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Curve Estimation Methods for Forecasting Infant Mortality Rates in Tamil Nadu

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Abstract
Child mortality rates are crucial statistics that portray a country's level of socio-economic development. In a global scenario, India accounts for thirty-three percent of child deaths, yearly. The chief reasons attributed to this being ineffective neonatal care, inadequate breastfeeding, undernourishment, minimal endurance and life-threatening occurrence of infectious diseases. Thus, there is a need to study the regional and state-wise analysis of the causes of under-5 deaths and to find factors such as socio-economic developments and health services which directly or indirectly influences in reducing the child mortality rate. The main objective of the paper is to examine the infant mortality rate trend lines for rural and urban areas of Tamil Nadu and try to forecast these rates for the next decade.

Keywords: *Child mortality rates, infant mortality rates, trend lines, rural, urban, line of best fit, forecast*

1. Introduction

An important statistic to keeps a tab on a country's level of social–economic development is best gauged by its child mortality rates. Its decline, therefore, is of utmost importance as it is linked to an improvement in overall living standards. Worldwide, India accounts for thirty-three percent of child deaths annually, i.e. about 2.1 million children in India die in the age group 0-5 years; half of these children die within the first four weeks thus accounting for about one-fourth of global infant deaths. Among the many reasons mentioned for this impoverished state of infant and child health in India are inadequate neonatal care, insufficient breastfeeding, malnutrition, low resistance and life-threatening occurrence of communicable diseases.

The Perinatal Mortality Rate (PMR) of India (2013) is 26 per 1000 births. In urban areas, it is 16 per 1000 births while in rural areas it is 28 per 1000 births. The PMR is not even across states, for e.g. in Kerala the PMR is no more than 9 per 1000 births, whereas for Odisha it is at 35 per 1000 births. The Neo-natal Mortality Rate (NMR) in India is also amongst the maximum in the globe and is skewed towards Rural India. As per Feb 2018 report, the NMR for India stands at 25.4 per 1000 births with greater mortality for girls than boys. In the 46th position, India has an Infant Mortality Rate (IMR) of 38 per 1000 births.

As per the latest government data released on May 30, 2019, India's IMR has reduced by 42% in the last decade alone from 57 per 1,000 births in 2006 to 33 in 2017. Child Mortality Rates (CMR) encompass both neonatal mortality and infant mortality. According to WHO the CMR for India is 39.4 per 1000 births.

To improve the survival rate of children under-5 in the state, and hence the country, there is a need to study the regional and state-wise analysis of the causes of under-5 deaths and to find factors such as socio-economic developments and health services which directly or indirectly influences in reducing the child mortality rate.

The major influencing factors of newborn and child wellbeing can be broadly classified into five major categories,

1. *Demographic factors*, like maternal age, child sex, birth order, and birth interval.
2. *Socio-economic factors*, for instance, mother's education, household conditions.
3. *Environmental sanitation and hygiene factors*, which consist of availability of safe drinking water, housing condition, toilet facility and source of fuel and lighting.
4. *Nutrient availability factors*, which include calorie intake of the mother, breastfeeding and other practices.
5. *Medical care factors*, such as prenatal care of mothers including immunization against tetanus during pregnancy,

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postnatal care including immunization of children against OPT, BCG and polio and treatment-seeking behavior.
With a vision to address the above-mentioned factors, the following nutrition supplementation programs have been implemented in India

- *Integrated Child Development Services Scheme (ICDS)*; for children in the age group 0-6 years, expecting and lactating mothers, and women in the age group 15-44 years.
- *Mid-day meal Programs (MDM)*; for children attending primary school. Priority is given to children belonging to backward classes, scheduled caste, and scheduled tribe families.
- *Special Nutrition Programs (SNP)*; for pre-school children, and expectant and lactating mothers of impoverished groups in urban slums and tribal areas. To provide additional nourishment and health care facilities including the supply of vitamin A solution and iron and folic acid tablets.
- *Wheat Based Nutrition Programs (WNP)*; for children in the age group 0-3 years and nursing and expectant mothers in areas with high infant mortality such as urban slums and backward rural areas.
- *Applied Nutrition Programs (ANP)*; for children aged between 3-6 years, expectant and lactating mothers, to make people aware of their nutritive needs and to provide additional nourishment.
- *Balwadi Nutrition Programs (BNP)*; for children between the age of 3-5 years, to provide for the calorie and protein requirements.
- *National Nutritional Anemia Prophylaxis Program (NNAPP)*; for children in the 1-5 age group, expectant and lactating mothers, female acceptors of life-threatening methods of family planning and IUDs.

The main objective of the paper is to examine the infant mortality rate trend lines for rural and urban areas of Tamil Nadu and try to forecast these rates for the next decade.

2. Literature Review

Of the 12716 consecutive births, studied by Ramesh K. Puri, et.al., (1981), for over a decade it was observed that perinatal mortality rates were 80.7, which comprised 41.4 of the stillbirth rates and 39.3 of an early neonatal death rate. Notably, PMR showed a significant correlation with factors such as preceding pregnancy wastages, obstetrical complications, critical infection, and persistent illnesses during pregnancy. The notion of an indirect relationship between infant death rates and socioeconomic status was clearly supported by the study conducted by Michael R. Rip, et.al., (1987). Overall it was observed that the post-neonatal mortality rates were four or five times higher for the most socially disadvantaged areas when compared with that in the higher socio-economic suburbs. A surveying study, piloted by Sashimi, et.al., (1989) among the populations of Consanguineous marriages revealed a highly significant relationship between mortality reported in neonatal, postnatal and childhood periods and inbreeding. The drive of this study steered by Nasra M. Shah, et.al., (2000)was to inspect whether socio-economic factors such as parents education, occupation and income had an impact on the perinatal mortality after regulating for maternal factors such as age and reproductive history and natural variables such as birth weight and span of gestation. Globally, newborn mortality accounts for almost forty percent of 0-5 year's mortality. Christiana R. Titaley, et.al., (2008) conducted a study on a five-year sample of birth data from 1997 to 2002 that was designed to identify the factors of newborn mortality in Indonesia. An exhaustive study to determine whether for a poor country with inadequate resources and access to health care could lessen neonatal mortality rates by training traditional midwives to cope up with numerous common perinatal conditions was carried out by Christopher J. Gili, et.al., (2010). A study by Surekha Tayade, et.al., (2012),was carried out to analyze the risk aspects associated with perinatal mortality and to determine the most common causes of early neonatal deaths. The prospective clinical study by Manisha Behal, et.al., (2015),was designed to get an insight on maternal risk factors associated with perinatal mortality. During the period of this study, among the 8202 deliveries done, 678 had perinatal deaths. From this study, it was revealed that the maternal risk factors comprising of pre-eclampsia, eclampsia and obstructed labor significantly increased perinatal mortality. In a developing country like Nigeria, the mortality rate of neonatal tetanus (NNT) is always high. The objective of the study by Shafique Sani Nass, et.al., (2017), was to evaluate the degree of association between selected NNT risk factors, the number of maternal tetanus toxoid injections, frequency of antenatal visits, place of delivery and cord care with newborn mortality as the consequence variable..

3. Methodology

Perinatal death means a fetal death (stillbirth) or an early neonatal death. Fetal death or stillbirth is the death of a fetus weighing 500g or more or of 22-weeks' gestation or more if weight is unavailable. An early neonatal death (END) is the death of a live newborn in the first week of life.
Perinatal Mortality Rate (PMR)is defined as the number of perinatal deaths per thousand live births during the year.
PMR is a crucial outcome pointer for newborn care and directly reflects prenatal, intrapartum, and newborn care.
Neonatal Mortality Rate (NMR) is defined as the number of infant deaths of less than 29 days per thousand live births during the year.
Postnatal Mortality Rate is the number of newborns dying between 29 and 364 days of age per thousand live births during the year.
Infant Mortality Rate is the number of newborns dying before one year of age per thousand live births during the year.

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Child Mortality Rate is an under-5 mortality rate and denotes the probability per thousand that a newborn baby will die before attaining age five.
Curve fitting is having a group of data points and creating a curve that passes through (or very near) these points. That curve can be used to evaluate the values of the points. This can be done either by interpolation or extrapolation.
Quantitative forecasting is a guess of unclear future events (factually, to "cast forward" by extrapolating from the former and recent data). It is the process of making predictions of future based on past and present data and most frequently by analysis of trends. It uses explicit mathematical models and statistical methods to a time series, cross-sectional or longitudinal data.

4. Statistical Analysis and Its Interpretation

4.1. Section 1

In this section the various child mortality rates, in the southern states of India namely Tamil Nadu, Kerala, Karnataka, and Andhra Pradesh are compared alongside that of India. As per Registrar General of India, Sample Registration System (SRS) 2013, the different mortality rates are as shown in table 1

Table 1: State wise Mortality Rates, SRS 2013

State	Child Mortality Rate			Infant Mortality Rate			Neonatal Mortality Rate		
	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban
India	49	55	29	40	44	27	28	31	15
Andhra Pradesh	41	46	29	39	44	29	25	31	10
Karnataka	35	38	28	31	34	24	22	27	12
Tamil Nadu	23	26	17	21	24	17	15	18	11
Kerala	12	13	9	12	13	9	6	7	3

On comparing the child mortality rate of India and the southern states of India, observe that Kerala has the least CMR with a total of 12 per 1000 births whereas Andhra Pradesh has a total CMR of 41 equivalent to that of the country that has the total CMR as 49 per 1000 births. Likewise, IMR for the state of Kerala is the least with a total of 12 per 1000 births whereas Andhra Pradesh has a total IMR of 39 almost at par with that of the country which has IMR as 40 per 1000 births. Also, from the above table, observe that the IMR and CMR are very closely associated. So, if IMR of a given region could be reduced, then eventually the CMR too of that region would reduce drastically. Consistently the NMR for the state of Kerala is the least with a total of 6 per 1000 births, a very positive and good sign indicating improved health care system, whereas Andhra Pradesh has a total NMR of 25 almost in par with that of the country which has NMR as 28 per 1000 births. On comparing the data of IMR with that NMR, observe that NMR is accountable for almost 64%, 71%, 71% and 50% of IMR in the states of Andhra Pradesh, Karnataka, Tamil Nadu, and Kerala respectively. So, in order to reduce the IMR of a given region, it is crucial to diminish its NMR.
Correspondingly, on studying the trend lines for the IMR from 2000 to 2016, observe that these rates are steadily decreasing as shown in figure 1

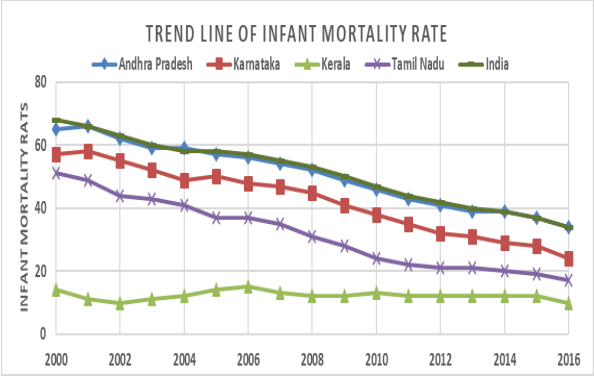

Figure 1: Trendlines for IMR in the new millennium in the southern states of India and the Indian subcontinent

From figure1, observe that the trend line for India and Andhra Pradesh are almost overlapping. In the year 2000, the IMR for India was 68 per 1000 births which reduced by exactly half to that of 34 per 1000 births by the year 2016. Andhra Pradesh shows similar statistics. For Kerala the IMR is almost uniformly distributed in the range 10 - 15 during this period, implying that it has attained its stability. The IMR for Karnataka reduced smoothly from 57 per 1000 births in 2000 to 24 per 1000 births in 2016. It is indeed worthy to note that for Tamil Nadu the IMR had a steady decrease from 51 per 1000 births in 2000 to 17 per 1000 births in 2016.

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4.2. Section 2

In this section, the trendlines for child mortality rates; namely perinatal, neonatal and postnatal are studied for the state of Tamil Nadu both in the urban and rural areas from the year 1971 to 2013.

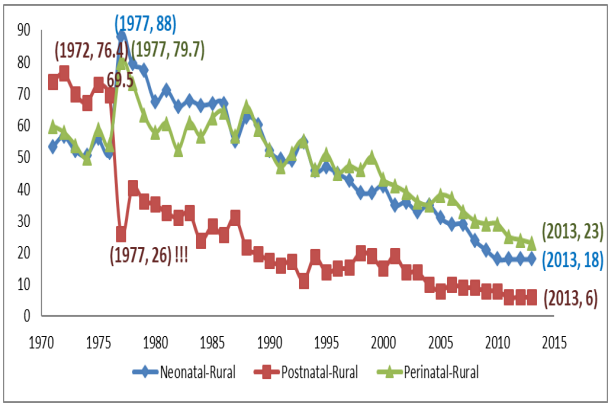

Figure 2: Trend lines for Rural Tamil Nadu from 1971 to 2013

It can be observed from figure 2, that in the year 1977 the postnatal mortality reduced drastically to 26 per 1000 births from a previous high of 69.5 per 1000 births in 1976. In 1978 it again increased marginally to 40 per 1000 births but from then on it has been gradually decreasing with minor fluctuations. Equally surprising is the jump in the neonatal and perinatal mortality rates by almost 30 per 1000 births from the year 1976 to the year 1977. Can it be attributed to better reporting of these cases or are there any other factors that attributed to this jump needs to be studied. The trend lines clearly depict that it took almost 20 years or more for the neonatal and perinatal mortality rates to show the pattern that existed prior to 1977. From the year 1998 onwards, these rates too are gradually reducing although at a slower rate.

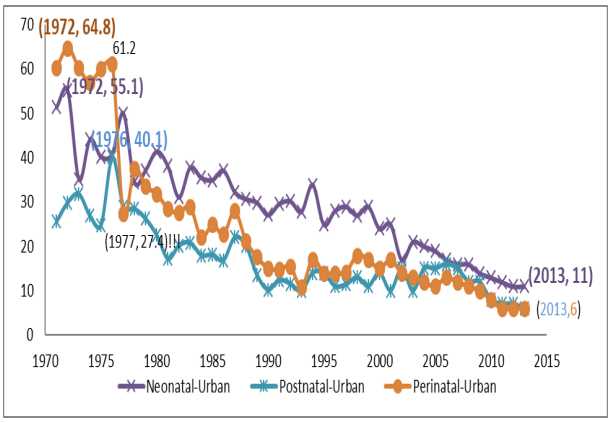

Figure 3: Trendlines for Urban Tamil Nadu from 1971 to 2013

From figure 3, it can be observed that in the year 1977 the perinatal mortality reduced drastically to 27.4 per 1000 births from a previous high of 61.2 per 1000 births in 1976. In 1978 it again increased marginally to 37.6 per 1000 births but from then on, it's gradually decreasing with minor fluctuations. The postnatal mortality rate for the urban area is uniformly distributed between the ranges of 10 to 20 per 1000 births for the period 1990 -2013 with slight fluctuations. Similarly, the neonatal mortality rate is also gradually reducing.

With the above information, an attempt is made to predict the mortality rates for Tamil Nadu both for the urban and rural areas for the next decade.

4.3. Section 3

In the previous section it was noticed that, the trend lines plotted for the period 1971-2013 had high fluctuations in the initial two decades, but by the dawn of the new millennium, these trends were gradually decreasing and attained some sort of stable pattern. Therefore, to forecast the mortality rates, data from 1990 till 2013has been used. Figure 4 shows the trend lines for the rural and urban areas of Tamil Nadu from 1990-2013

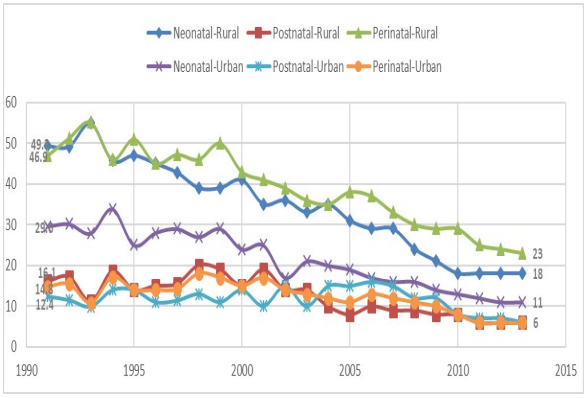

Figure 4: Trend lines for rural and urban Tamil Nadu from 1990-2013

From figure 4, observe that the mortality rates reduced significantly from the year 1990 to the year 2013 and is summarized in the table 2

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Table 2: Infant Mortality Rates- Rural vs Urban

	Mortality Rates	1990	2013	% decrease
Rural	Perinatal	46.9	23	50.95
	Neonatal	49.3	18	63.48
	Postnatal	16.1	6	62.73
Urban	Perinatal	14.8	6	59.45
	Neonatal	29.6	11	62.86
	Postnatal	12.4	6	51.61

In table 2, on comparing the different infant mortality rates in rural and urban areas of Tamil Nadu for the year 1990 with that of the year 2013,observe that these rates have reduced considerably by more than 50%.
Figures 5, 6 and 7 depict the trendline for perinatal, neonatal and postnatal mortality rates respectively for both the rural and urban areas of Tamil Nadu. The equation of best fit and the corresponding R^2 values are also represented for each of the mortality rates.

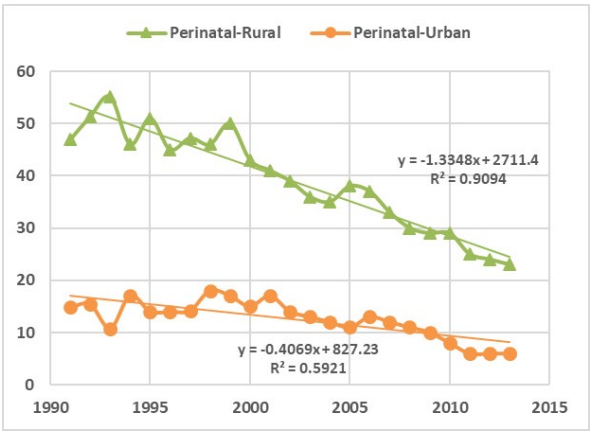

Figure 5: Perinatal mortality rates for rural and urban areas.

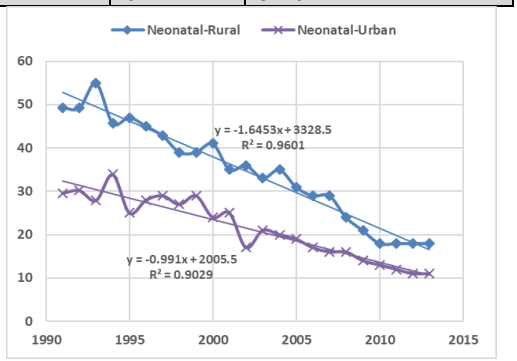

Figure 6: Neonatal mortality rates for rural and urban areas

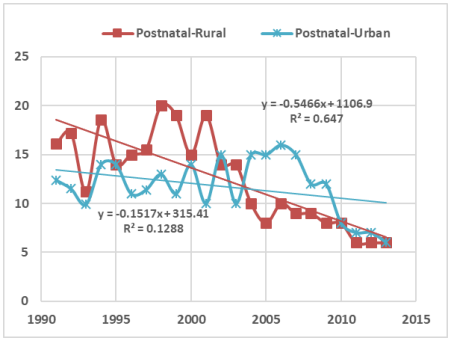

Figure 7: Postnatal mortality rates for rural and urban areas

As observed in Figures 5, 6 and 7, Linear Fit is the line of best fit for perinatal, neonatal and postnatal mortality rates. The equation of best fit and the corresponding R^2 value is summarized in table 3.

Table 3: Linear equation of best fit and R^2 values

Mortality Rates		Equation of best fit	R^2 value
Perinatal	Rural	2711.4 - 1.3348*X	0.9094
	Urban	827.23 - 0.4069*X	0.5921
Neonatal	Rural	3328.5 – 1.6453*X	0.9601
	Urban	2005.5 – 0.991*X	0.9029
Postnatal	Rural	1106.9 – 0.5499*X	0.647
	Urban	315.41 – 0.1517*X	0.1288

The linear equation of best fit was further validated by carrying out the chi-square test for goodness of fit, for the observed and expected data from 2000-2013. For both the rural and urban areas the hypothesis was accepted.

Using these equations of best fit the mortality rates are forecasted as shown in table 4. It provides a bird's eye view of the forecasted prenatal, neonatal and postnatal mortality rates for the rural and urban areas of Tamil Nadu for a decade.

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Table 4: Forecasted Infant Mortality Rates using Linear equation of best fit

Year	Perinatal		Neonatal		Postnatal	
	Rural	Urban	Rural	Urban	Rural	Urban
2014	23.1	7.7	14.9	9.6	6.0	9.9
2015	21.8	7.3	13.2	8.6	5.5	9.7
2016	20.4	6.9	11.6	7.6	5.0	9.6
2017	19.1	6.5	9.9	6.7	4.4	9.4
2018	17.8	6.1	8.3	5.7	3.9	9.3
2019	16.4	5.7	6.6	4.7	3.3	9.1
2020	15.1	5.3	5.0	3.7	2.8	9.0
2021	13.8	4.9	3.3	2.7	2.2	8.8
2022	12.4	4.5	1.7	1.7	1.7	8.7
2023	11.1	4.1	0.1	0.7	1.1	8.5

5. Conclusion

- On comparing the child mortality rates of India and the southern states of India it is observed that higher the level of social-economic development of a given region, lower are the incidences of Child Mortality Rates. This fact is evident from the analysis of table 1 and from the trendlines plotted in figure 1.
- On comparing the trendlines for the new millennium plotted in figure 4 and from table 2, the awareness programs on health and nutrition initiated by the government has helped to decrease the mortality rates drastically in the rural as well as urban areas of Tamil Nadu.
- From the equation of best fit illustrated in figures 5, 6 and 7 and summarized in table 3, the R^2 value obtained is above 90% in three cases and around 60-65% in two cases implying that the linear fit is significantly good.
- One interesting observation with the trend line obtained in figure 7 is that, the postnatal mortality for the Rural area was below that of the Urban area!!!, and this trend is evidently distinct for the period 2004 - 2010.

o From 1990 - 2009 the postnatal mortality rates for the urban area was below the rural area and was fluctuating between 10 to 15 per 1000 births.

o But for the last 4 years of the observed data from 2010 to 2013, it was 8, 7, 7 and 6 per 1000 births respectively

o Globally it is observed that the rural mortality rate is always higher than the urban mortality rates, but in this case, it's reversed!

- An in-depth study is required to have a better understanding of the fluctuations in the data.

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