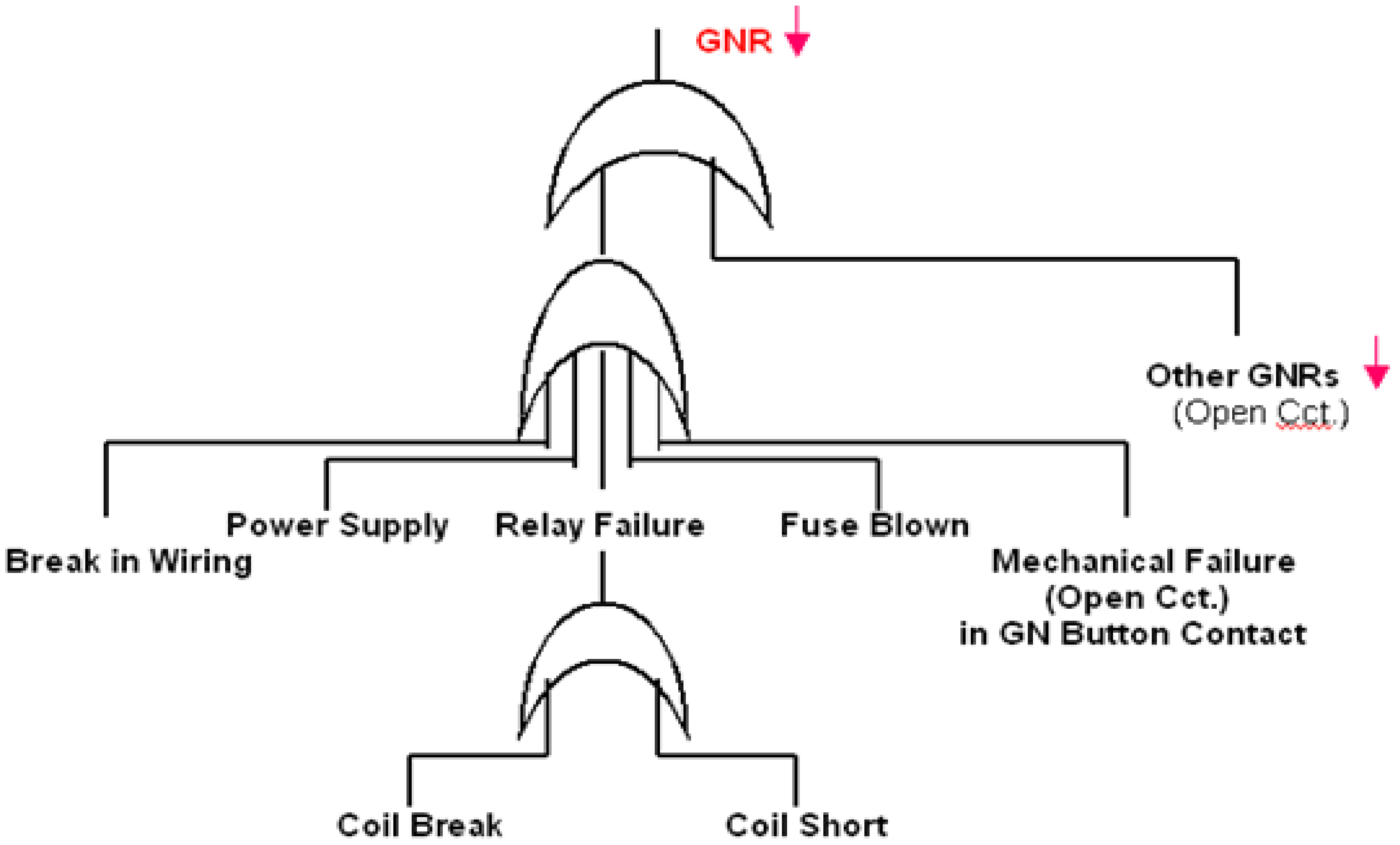
$$\lambda^{DU} = n_{DI}\lambda_{DI}^{DU} + n_{DO}\lambda_{DO}^{DU} + \lambda_{D}^{DU} + n_{AI}\lambda_{AI}^{DU} + n_{AO}\lambda_{AO}^{DU} + \lambda_{A}^{DU} + \lambda_{MP}^{DU} + \lambda_{R}^{DU} + \lambda_{PS}^{DU}$$

SIGNAL BUTTON CIRCUIT IN RELAY INTERLOCKING





FAULT TREE FOR SAFE FAILURE OF SIGNAL BUTTON RELAY (GNR) OF BRITISH ROUTE RELAY INTERLOCKING



$\lambda_{safe} = \lambda_{GNR} + \lambda_{FUSE} + \lambda_{POWER} + \lambda_{WIRING} + \lambda_{CONTACT.\ FLT\ (Button)} + \lambda_{Other\ GNRs\ (13)}$

AS PER RAILTRACK IRM CCA MODEL,

$\lambda_{RELAY\ (open)} = 0.7495 \times 10^{-6}$ / Hr.,

$\lambda_{RELAY\ (short)} = 0.4307 \times 10^{-6}$ / Hr

$\lambda_{WIRING\ (Open)} = 6.554 \times 10^{-8}$ / Hr.,

$\lambda_{FUSE} = 0.04 \times 10^{-6}$ / Hr.,

$\lambda_{POWER} = 0.04 \times 10^{-6}$ / Hr.

AND AS PER MIL STD. 217F (CONSIDERING 5 OPERATIONS / HR.),

$\lambda_{CONTACT\ FLT} = 0.3468 \times 10^{-6}$ / Hr. (for GN Button)

REPLACING THESE VALUES IN THE EQUATION,

$\lambda_{safe} = (0.7495 \times 10^{-6} + 0.4307 \times 10^{-6} + 6.554 \times 10^{-8} + 2 \times 0.04 \times 10^{-6} + 0.3468 \times 10^{-6} + 13 \times 0.7495 \times 10^{-6})$ / Hr $= \underline{11.416 \times 10^{-6} / Hr.}$

FAILURE RATE FOR RESISTORS USED IN AXLE COUNTER AS PER MIL 217F ITEM 9.1)

$$\lambda_{B} = 4.5 \times 10^{-9} \exp^{(12\ (T + 273) / 343)} \exp^{(S / 0.6)\ (T + 273) / 273)}$$

LET US TAKE AN EXAMPLE – A RESISTOR OF VALUE 2.2 KΩ OF LOW QUALITY WORKING AT 45 °C WILL HAVE

$$\lambda_B = 4.5 \times 10^{-9} \exp^{(12\ (45 + 273) / 343)} \exp^{((0.1 / 0.6)\ X\ (45 + 273) / 273)}$$

$$= 4.5\ X\ 10^{-9} \exp^{(12\ X(318 / 343)} \exp^{(0.1666\ X\ (318 / 273))}$$

$$= 4.5\ X\ 10^{-9} \exp^{(12\ X\ 0.92711)} \exp^{(0.1666\ X\ 1.16483)}$$

$$= 4.5\ X\ 10^{-9} \exp^{11.12536} \exp^{0.19406}$$

$$= 4.5\ X\ 10^{-9}\ X\ 67870.72\ X\ 1.21417$$

$= 370829.399\ X\ 10^{-9}$ = <u>0.00037</u> / <u>10^6 Hrs.</u>

THE MODIFIED FAILURE RATE (UNDER STRESS) OF THE RESISTOR

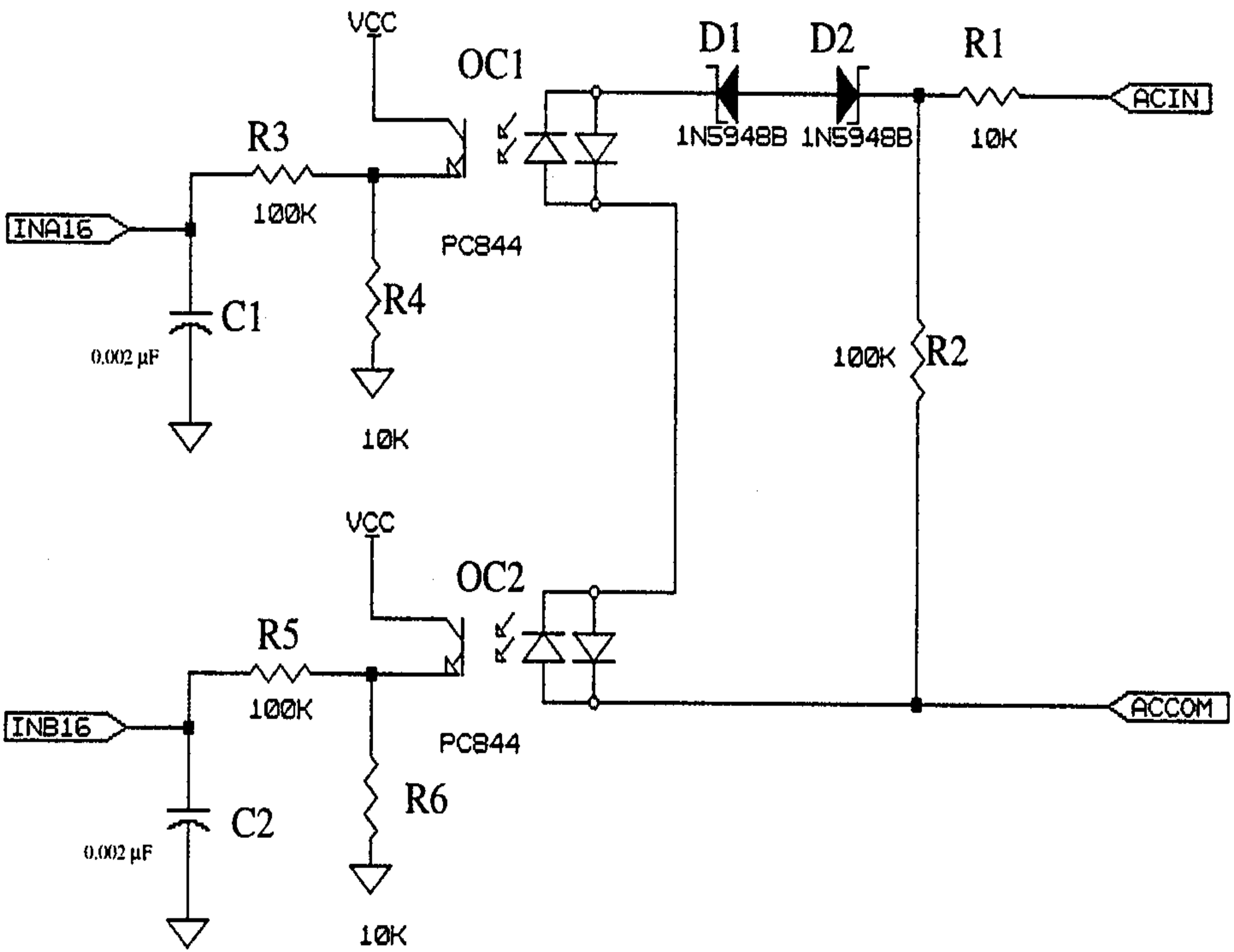
$\lambda_P = \lambda_B\ X\ \Pi_Q\ X\ \Pi_E\ X\ \Pi_R$ = 0.00037 X 15 X 3 X 1 = <u>0.016687/10^6 Hrs.</u>

EFFECT OF AMBIENT TEMPERATURE AND COMPONENT QUALITY (AMPL.– RECT.CARD OF CEL AXLE COUNTER)

Part Description	λ_P at 45°C	λ_P at 30°C	λ_P at 30°C and better Quality Parts	Contribution percentage
Capacitors	3.120181	2.0211954	0.4937654	38.33 %
Resistors	3.5059	2.38384	1.01048	43.07 %
Semiconductors	0.25688	0.25688	0.112088	3.15 %
Transformers & Coil	1.023	0.8884	0.34558	12.5 %
Connectors	0.16747	0.11847	0.0389	2.05 %
Reflow Connections	0.06541			0.8 %
TOTAL	8.13884	5.73419	1.62183	

CHANGE IN AMBIENT TEMPERATURE IMPROVES FAILURE RATE BY 29.5% AND CHANGE IN COMPONENT QUALITY , ALONG WITH TEMPERATURE, BY 80%

FMECA OF AN INPUT INTERFACE CIRCUIT



Failure Modes, Effects and Diagnostic Analysis

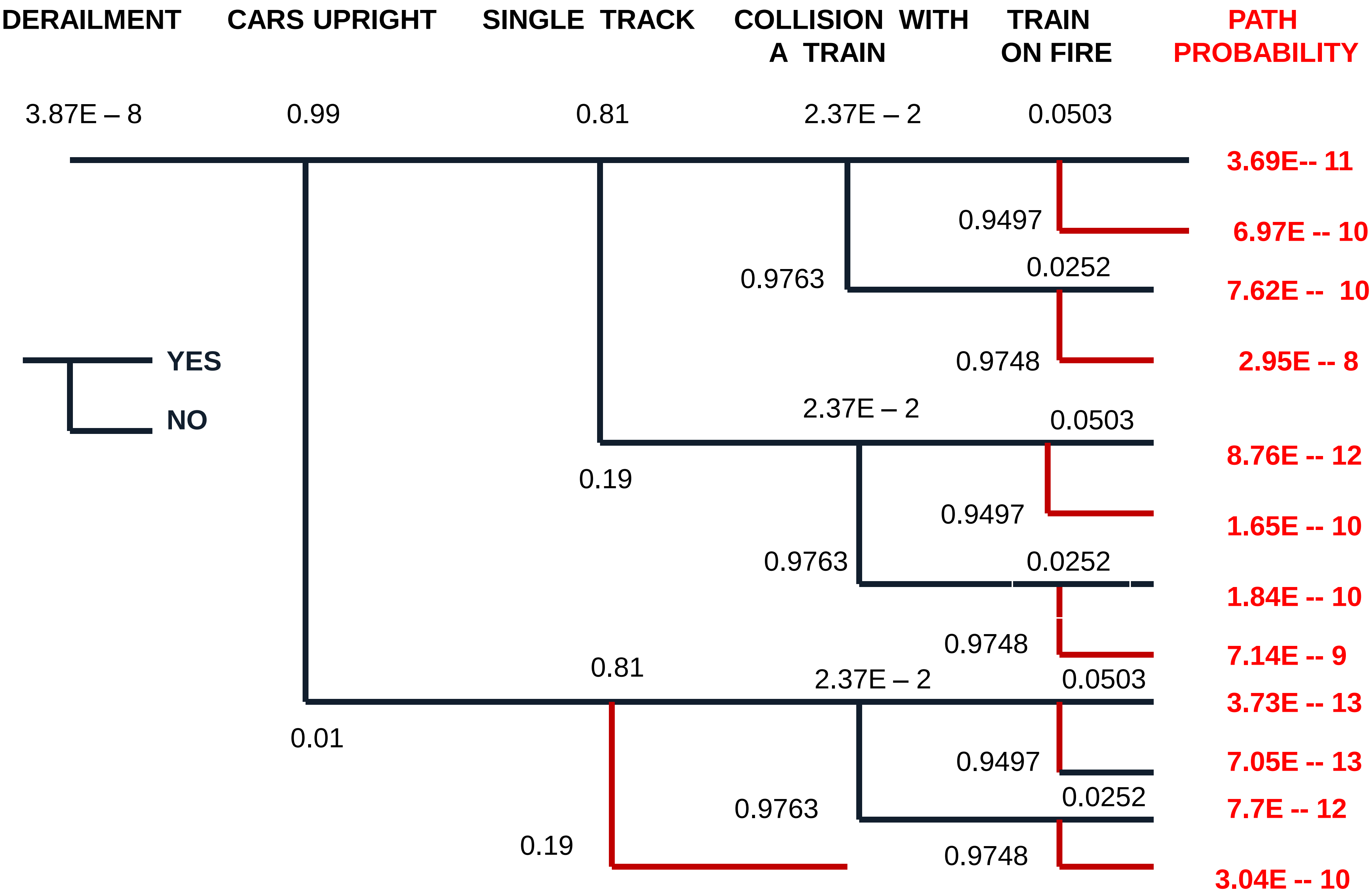
1 Name	2 Code	3 Function	4 Mode	5 Cause	6 Effect	7 Criticality	λ 8	9 Remarks	10 Det.	11 Diagnostics	12 Mode	13 SD	14 SU	15 DD	16 DU
R1-10K	4555-10	Input threshold	short		Threshold shift	Safe	0.125		0		1	0	0.13	0	0
			open	solder open	open circuit	Safe	0.5		1	lose input pulse	1	0.5	0	0	0
			drift low			Safe	0.01	none until too low	0		1	0	0.01	0	0
			drift high			Safe	0.01	none until too high	1	lose input pulse	1	0.01	0	0	0
R2100K	4555-100	current limit	short		short input	Safe	0.125		1		1	0.13	0	0	0
			open	solder open		Safe	0.5		1	lose input pulse		0	0	0.5	0
			drift low			Safe	0.01	none until too low	0		1	0	0.01	0	0
			drift high			Safe	0.01	none until too high	1	lose input pulse	1	0.01	0	0	0
D1	4200-7	voltage drop	short	surge	overvoltage	Safe	2		1	lose input pulse	1	2	0	0	0
			open		open circuit	Safe	5		1	lose input pulse	1	5	0	0	0
D2	4200-7	voltage drop	short	surge	overvoltage	Safe	2		1	lose input pulse	1	2	0	0	0
			open		open circuit	Safe	5		1	lose input pulse	1	5	0	0	0
OC1	4805-25	isolate	led dim	wear	no light	Safe	28		1	Comp. mismatch	1	28	0	0	0
			tran. short	internal short	read logic 1	Dang.	10		1	Comp. mismatch	0	0	0	10	0
			tran. open		read logic 0	Safe	6		1	Comp. mismatch	1	6	0	0	0
OC2	4805-25	isolate	led dim	wear	no light	Safe	28		1	Comp. mismatch	1	28	0	0	0
			tran. short	internal short	read logic 1	Dang.	10		1	Comp. mismatch	0	0	0	10	0
			tran. open		read logic 0	Safe	6		1	Comp. mismatch	1	6	0	0	0
OC1/OC2			cross channel short		same signal	Dang.	0.01		0		0	0	0	0	0.01

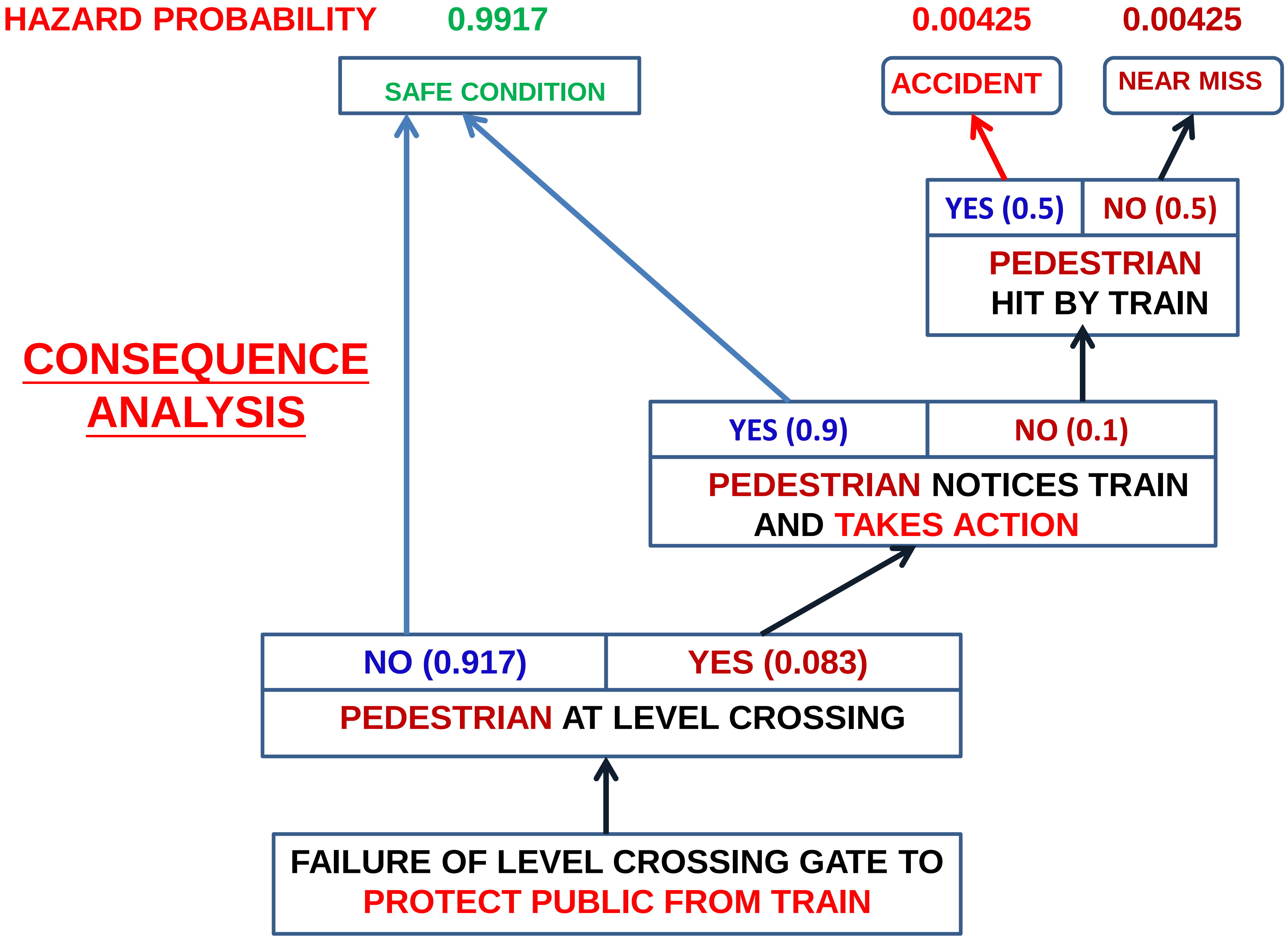
R3-100K	4555-100	filter	short	lose filter	Safe	0.125	0		1	0	0.13	0	0
			open	input float high	Dang.	0.5	1	Comp. mismatch	0	0	0	0.5	0
R4-10K	4555-10	voltage divider	short	read logic 0	Safe	0.125	1	Comp. mismatch	1	0.13	0	0	0
			open	read logic 1	Dang.	0.5	1	Comp. mismatch	0	0	0	0.5	0
R5-100K	4555-100	filter	short	lose filter	Safe	0.125	0		1	0	0.13	0	0
			open	input float high	Dang.	0.5	1	Comp. mismatch	0	0	0	0.5	0
R6-10K	4555-10	voltage divider	short	read logic 0	Safe	0.125	1	Comp. mismatch	1	0.13	0	0	0
			open	read logic 1	Dang.	0.5	1	Comp. mismatch	0	0	0	0.5	0
C1	4350-32	filter	short	read logic 0	Safe	2	1	Comp. mismatch	1	2	0	0	0
			open	lose filter	Safe	0.5	0		1	0	0.5	0	0
C2	4350-32	filter	short	read logic 0	Safe	2	1	Comp. mismatch	1	2	0	0	0
			open	lose filter	Safe	0.5	0		1	0	0.5	0	0
						110.8				86.9	1.4	22.5	0.01

Total Failure Rate	110.8	Safe Coverage	0.9839
Total Safe Failure Rate	88.29	Dang. Coverage	0.9996
Total Dangerous Failure Rate	22.51		
Safe Detected Failure Rate	86.895		
Safe Undetected Failure Rate	1.395		
Dangerous Detected Failure Rate	22.5		
Dangerous Undetected Failure Rate	0.01		

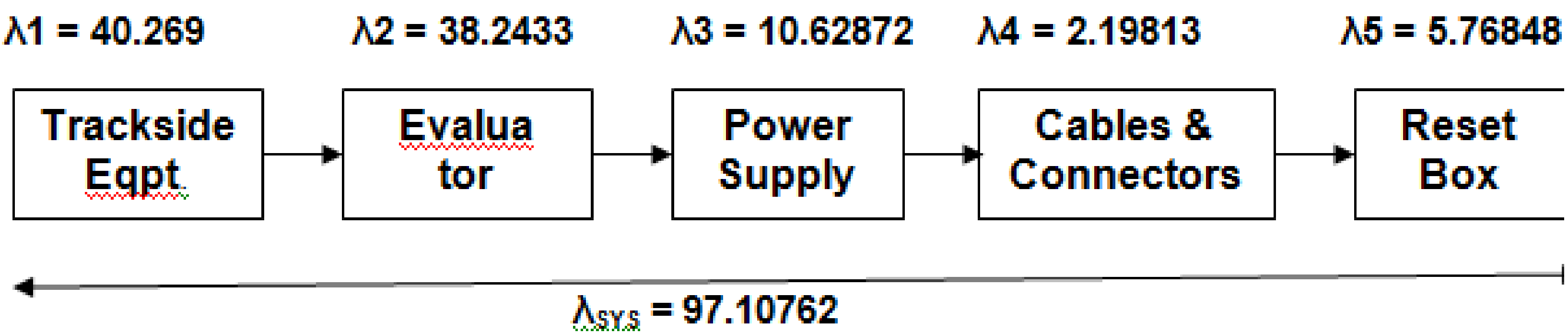
Failures per Billion Hours

EVENT TREE ANALYSIS




HAZARD PROBABILITY
0.9917
0.00425
0.00425
SAFE CONDITION
ACCIDENT
NEAR MISS
YES (0.5)
NO (0.5)
PEDESTRIAN HIT BY TRAIN
CONSEQUENCE ANALYSIS
YES (0.9)
NO (0.1)
PEDESTRIAN NOTICES TRAIN AND TAKES ACTION
NO (0.917)
YES (0.083)
PEDESTRIAN AT LEVEL CROSSING
FAILURE OF LEVEL CROSSING GATE TO PROTECT PUBLIC FROM TRAIN

RELIABILITY BLOCK DIAGRAM OF UNIVERSAL AXLE COUNTER.



CALCULATING INDIVIDUAL RELIABILITY VALUES, WE FIND

R1 = 0.99995963, R2 = 0.9999617, R3 = 0.9999894,
R4 = 0.9999978 AND R5 = 0.9999942

$R_{SYS} = R1 \times R2 \times R3 \times R4 \times R5$

$= (0.99995963 \times 0.9999617 \times 0.9999894 \times 0.9999978 \times 0.9999942)$
$= 0.999902865$

SEPARATELY CALCULATING R_{SYS} **FROM** λ_{SYS} **THE VALUE IS 0.999902897**

FAILURE RATE OF A TYPICAL ELECTRONIC INTERLOCKING EQPT.

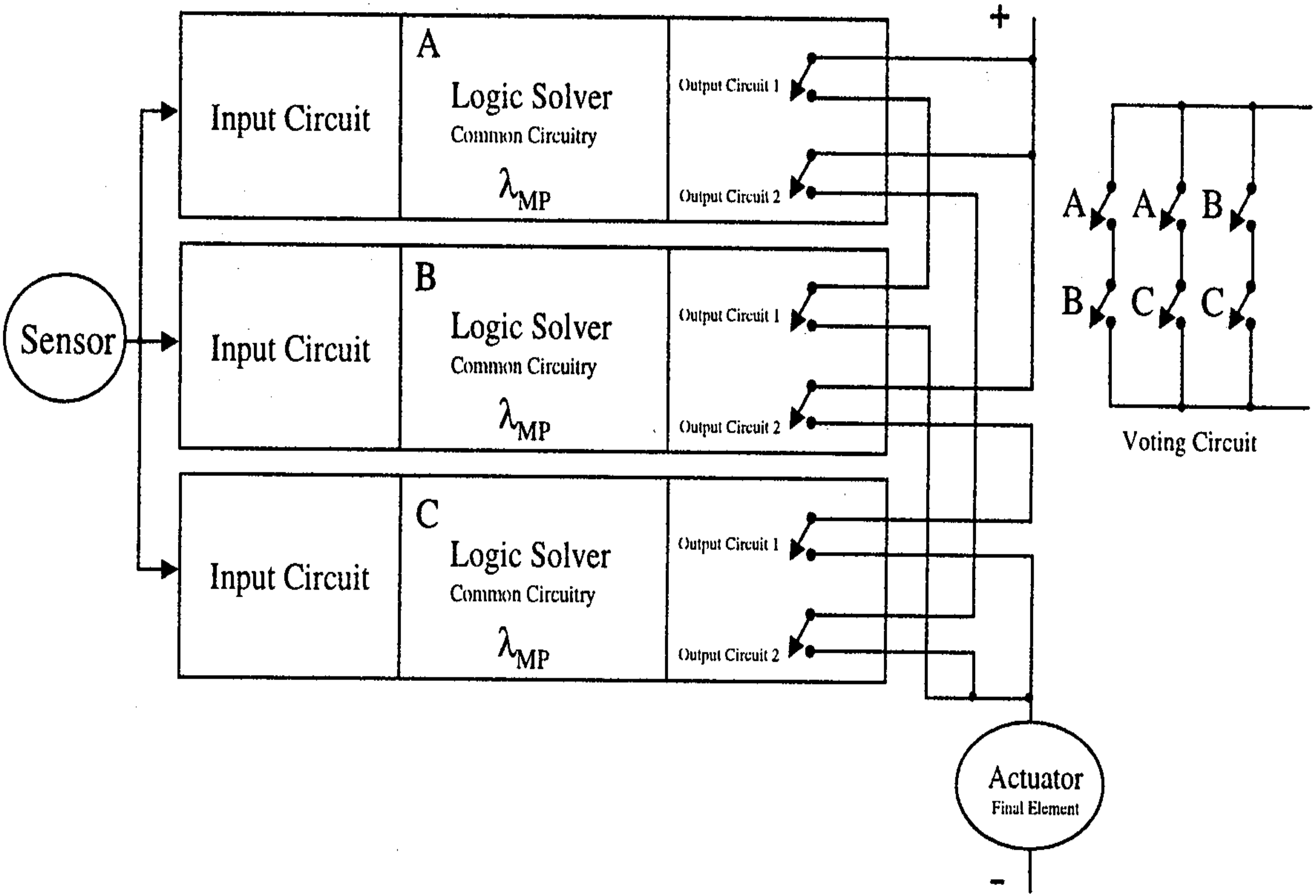
SUB-SYSTEM NAME	QTY	FAULTS/10^6 Hr	TOTAL FAULTS/10^6 Hr
PROCESSOR BOARD	1	2.14470	2.1447
I/O BUS INTERFACE BOARD	1	2.8679	2.8679
CODE SYSTEM INTERFACE BOARD	1	2.9182	2.9182
PERIPHERAL BOARD	1	2.1412	2.1412
CPU POWER SUPPLY	1	1.5545	1.5545
12V INPUT BOARD	7	1.2741	8.9187
RELAY DRIVER BOARD	7	0.7102	4.9714
I/O POWER SUPPLY	1	0.8234	0.8234
TOTAL			**26.34**

BUT RELIABILITY IS REDUCED WITH TIME !

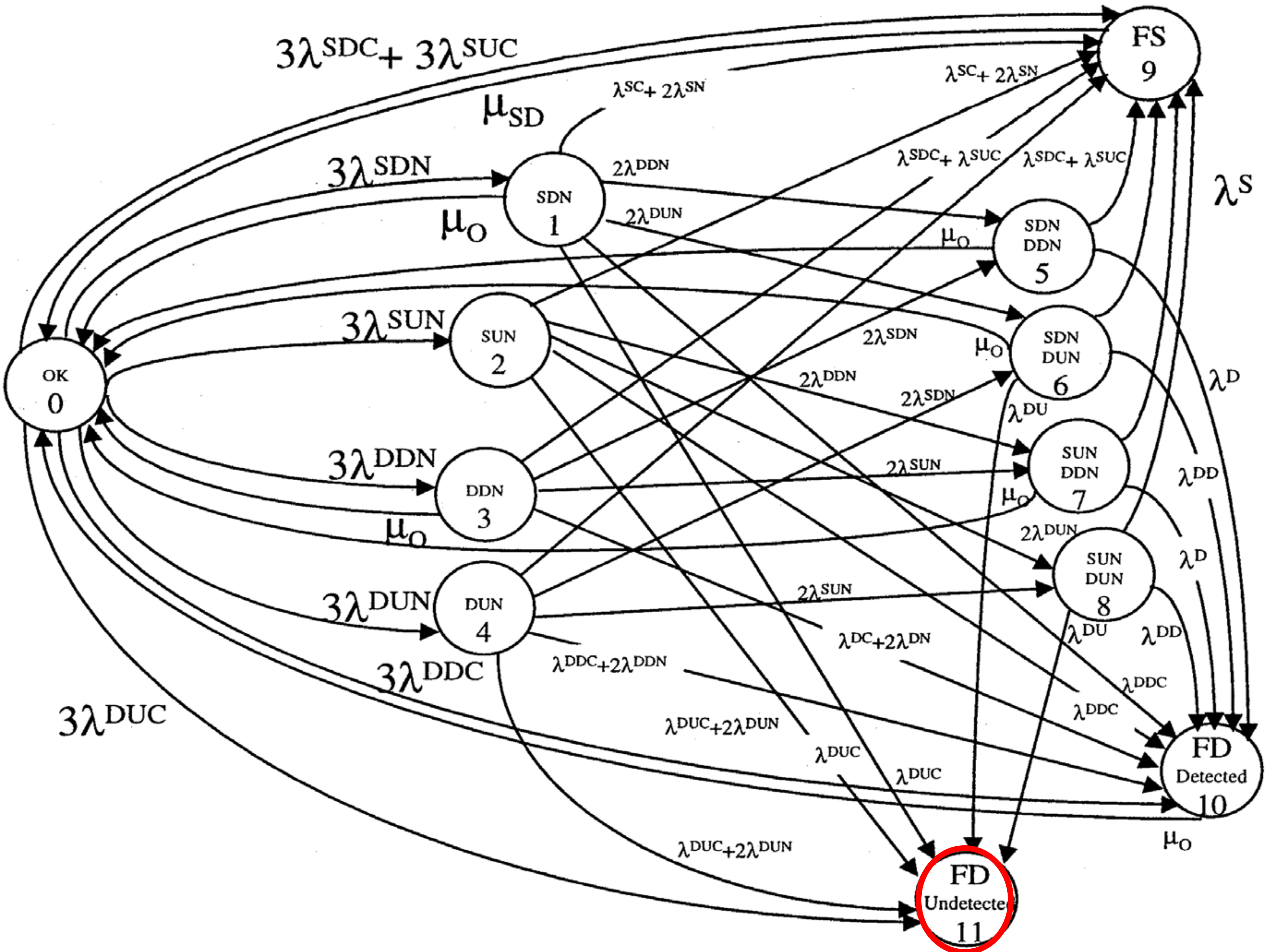
Const. Failure Rate / Hr	After 1 Year	After 2 Years	After 3 Years	After 4 Years	After 5Years
$3 / 10^7$ Hrs	99.7375%	99.4758%	99.2147%	98.9543%	98.6946%
$3 / 10^8$ Hrs	99.9723%	99.9474%	99.9212%	99.8949%	99.8687%

RELIABILITY AT THE END OF LIFE MUST BE USED TO DETERMINE THE INITIAL RELIABILITY.

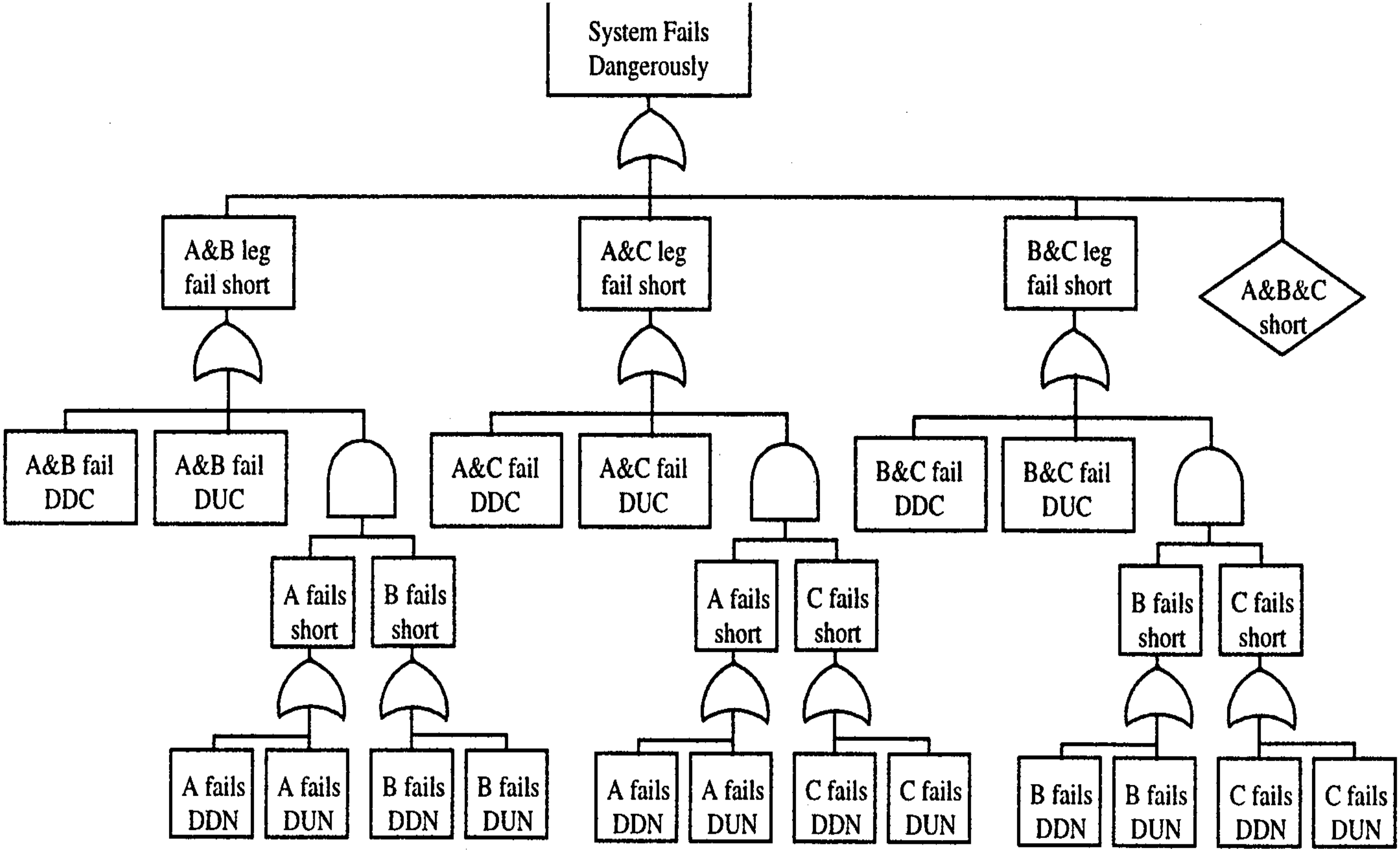
2oo3 ARCHITECTURE



2oo3 ARCHITECTURE MARKOV DIAGRAM



PFD FAULT TREE FOR 2oo3 SYSTEM

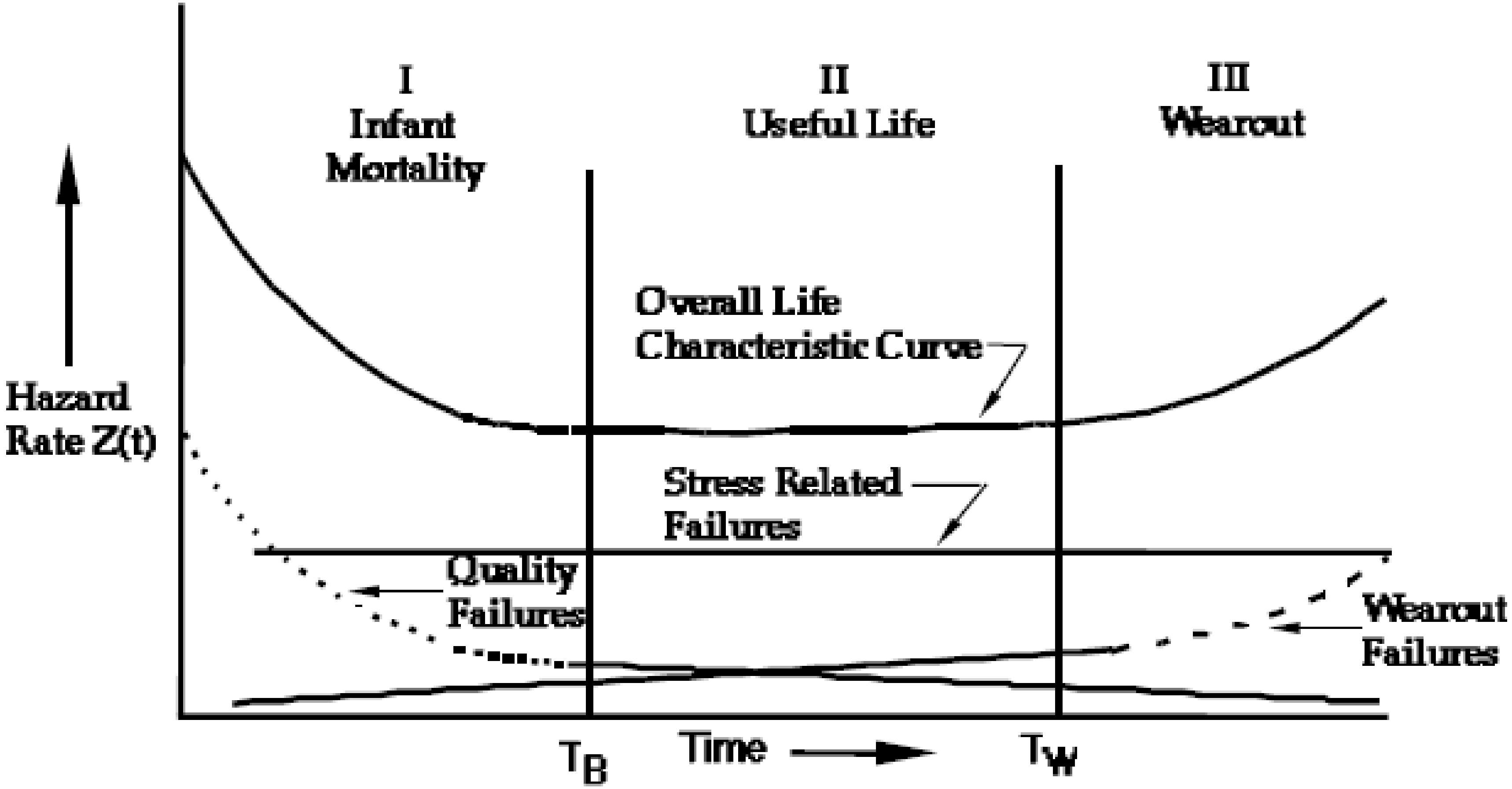


$$PFDavg_{2oo3} = 3\lambda^{DUC}*TI/2 + 3\lambda^{DDC}*RT + 3[(\lambda^{DDN}*RT)^2 + (\lambda^{DDN}*RT*\lambda^{DUN}*TI)/2 + (\lambda^{DUN}*TI)^2/3]$$

COMPARISON BETWEEN ANALYSIS TECHNIQUES

ANALYSIS TECHNIQUES	FMECA	RBD	FTA	HYBRID TECHNIQUE	MARKOV MODEL
ASPECTS COVERED					
EFFECTS OF REDUNDANCY		√	√	√	√
COMMON CAUSE FAILURES		√	√	√	√
SYSTEMATIC FAILURES	√	√	√		√
EFFECTS OF DIAGNOSTICS	√		√	√	√
EFFECTS OF TEST & REPAIR			√	√	√
TIME / SEQUENCE DEPENDENT ASPECTS					√

BATH TUB CURVE (HAZARD RATE vs TIME)



T_B = possible burn-in time T_W = wear begins

IMPROVEMENT IN LIFE-TIME RESULTING FROM AN INITIAL BURN-IN PERIOD

LET A COMPONENT FOR AXLE COUNTER CARD HAVE A DECREASING FAILURE RATE OF $\lambda T = 0.0005\ (T/1000)^{-0.5}$ / YEAR. FIND THE INFLUENCE OF A BURN-IN PERIOD OF 6 MONTHS ON THE LIFE-TIME OF THE COMPONENT, CONSIDERING RELIABILITY OF 0.9.

Answer: $R_{(t)} = 0.9$, i.e. $\exp[-(t/1000)^{-0.5} = 0.9$ FROM THIS,

$t = 1000\ \{-\ln(0.9)\}^2 = 1000 \text{ X } (0.10536)^2 = 1000 \times 0.0111 = 11.1$ Yrs

WHEN A BURN-IN PERIOD OF 6 MONTHS (0.5 YR) IS INTRODUCED,

$R_{(t\ |T)} = 0.9$, i.e.

$\exp[-(t + 0.5/1000)^{-0.5}] / \exp[-(0.5/1000)^{-0.5}] = 0.9$

$t = 1000\ \{-\ln 0.9 + (0.5/1000)^{-0.5}\}^2 - 0.5 = 1000\ \{0.10536 + 0.02236\}^2 - 0.5$

$= 1000\ \{0.12772\}^2 - 0.5 = (1000 \text{ X } 0.1631) - 0.5 = 16.31 - 0.5$

$= 15.81$ Yrs

AN INCREASE OF 4.71 YRS IN THE DESIGNED LIFE OF THE COMPONENT.

SPARE PARTS CALCULATION

LET $\lambda = 1 \times 10^{-5}$ / hr. BE THE CONSTANT FAILURE RATE OF A VITAL SPARE PART IN A SYSTEM. THERE ARE 6 SYSTEMS INSTALLED AND A CUMULATIVE OPERATING TIME OF 50,000 HRS FOR EACH SYSTEM IS NEEDED. DESIRED SYSTEM RELIABILITY IS $\geq$ 0.99. HOW MANY SPARE PARTS ARE NEEDED?

ANSWER: **FOR CENTRALIZED STORE**

NO. OF FAILURES = 50000 / 100000 = 0.5 ≈ **1 AND RELIABILITY** = **0.99**

FOR THIS VALUE, **d = 2.33** (FROM **STANDARD NORMAL DISTRIBUTION TABLE**) AND **kd/2 = 1.165, as k (COEFFICIENT of DISTRIBUTION) = 1**

Now **$KT\lambda$ = 6x50000x0.00001** = 3, where K = No. of SYSTEMS

So, $n = [kd/2 + \{(kd/2)^2 + KT\lambda\}^{1/2}]^2$

$= [1.165 + \{(1.165)^2 + 3\}^{1/2}]^2$

$= [1.165 + 2.0874]^2 = (3.2524)^2 = 10.57 \approx 11$

FOR DECENTRALIZED STORE

NO. OF FAILURES = 50000 / 100000 = 0.5 ≈ 1

INDIVIDUAL RELIABILITY AT EACH SYSTEM IS $(0.99)^{1/6}$ **= 0.99888**

FOR THIS VALUE, **d = 2.99**

(FROM **STANDARD NORMAL DISTRIBUTION Table**)

AND **kd/2 = 1.495**

NOW KTλ = 50000x0.00001 = 0.5

So, $n = [kd/2 + \{(kd/2)^2 + KT\lambda\}^{1/2}]^2$

$= [1.495 + \{(1.495)^2 + 0.5\}^{1/2}]^2$

$= [1.495 + 1.6538]^2$

$= (3.783)^2 = 9.915 \approx$ **10**

FOR THE SYSTEM HAVING **SIX EQUIPMENT**, **TOTAL SPARES NEEDED** WILL BE **60**.

SO, DECENTRALIZED STORES NEED MUCH MORE SPARES.

ADEQUACY OF SPARE PARTS

SUPPOSE A COMPONENT IN A SIGNALLING EQUIPMENT HAS A FATIGUE RATE OF 0.000003/ Hr. SIGNAL REPAIR SHOP HAS PROCURED TWO SPARE COMPONENTS. IF THE DESIGN LIFE OF THE EQUIPMENT IS 20 Yrs, WHAT IS THE PROBABILITY THAT SPARES WILL BE ADEQUATE FOR 10 SUCH EQUIPMENT?

ANSWER

EXPECTED FAILURES DURING EQUIPMENT LIFE IS

$$= 10 X 3 X 10^{-6} X 20 X 8760 = 5.256.$$

PROBABILITY OF ≤ 2 FAILURES IN 20 Yrs,

$$R_{(20)} = \sum_{n=0}^{2} \{ e^{-5.256} (5.256)^{n} / N! \}$$

$$= e^{-5.256} \{ (5.256)^{0} /0! + (5.256)^{1} /1! + (5.256)^{2} /2!$$

$$= 0.005216 \{1 + 5.256 + 13.812768\}$$

$$= 0.005216 X 20.068768$$

$$= 0.1046787$$

INFLUENCE OF PERIODICAL INSPECTION ON AVAILABILITY

LET US CONSIDER A UNIVERSAL AXLE COUNTER EQUIPMENT HAVING A CONSTANT FAILURE RATE OF 0.0000971 FAILURE/ 10^6 HRS.

ANY DEFECTIVE COMPONENT WOULD BE REPLACED / REPAIRED, IF FOUND DEFECTIVE DURING THE PERIODIC INSPECTION.

THE INSPECTION TIME IS 1 HR AND REPAIR / REPLACEMENT TAKES 8 HRS (WORST CASE).

WHAT IS THE OPTIMUM TIME BETWEEN INSPECTIONS?

ANSWER:

WE USE THE FORMULA $A_{(T)} = (1 - e^{-\lambda T}) / \lambda \, [T + t1 + t2 \, (1 - e^{-\lambda T})]$

WHERE,

λ = 0.0000971, t1 = 1 hr, t2 = 8 hr and **T = INSPECTION PERIODICITY**.

LET US CONSIDER 168 HRS, 336 HRS, 504 HRS AND 672 HRS AS THE INSPECTION INTERVALS AND FIND AVAILABILITY AT THESE PERIODS.

$A_{(168)} = (1 - e^{-0.0000971X\,168}) / [0.0000971\{168 + 1 + 8(1 - e^{-0.0000971X\,168})\}]$

$= (1 - e^{-0.0163128}) / [0.0000971\{169 + 8(1 - e^{-0.0163128})]\}$

$= (1 - 0.98388195) / [0.0000971\,\{169 + 8\,(1 - 0.98388195)\}]$

$= 0.0161804 / [0.0000971\,\{169 + 8\,X(0.0161804)\}]$

$= 0.0161804 / [0.0000971\,X\,169.1294432] = 0.0161804 / 0.01642247$

$= 0.9852598$

BY SIMILAR CALCULATIONS, WE FIND THE VALUES:

$A_{(336)} = 0.9801959$, $A_{(504)} = 0.9732559$, $A_{(672)} = 0.9662714$

MAXIMUM AVAILABILITY IS FOR AN INSPECTION INTERVAL OF 168 HRS.

WE NOW CONSIDER INSPECTION PERIODICITY OF 96 HRS AND 240 HRS.

$A_{(96)} = 0.98434$ AND $A_{(240)} = 0.983582$

T (Hr)	96	168	240	336	504	672
$A_{(T)}$	0.98434	0.9852598	.983582	.9801959	0.9732559	0.9662714

EXAMPLE OF QUANTIFICATION OF SOFTWARE TESTING

TOTAL STATEMENTS	= 10
NESTED LEVEL	= 4
TOTAL LINES	= 79
SOURCE ONLY LINES	= 21
SOURCE & COMMENTS LINES	= 0
COMMENTS ONLY LINES	= 55
EMPTY LINES	= 3
COMMENTS LINES RATE	= 69.62%

SOME SAFETY QUANTIFICATION PARAMETERS

FAILURE RATE	$= 10^{-6}$/Hr
SAFE FAILURE RATIO	> 0.99
DIAGNOSTIC COVERAGE FACTOR	= 0.99
COMMON CAUSE (β) FACTOR	= 0.05
REPAIR TIME	= 4 Hrs. TO 1 DAY
PROOF TEST TIME	= 0.25 TO 1 YEAR
PROOF TEST COVERAGE FACTOR	= 0.8
TIME TO COMPLETE OVERHAUL	= 4 TO 6 YEARS

TRAINING MODULES IN QUANTITATIVE TECHNIQUES

FAULT TREE ANALYSIS.

FMECA AND FAULT INJECTION TECHNIQUES.

MARKOV DIAGRAM AND ANALYSIS.

RELIABILITY BLOCK DIAGRAMS.

HAZARD IDENTIFICATION AND RANKING.

SAFETY INTEGRITY LEVEL CALCULATION.

CAUSAL & CONSEQUENCE ANALYSIS.

LOSS, OPTIONS & IMPACT ANALYSIS.

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धन्यवाद !

THANK YOU !

谢谢

MERCI !

DANKE SCHÖN !

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СПАСИБО !

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GRACIAS !

TACK !