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Fuzzy matrix model: applied to health problem

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Abstract

In the present paper we have collected a data of 500 labourers working from dawn to late evening in the factories of Bangles and other lead made products in city Firozabad (also called Suhag Nagari) Uttar Pradesh. Data has been managed to collect the different cardiovascular symptoms in different age groups of labourers. With the help of ATD, RTD and CETD-matrices and their graphs, conclusion for maximum age in which the labourers suffer due to heart disease have been calculated through sections 1 to 4. This is due to pollution of carbon-di-oxide and lead oxide inhaled by the labourers in the factories. In section 5 and 6, the specificity of the data is studied. Finally a conclusion in detail has been given.

Introduction-

A survey on random 500 labourers from the factories of bangles and other lead made products, situated at Firozabad, U.P. was made most of the labourers reported following symptoms:

S_1 – Asthma, S_2 – Pain in lungs, S_3 – Back Pain, S_4 – Pain at rib side, S_5 – Pain in chest, shoulders and arms, S_6 – Left leg pain, S_7 – Chest burning, S_8 – Blood pressure (low or high)

According to medical experts these are cardio vascular problem symptoms.

In this paper we have estimated the maximum age group of the labourers of lead product factories situated Firozabad to fall for Heart problem hazards.

Procedure for solving the above problem

Step-1- The above symptoms have been collected on the age group of 20-30, 31-43, and 44-65. These are taken as rows of the matrix. Frequencies reporting above 8 symptoms have been taken as columns of initial row data matrix. Interaction of row and column give appropriate frequency.

Step-2- In order to obtain an unbiased uniform effect on each and every data so collected, transform this initial row data matrix into average time dependent data (ATD) $((a_{ij}))$ by dividing the rows by

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corresponding intervals of ages i.e. time period for example first row will be divided by $30-20+1 = 11$, secondly row by $43-31+1 = 13$ and third row by $65-44+1 = 22$.

Step-3- to make the collection easier and simpler we in this stage using simple average technique convert the above ATD-matrix in to refined time dependent with entries $\{-1,0,1\}$ call the entries b_{ij} and matrix as RTD-matrix

Description of average technique-

Mean and Mean deviations of every column of ATD-matrix was determined
 Let us choose $\alpha \in [0,1]$ called parameter. let the j^{th} column has average μ_j and mean deviation M_j . Now
 if $a_{ij} \leq \mu_j - \alpha * M_j$ Then $b_{ij} = -1$
 else if $(\mu_j - \alpha * M_j) < a_{ij} < (\mu_j + \alpha * M_j)$ then $b_{ij}=0$
 else if $a_{ij} \geq \mu_j + \alpha * M_j$ then $b_{ij} = 0$

where a_{ij} are entries in ATD-matrix and b_{ij} are entries of RTD-matrix or fuzzy matrix.

Step-4- Adding the corresponding rows of RTd-matrix we get row sum matrix (RSM-matrix).This RSM-matrix gives the maximum age group, who are prone to the health hazard

Step-5- Add all the RTD-matrices for different parameters. This matrix is called CETD. It gives commutative effect of all these entries.

Step-6- Prepare the row sum of CETD-matrix graphs,of RTD and CETD-matrices are prepared and then final conclusion follows (Kandasamy, 2006 and 2007).

Real world case study- Following is initial row data matrix of C.V.problem of order 3×8 (collected form the workers described above.)

Table .1

S.No.	Symptoms→ Years↓	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	Total	Moving average	Moving average
1	20-30	23	18	24	16	23	10	16	10	140	179 180	179.5
2	31-43	35	29	35	31	30	18	30	10	218		
3	44-65	22	21	21	22	20	11	20	5	142		
	Total	80	68	80	69	73	39	66	25	500		

Applying the method of moving averages in analysis of time series. We see from table (1) that the trend falls in the age group of 31-43.

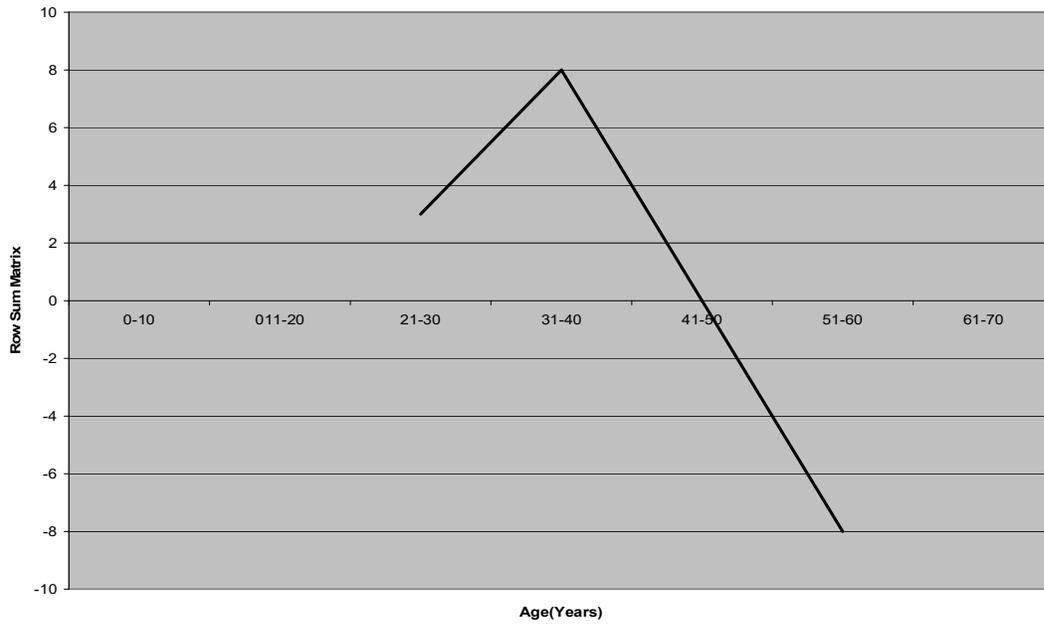
ATD matrix of C.V. problem of order 3×8

$$\begin{bmatrix} 2.09 & 1.64 & 2.18 & 1.46 & 2.09 & 0.91 & 1.46 & 0.91 \\ 2.69 & 2.23 & 2.69 & 2.39 & 2.30 & 1.39 & 2.30 & .077 \\ 0.00 & 0.95 & 0.95 & 1.00 & .091 & 0.50 & .091 & 0.23 \end{bmatrix}$$

Let $\alpha = 0.2$

Average μ	1.93	1.61	1.94	1.62	1.76	0.93	1.56	0.64
M_d	0.62	0.36	0.66	0.52	0.34	0.30	0.49	0.27
$\mu - \alpha * M$	1.806	1.538	1.808	1.516	1.692	0.870	1.462	0.586
$\mu + \alpha * M$	2.054	1.682	2.072	1.724	1.828	0.99	1.654	0.694

$$\text{RTD-Matrix for } \alpha = 0.2 \begin{bmatrix} +1 & 0 & +1 & -1 & +1 & 0 & 0 & +1 \\ +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix} \quad \text{Row Sum Matrix} \begin{bmatrix} +3 \\ +8 \\ -8 \end{bmatrix}$$

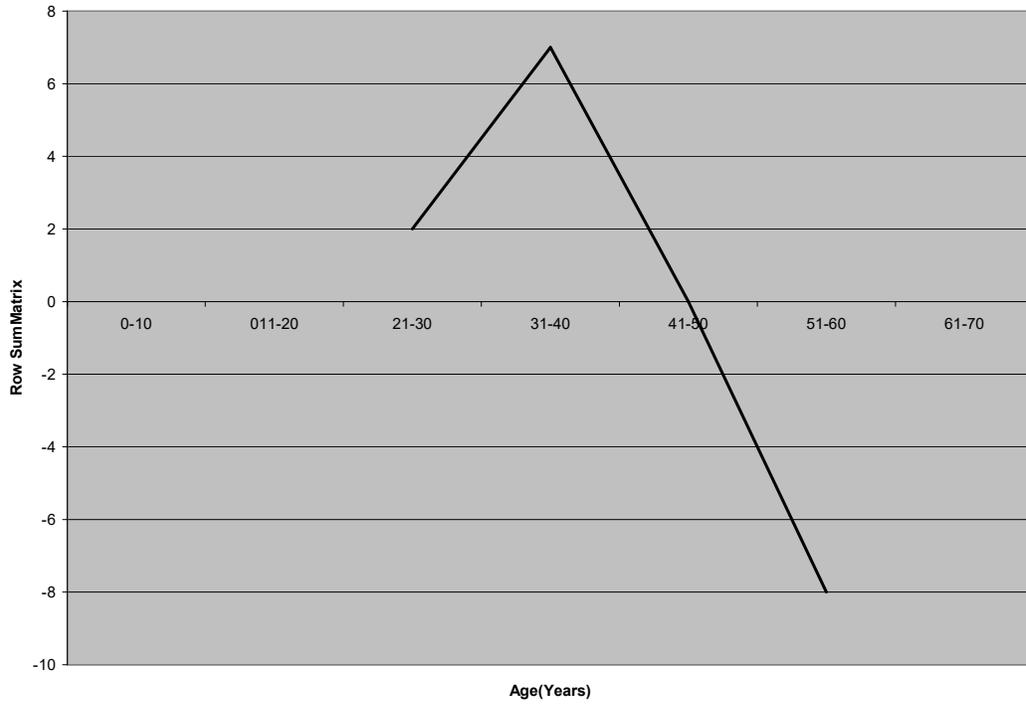


Graph-1

Let $\alpha = 0.5$ RTD Matrix is

Row Sum Matrix

$$\begin{bmatrix} 0 & 0 & 0 & 0 & +1 & 0 & 0 & +1 \\ +1 & +1 & +1 & +1 & +1 & +1 & +1 & 0 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix} \quad \begin{bmatrix} +2 \\ +7 \\ -8 \end{bmatrix}$$

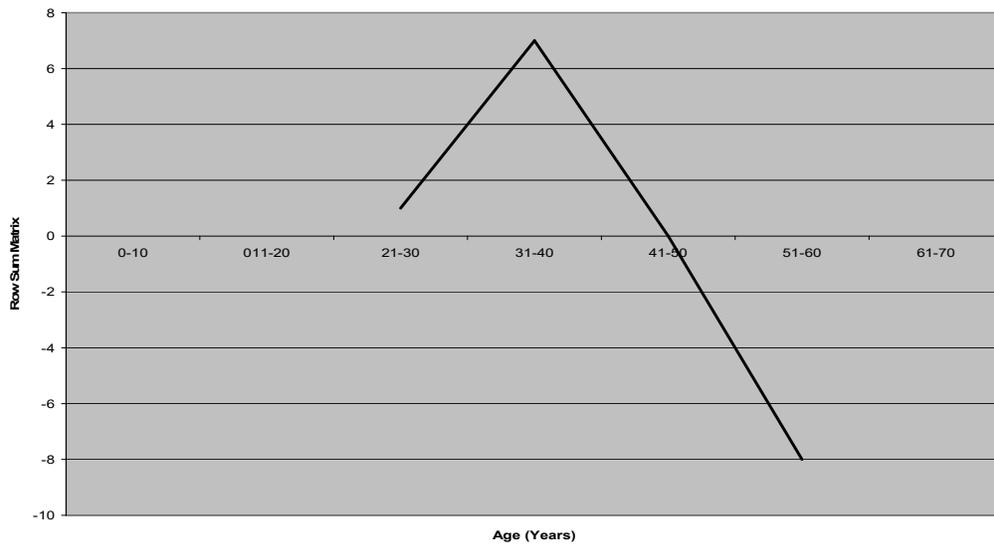


Graph-2

Let $\alpha = 0.8$ RTD Matrix is

Row Sum Matrix

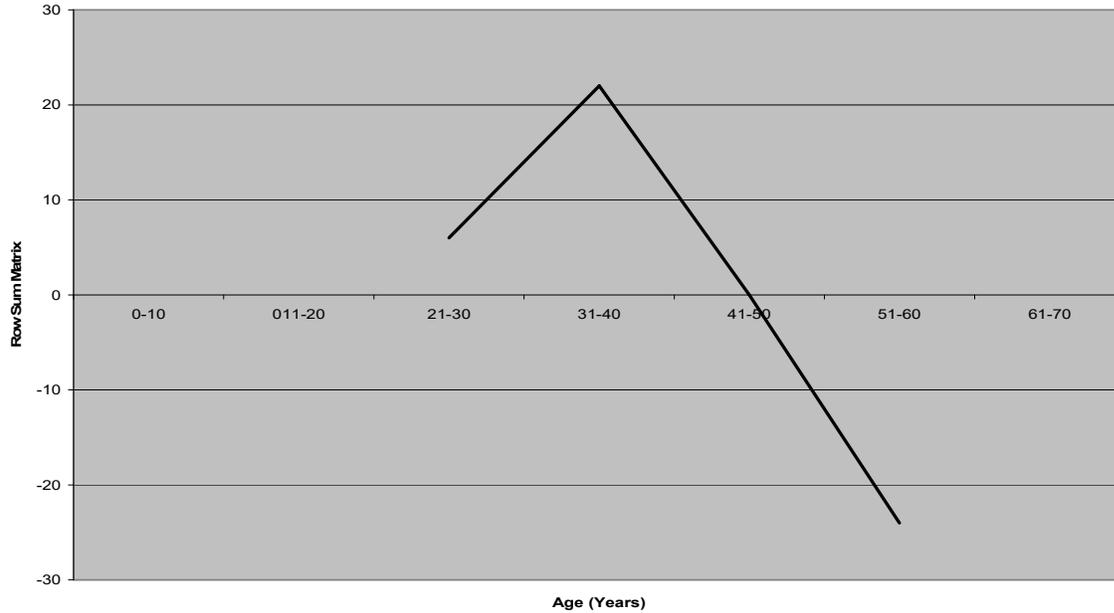
$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & +1 \\ +1 & +1 & +1 & +1 & +1 & +1 & +1 & 0 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix} \quad \begin{bmatrix} +1 \\ +7 \\ -8 \end{bmatrix}$$



Graph-3

The CETD and the row sum matrices are given below:

$$\text{CETD-Matrix} \begin{bmatrix} +1 & 0 & +1 & -1 & +2 & 0 & 0 & +3 \\ +3 & +3 & +3 & +3 & +3 & +3 & +3 & +1 \\ -3 & -3 & -3 & -3 & -3 & -3 & -3 & -3 \end{bmatrix} \text{Row Sum Matrix} \begin{bmatrix} +6 \\ +22 \\ -24 \end{bmatrix}$$



Graph-4

From the Graph (1-3), we observe that the maximum age group getting c.v. problem is 31-43 move precisely from 35-38. This result has no change by taking different parameters in [0,1]. The same result has been confirmed by combined effect time dependent data matrix also.

Maximum age group estimation, using 4 × 8 matrix

From above we see that the maximum age of the labors who get effected due to c.v. problem falls in 31-43.i.e.37 years approximately but this group is of 13 years, hence to make the study more sensitive. We see whether the decision arrived is more sensitive to the earlier one.

Table 2

S.No.	Symptoms→ Years↓	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	Total	Moving	average
1	20-30	2.3	18	24	16	23	10	16	10	140	} 122.6 } 123.3	} 122.95
2	31-36	17	16	19	20	17	10	20	5	134		
3	37-43	18	13	16	11	13	8	10	5	94		
4	44-65	22	21	21	22	20	11	20	5	142		

From moving average technique of time series analysis trend falls in s.no.2. thus the maximum age group falls in the range of 31-36.

Now let us analysis by ATD, RTD and CETD-matrices

ATD-matrix of C.V. problem of order 3 x 8 is

$$\begin{bmatrix} 2.09 & 1.64 & 2.18 & 1.46 & 2.09 & 0.91 & 1.46 & 0.91 \\ 2.83 & 2.66 & 3.16 & 3.34 & 2.83 & 1.67 & 3.34 & 0.83 \\ 2.57 & 1.85 & 2.28 & 1.57 & 1.85 & 1.14 & 1.42 & 0.83 \\ 1 & 0.95 & 0.95 & 1 & 0.91 & 0.50 & .91 & 0.23 \end{bmatrix}$$

Calculation of CETD-matrix at $\alpha = 0.2$ is

$$\begin{bmatrix} 2.09 & 1.64 & 2.18 & 1.46 & 2.09 & 0.91 & 1.46 & 0.91 \\ 2.83 & 2.66 & 3.16 & 3.34 & 2.83 & 1.67 & 3.34 & 0.83 \\ 2.57 & 1.85 & 2.28 & 1.57 & 1.85 & 1.14 & 1.42 & 0.83 \\ 1 & 0.95 & 0.95 & 1 & 0.91 & 0.50 & 0.91 & 0.23 \end{bmatrix}$$

8.49 7.10 8.57 7.37 7.68 4.22 7.13 2.80

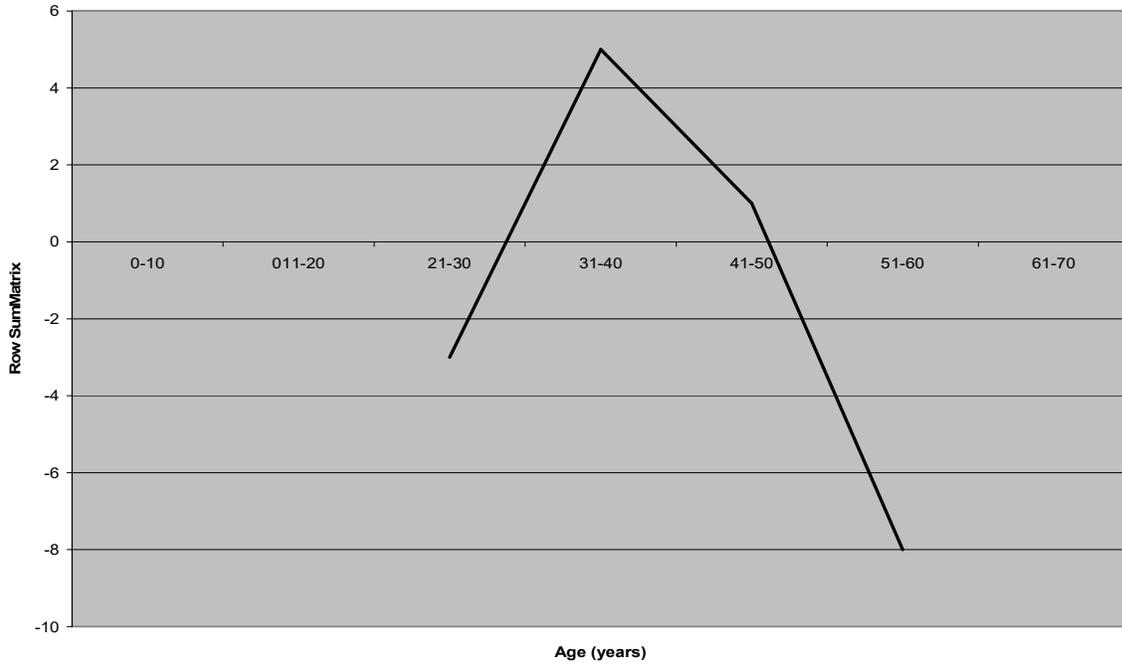
Average μ	2.120	1.775	2.14	1.84	1.920	1.055	1.780	0.70
M	0.58	0.48	0.60	0.75	0.54	0.25	0.78	0.24
$\alpha * M$	0.116	0.096	0.120	0.150	0.108	0.050	0.156	0.048
$\mu - \alpha * M$	2.004	1.769	2.020	1.690	1.812	1.005	1.624	0.652
$\mu + \alpha * M$	2.236	1.871	2.26	1.99	3.728	2.105	3.404	0.748

RTD matrix is

$$\begin{bmatrix} 0 & -1 & 0 & -1 & 0 & -1 & -1 & +1 \\ +1 & +1 & +1 & +1 & 0 & 0 & 0 & +1 \\ +1 & 0 & +1 & -1 & 0 & 0 & -1 & +1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix}$$

Row Sum Matrix

$$\begin{bmatrix} -3 \\ +5 \\ +1 \\ -8 \end{bmatrix}$$



Graph-5

Let $\alpha = 0.5$ then RTD Matrix will be calculated:

Following is ATD-matrix

$$\begin{bmatrix} 2.09 & 1.64 & 2.18 & 1.46 & 2.09 & 0.91 & 1.46 & 0.91 \\ 2.83 & 2.66 & 3.16 & 3.34 & 2.83 & 1.67 & 3.34 & 0.83 \\ 2.57 & 1.85 & 2.28 & 1.57 & 1.85 & 1.14 & 1.42 & 0.83 \\ 1 & 0.95 & 0.95 & 1 & 0.91 & 0.50 & 0.91 & 0.23 \end{bmatrix}$$

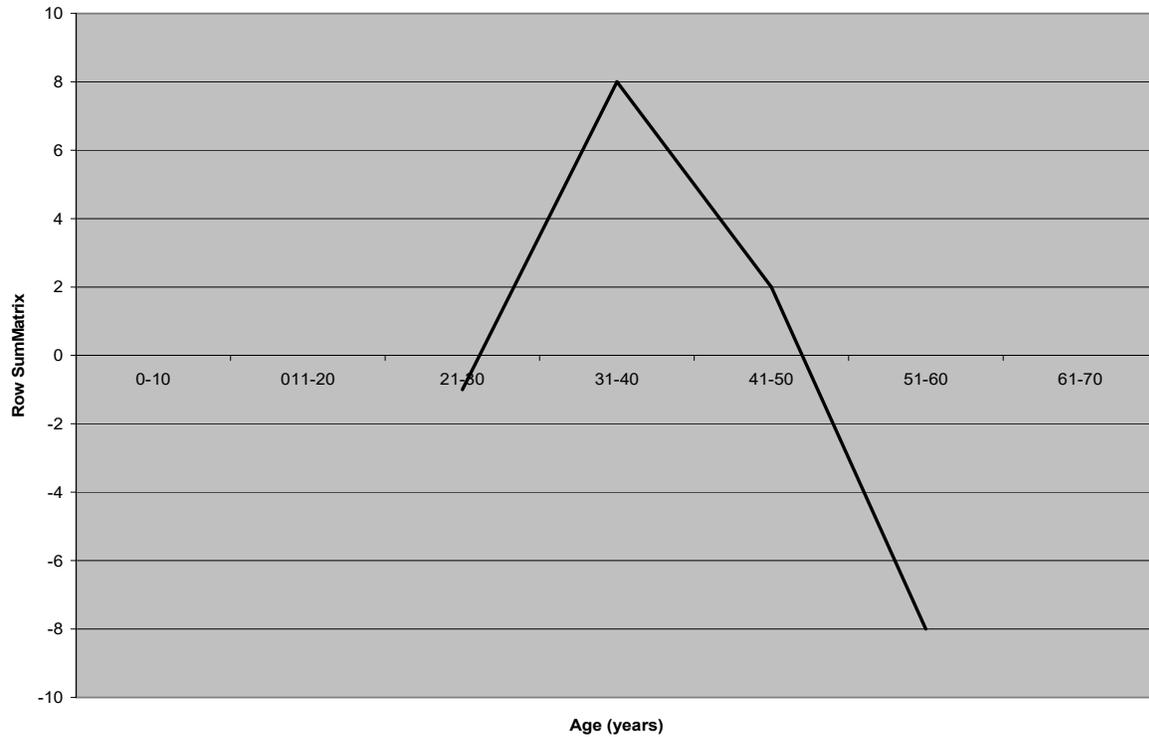
Average μ	2.120	1.775	2.14	1.84	1.920	1.055	1.780	0.70
M	0.58	0.48	0.60	0.75	0.54	0.25	0.78	0.24
αM	0.29	0.24	0.30	0.37	0.27	0.12	0.39	0.12
$\mu - \alpha M$	1.93	1.53	1.84	1.47	1.65	0.935	1.39	0.58
$\mu + \alpha M$	2.41	2.01	2.44	2.21	2.19	1.175	2.17	0.82

RTD Matrix is given by

$$\begin{bmatrix} 0 & 0 & 0 & -1 & 0 & -1 & 0 & +1 \\ +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & 0 & 0 & 0 & 0 & 0 & 0 & +1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix}$$

Row Sum Matrix

$$\begin{bmatrix} -1 \\ +8 \\ +2 \\ -8 \end{bmatrix}$$



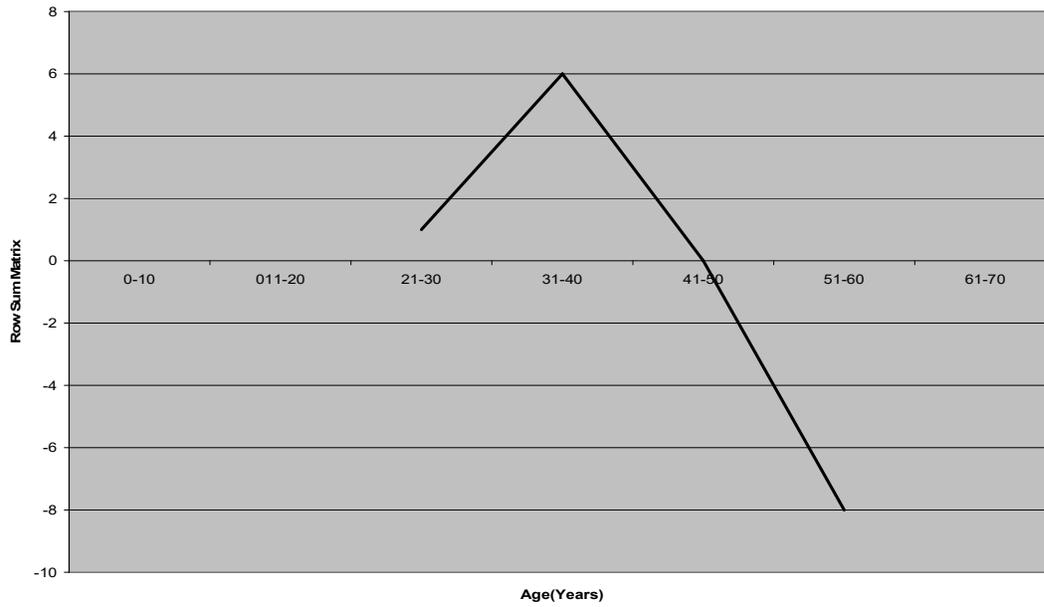
Graph-6

Let $\alpha = 0.8$ then RTD Matrix will be calculated:
Following is ATD-matrix

$$\begin{bmatrix} 2.09 & 1.64 & 2.18 & 1.46 & 2.09 & 0.91 & 1.46 & 0.91 \\ 2.83 & 2.66 & 3.16 & 3.34 & 2.83 & 1.67 & 3.34 & 0.83 \\ 2.57 & 1.85 & 2.28 & 1.57 & 1.85 & 1.14 & 1.42 & 0.83 \\ 1 & 0.95 & 0.95 & 1 & 0.91 & 0.50 & 0.91 & 0.23 \end{bmatrix}$$

Average μ	2.120	1.775	2.14	1.84	1.920	1.055	1.780	0.70
M	0.58	0.48	0.60	0.75	0.54	0.25	0.78	0.24
αM	0.466	0.384	0.480	0.600	0.432	0.200	0.624	0.192
$\mu - \alpha M$	1.654	1.391	1.660	1.240	1.488	0.855	1.156	0.508
$\mu + \alpha M$	2.586	2.159	3.620	2.440	2.352	1.255	2.404	0.892

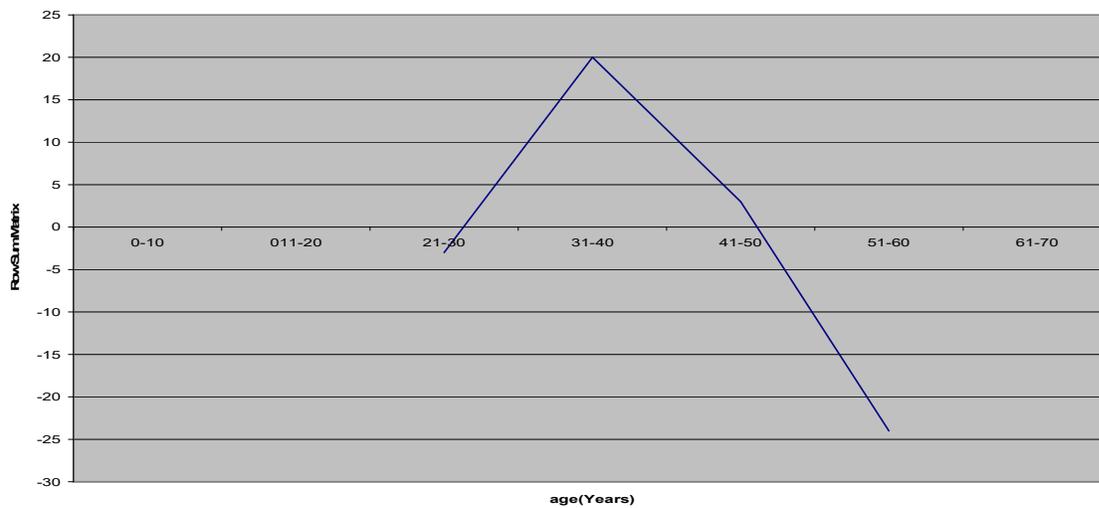
RTD Matrix is given by $\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & +1 \\ +1 & +1 & 0 & +1 & +1 & +1 & +1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix}$ Row Sum Matrix $\begin{bmatrix} +1 \\ +6 \\ 0 \\ -8 \end{bmatrix}$



Graph-7

Now CETD matrix for $\alpha = 0.2, 0.5$ and 0.8 is given by

$$\text{CETD-Matrix} \begin{bmatrix} 0 & -1 & 0 & -2 & 0 & -2 & -1 & +3 \\ +3 & +3 & +3 & +3 & +2 & +2 & +2 & +2 \\ +2 & 0 & +1 & -1 & 0 & 0 & -1 & +2 \\ -3 & -3 & -3 & -3 & -3 & -3 & -3 & -3 \end{bmatrix} \quad \text{Row Sum Matrix} \begin{bmatrix} -3 \\ +20 \\ +3 \\ -24 \end{bmatrix}$$



(Graph-8)

Conclusion

From the above graphs and CETD-matrix. We observe that

1. Cardio vascular problem starts at the age of 25
2. The maximum age for getting cardio-vascular problem is 31-36
3. The peak period for the heart problem is 33.5

Information Transmission- In the above we have collected a data of 500 laborers suffering due to eight symptoms S_1 to S_8 over 4 age groups vise 20-30, 31-36, 37-43, 44-65.call these age groups I,II ,III, IV. Thus we have two sets

$$X = \{S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8\} \text{ and } Y = \{I, II, III, IV\}$$

Now let us take the problem whether X and Y are interactive .In other words “Do the symptoms depend on age group” In order to solve this problem we can consider” Hartley Information for $\alpha =0.2$.Let us use RTD-matrix as the relation R on two sets. Notice that if $R(x, y) = 1$ for $x \in X, y \in Y$, then we say x does not constrain otherwise constrain. Then our RTD-matrix for $\alpha =0.2$

$$\begin{matrix}
 & S_1 & S_2 & S_3 & S_4 & S_5 & S_6 & S_7 & S_8 \\
 I & \left[\begin{array}{cccccccc}
 0 & -1 & 0 & -1 & 0 & -1 & -1 & +1 \\
 II & +1 & +1 & +1 & +1 & 0 & 0 & 0 & +1 \\
 III & +1 & 0 & +1 & -1 & 0 & 0 & -1 & +1 \\
 IV & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1
 \end{array} \right]
 \end{matrix}$$

Thus we see that I and S_8 does not constrain, however I constrain with all rest symptoms. II does not constrain with S_1, S_2, S_3, S_4 and S_8 .III does not constrain with S_1, S_3 and S_8 and finally IV constrain with all.

Apply Hartley information we have:

$$\begin{aligned}
 I(x) &= \log_2|x| &= \log_2 8 &= 3\log_2 2 = 3 \\
 I(y) &= \log_2|y| &= \log_2 4 &= 2\log_2 2 = 2 \\
 I(x,y) &= \log_2|R| &= \log_2 9 &= \frac{\log_{10} 9}{\log_{10} 2} = \frac{0.95}{0.30} = 3.16 \\
 I(x/y) &= I(x,y) - I(y) = 3.18 - 2 = 1.18 \\
 I(y/x) &= I(x,y) - I(x) = 3.16 - 3 = 0.16 \\
 I(x,y) &= I(x) + I(y) - I(x,y) = 5 - 3.16 = 1.84 > 0
 \end{aligned}$$

Thus the information transmission is $1.84 > 0$, which implies that the sets X and Y are interactive

Shanon Entropy -Let $X = \{S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8\}$, where S_i are the symptoms stated above

Let the above table (2) be written as :

Table. 3

Symptoms	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	Total
Frequency	80	68	80	69	73	39	66	25	500

Table (3) express the frequencies for the different symptoms $p_i = \frac{f_i}{500}$, where

f_i is frequency of S_i then

$$p_1 = \frac{80}{500} = 0.16, \quad p_2 = \frac{68}{500} = 0.14, \quad p_3 = \frac{80}{500} = 0.16, \quad p_4 = \frac{69}{500} = 0.14$$

$$p_5 = \frac{73}{500} = 0.146, \quad p_6 = 0.08, \quad p_7 = \frac{66}{500} = 0.13, \quad p_8 = 0.02$$

Shanon entropy $H(x) = H\{p(x) | x \in X\}$

$$= - \sum_{x \in X} p(x) \log_2 p(x)$$

$$= - \sum_{i=1}^8 p_i \log_2 p_i$$

$$= -0.14 \log_2 0.16 - 0.14 \log_2 0.14 - 0.16 \log_2 0.16$$

$$- 0.14 \log_2 0.14 - 0.17 \log_2 0.17 - 0.08 \log_2 0.08$$

$$- 0.13 \log_2 0.13 - 0.05 \log_2 0.05 = 2.86$$

Since shanon entropy is a measure of uncertainty and information thus we have in this case find that the measure uncertainty and information that a worker has a particular symptomd is 2.86

Let us consider another set (as given in section (5))

$$Y = \{I, II, III, IV\}$$

Table 2, be re-written as

S.No.	1	2	3	4	5
Age group	I	II	III	IV	Total
Frequency	140	134	94	142	500

Let q_i be the probability of s.n. 'i', then

$$q_1 = \frac{140}{500} = 0.28, \quad q_2 = \frac{134}{500} = 0.27, \quad q_3 = \frac{94}{500} = 0.19$$

$$q_4 = \frac{142}{500} = 0.26$$

Then Shanon entropy = 1.91

Conclusion

In the above we have collected a data of different symptoms of health problem for different ages of workers serving before the furnace from dawn to late evening. the effect of heat, coal gasses, and lead

oxide etc. they are facing cardio vascular symptoms in different ages, Upto section (4) we have seen that they are going to be heart patient at the age of 33.5 and onwards. Following is the quarry which is solved in section 5 and 6. Is the data under consideration is non specific, In other words what is the degree of uncertainly?

To answer this question we have applied the theory of Hartley Information and have calculated Shanon entropy for the sets X and Y separately.

From the above i.e. from section (5) it is clear that Information transmission calculated by Hartley information theory is $1.84 > 0$, which says that the data in sets X and Y are interactive.

The degree of non specificity of X and and jointly X x Y are 3, 2, 3.16 respectively, which says that symptoms collected in different age groups are not certain they may increase or decrease. Next in section-6 we have calculated the probability of happening of each symptoms i.e. probability of member of X and next we have calculated the happening of labourer in certain age group i.e. we have calculated probability of members of Y. the shanon entropy for X and Y separately comes out to be 2.86 and 1.91 respectively both are > 0 . This confirms the uncertainty informed by Hartley.

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