



# Estimating Maternal Mortality Ratio for the Districts of Tamil Nadu Using a State Based Regression Model

Dr.B.Viswanathan,M.Sc;M.A;Ph.D.

Director,

Tamil Nadu State Statistical Training Institute,

Directorate of Economics and Statistics, Chennai.6,

E-mail:viswanaath2012@gmail.com, Cell No.9840860467

## Abstract

**Background & Objectives:** So far, no study or survey has been conducted to estimate Maternal Mortality Ratio (MMR) at the district level due to huge operating costs and the requirement of large sample sizes as the maternal deaths are being rare events to capture. In this paper, an attempt is made to provide precise, cost effective and timely estimates of MMR at the district level for the State of Tamil Nadu through a State based regression model.

The primary objective of this study is to estimate MMR at the district level for the State of Tamil Nadu at three different time points, viz.2001, 2011, and 2017 and compare the levels of MMR over the time periods and identify the districts which have achieved Sustainable Development Goal (SDG) target of less than 70 per 100,000 live births and hotspot districts which require urgent attention.

**Material &Methods:** Data on MMR at the State level published by the Sample Registration System by the Office of the Registrar General of India is regressed on two data elements, viz. General Fertility Rate (GFR) and Crude Death Rate for Women (CDRW) aged 14-49 at three time points, viz.2001, 2011, and 2017 and constructed three regression models. District level estimates of MMR were generated based on the regression models using the district level GFR and CDRW data which were easily calculated from Population Censuses 2001 and 2011 and the age specific fertility and mortality rates published by the SRS.

**Results:** The precision level of MMR estimates predicted for the districts are higher as the relative standard errors are almost less than 10% for all the districts and the high predictability ( $R^2$ ) of the regression models. It was identified that already 14 districts in Tamil Nadu have achieved sustainable development goal target of less than 70 per 100,000 live births and another 15 districts are on the threshold of reaching the goal soon. Sustained efforts are essential in the remaining 3 districts to accomplish SDG target.

**Interpretation & Conclusion:** The State based regression model provides a precise, cost effective and timely estimate for all the districts. It requires data only on GFR and CDRW for the districts. Hence, it becomes easier to generate district level estimates, once the state level data on MMR is released by the SRS. The regression models developed has high accuracy and able to identify the hotspot districts which require urgent attention. Even though the State of Tamil Nadu has achieved the SDG target, it is learnt that only 14 districts in Tamil Nadu have achieved the SDG target and sustained efforts are required in the remaining 18 districts to achieve the same on time.

**Key Words:** Maternal Mortality Ratio, Sustainable Development Goal, GFR, CDRW

## Introduction

Maternal mortality is a vital indicator of effective clinical health services to the masses, and in fact one of the important indices to assess the country's progress. India's maternal mortality rate is high and accounts for 12 percent of global deaths occurring due to preventable causes related to pregnancy and childbirth<sup>1</sup>. Due to the continuous efforts and interventions such as implementation of schemes such as Janani Suraksha Yojana, the Indira Gandhi Matritva Sahayog Yojana, Dr.Muthulakshmi Reddy Maternity Assistance scheme in Tamil Nadu, conditional cash transfer schemes for improving the care during pregnancy and promoting institutional deliveries, the Maternal Mortality Ratio (MMR) has dropped from

314 deaths per 100,000 live births in 2001 to 122 deaths in 2015-17<sup>2</sup>. But the fall in MMR is not sufficient to achieve the Sustainable Development Goal(SDG) target of 70 deaths per 1,00,000 live births, and only three states-Kerala, Maharashtra and Tamil Nadu have been able to achieve the goals so far.

The maternal mortality ratio is the number of women who die from any cause related to pregnancy and childbirth within 42 days of termination of pregnancy, per 100,000 live births. There are various approaches for measuring maternal mortality like Civil Registration System (CRS), household surveys, census, Reproductive Age Mortality Studies (RAMOS), etc. In India, the Office of the Registrar General of India (ORGI) under the Ministry of Home Affairs, Government of India, provides estimates of Maternal Mortality Ratio (MMR) using demographic data collected through the Sample Registration System (SRS) only at the State level. As the maternal deaths are being rare events, it requires prohibitively large sample sizes to provide accurate estimates. In order to enhance the SRS sample size, the MMR estimates are derived by pooling 3 years data to yield reliable estimates of MMR.

Thus, at the state level we have good information on these estimates. However, at the district level, there is no data about the levels and differentials of MMR. If district level estimates are to be developed, the sample size will have to increase massively. This is an inherent limitation of sample registration system<sup>3</sup>. Precise district level estimates are vital for setting priorities, allocating resources and targeting areas where maternal mortality is high. In India, there is large inter district variation in the level of socio economic development among districts within a state. With decentralized planning, it has become inevitable to plan at the district level. Hence, the need for data on critical indicators like MMR is manifold at the district level. As of date, no survey provides estimates of critical indicators on fertility and mortality at the district level. Even the Annual Health Surveys conducted in 2010-11, 2011-12 and 2012-13 by the Registrar General of India in 9 states have published MMR at the administration level (group of districts) only<sup>4</sup>. Hence, there is a need for generating timely and precise estimates at the district level for decision making in the health sector. In this paper, an attempt is made to provide estimates of MMR at the district level for the State of Tamil Nadu through a regression model using State level data for three different time points, viz. 2001, 2011 and 2017 and examined the progress over the period from 2001 to 2017 in reducing the MMR.

## 1.0 Trends in Reduction of MMR in India

Overall, India has made significant progress in reducing MMR from 327 during 1999-01 to 122 in 2015-17<sup>5</sup>. Among the major States, Kerala, continues to be at the top in reducing MMR with a 72 percentage fall during 1999 -2017, whereas in Assam, percentage fall is only 42 points which clearly shows that unless sustained efforts are taken by all stakeholders, achieving SDG target by 2030 in states like Bihar (165), Madhya Pradesh (188), Chhattisgarh (141), Orissa (168), Rajasthan (186), Uttar Pradesh (216) and Assam (229) is very challenging. Eight other states, viz. Andhra Pradesh, Telengana, Jharkhand, Uttarakhand, Gujarat, West Bengal, Karnataka and Haryana have made remarkable achievement in reducing the MMR and are on the verge of reaching the SDG target soon. Tamil Nadu, Kerala and Maharashtra are the other states have already achieved the SDG target.

Table-1  
MMR –India and States

States	1999-01	2001-03	2010-12	2015-17	Percentage Reduction during 1999-2017
India	327	301	178	122	63
Kerala	149	110	66	42	72
Maharashtra	169	149	87	55	67
Tamil Nadu	167	134	90	63	62
Andhra Pradesh	220	195	110	74	66
Gujrat	202	172	122	87	57
West Bengal	218	218	117	94	57
Karnataka	266	228	144	97	64
Haryana	176	162	146	98	44
Punjab	177	178	155	122	31
Bihar	400	371	219	165	59
Odisha	427	358	235	168	61
Rajasthan	501	445	255	186	63
Madhya Pradesh	407	379	230	188	54
Uttar Pradesh	537	517	292	216	60
Jharkhand	N.A.	N.A.	N.A.	76	-

Chattisgarh	N.A.	N.A.	N.A.	141	-
Uttarakhand	N.A.	N.A.	N.A.	89	-
Telangana	N.A.	N.A.	N.A.	76	-
Assam	398	490	328	229	42

Note: N.A. – Not Available

## 2.0 Objectives:

Maternal Mortality, not only captures the reproductive health status of women, but also provides an opportunity to know the rich and adequacy of maternal health services provided to women. Reliable direct estimates at the state level are being published by SRS for major states of India. Hence, an attempt is made to estimate MMR at district level for the State of Tamil Nadu using a regression model based on state level data published by the SRS and censuses of 2001 and 2011 and also to assess the progress made in this regard by the districts in Tamil Nadu for the period from 2001 to 2017. However, before describing the details of the data and methods, a brief review of the available direct and indirect methods of estimation of MMR, along with their shortcomings, is given below.

## 3.0 Review of Methods

Precise estimates of maternal mortality are very tough to estimate in a population as it is challenging to identify maternal deaths exactly, especially where routine recording of deaths is not complete within the Civil Registration systems. In countries, where civil registration of deaths is in place, maternal deaths may be missed due to misclassification<sup>4</sup>.

### Institutional Records

Maternal deaths recorded in hospitals can provide estimates of MMR in countries where almost all maternal deaths take place in the hospitals or where all women are brought into hospital soon after death outside the hospital. But, in economically poor countries, where home deliveries are substantial, institution based studies cannot provide precise estimates of MMR. Hence, institution based MMR can only be used at the institution level to observe trends over time and helpful to classify deaths as maternal deaths or not.

### Census and population or household surveys

Census data provide a comprehensive view of the populations and provide estimates with shorter confidence intervals due to the large sample sizes. But, censuses are normally conducted once in 10 years and records pregnancy-related deaths only. Moreover, if early pregnancy deaths are under-reported, maternal mortality can be over-estimated where death was incidental and not due to the pregnancy.

### Sisterhood methods

Under sisterhood methods<sup>6</sup> (Direct and Indirect), information is collected on large number of women of reproductive age where queries raised about the deaths of adult sisters, but both these methods suffer due to the fact that the respondent sisters unable to distinguish between maternal and non-maternal deaths with certainty and have wide margins of error. Hence, sisterhood studies cannot be used to monitor changes in maternal mortality and WHO recommended these methods only for countries where no other reliable source of data is available and this method is frequently used as part of the 5-year health studies in low- and middle-income countries.

### Reproductive Age Mortality Studies (RAMOS)

In the absence of a Civil Registration System, RAMOS is feasible in low- and middle-income settings and provides contemporaneous estimates of MMR<sup>7</sup>. The RAMOS approach provides the most complete and current estimation of MMR as the data on the number of maternal deaths is collected from various sources and each death is examined whether the death is a maternal death or not. However, the RAMOS approach will result in under estimation if a comprehensive list of deaths is not available. Also, these studies are expensive and time consuming when conducted on a larger scale. Hence, Regression Estimation provides the most promising method for developing precise, cost-effective and timely estimates of MMR for the districts in developing countries like India.

## 4.0 Data and Method:

The method used to estimate MMR requires two data elements; viz. Crude Death Rate for Women aged 14-49(CDRW) years and General Fertility Rate (GFR). The basic Regression model used to have estimates of MMR is presented in equation (1) was constructed using the state level data for 2001, 2011 and 2017.

$$MMR=a+b_1CDRW+b_2GFR+b_3CDRW^2+b_4GFR^2+b_5CDRW*GFR+ Error \text{ ----- (1)}$$

This Model does not require any assumption regarding the stability or quasi stability of populations. The data required are CDRW and GFR where CDRW is the crude death rate for women aged 14-49 years

and is calculated as the ratio of total number of deaths of women aged 14-49 years to the total number of women aged 14-49 years for which data on age-specific death rates published by SRS is used and the data on total number of women aged 14-49 years is collected from the Censuses 2001 and 2011 and projected for 2017 based on 2011 census data. Similarly, GFR data for the states is collected from SRS.

The state level MMR estimates for 2001 is computed as the average of the MMR estimates published by the SRS for the years 1999-01 and 2001-03<sup>8</sup>. Similarly, MMR estimates for 2011 and 2017 are collected from the SRS for the years 2010-12<sup>9</sup> and 2015-17 respectively. In this regression, MMR values (16 observations - pertaining to 15 states and MMR estimate of India for 2001 and 2011, 20 observations - pertaining to 19 states and MMR estimate of India for 2017) are regressed on CDRW and GFR and three regression models presented in Table-2 were constructed. It is apparent from the table-2 and figures 1 and 2 that the relationship between MMR and GFR / CRDW is quadratic.

The characteristics of the regression model constructed using state level data for 2001, 2011, 2017 is presented in table-2.

**Table-2**  
**Characteristics of the Regression Model for Estimating Maternal Mortality Ratio**

S.No.	Year	No. of Observations	Regression Equation	R <sup>2</sup> (%)	Adj. R <sup>2</sup> (%)	Durbin Watson Statistic
1.	2001	16	$MMR=13.96CDRW^2+0.018GFR^2$	96.8	96.4	1.86
2.	2011	16	$MMR=21.09CDRW^2+0.0023GFR^2+81.6D^*$	98.0	97.6	2.30
3.	2017	20	$MMR=15.7CDRW^2+0.013GFR^2$	94.3	93.7	1.52

Note: D\* is a dummy variable for outliers.

**Figure-1**

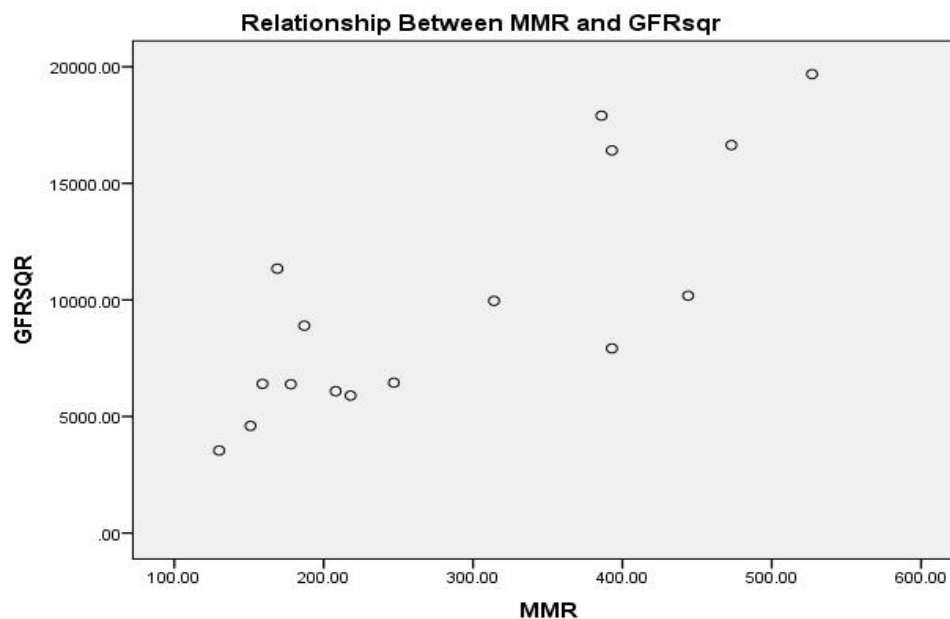
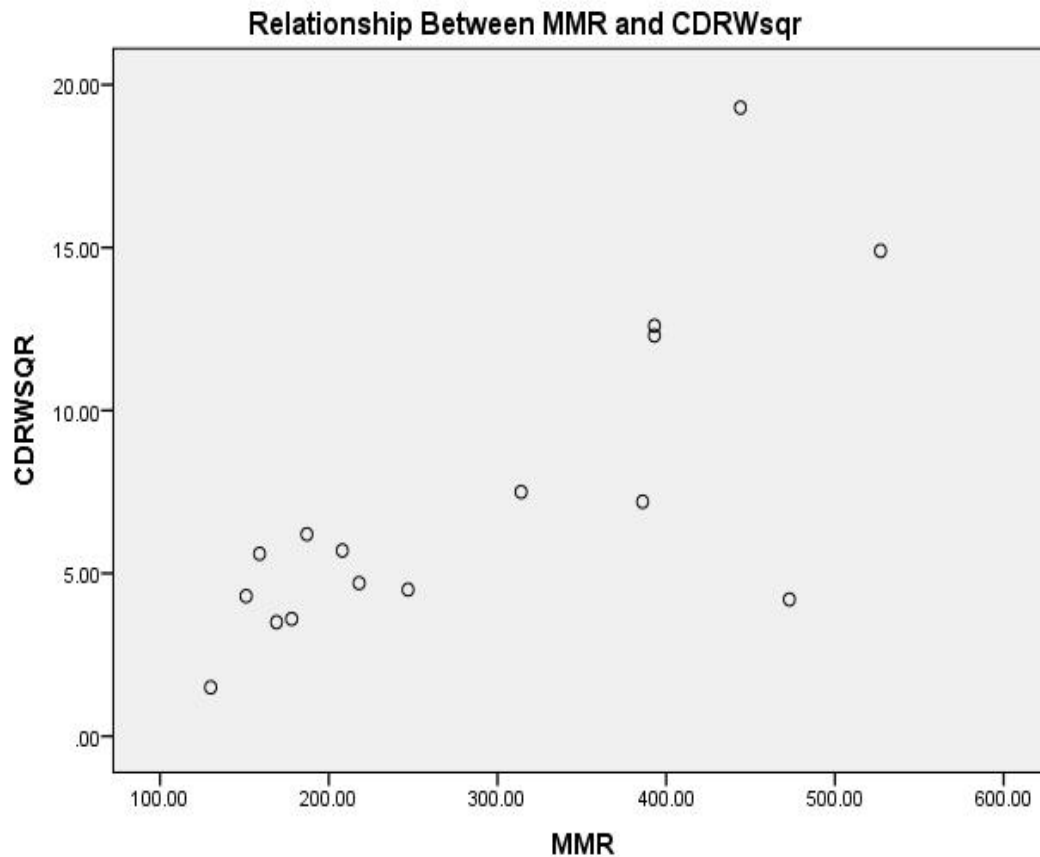


Figure-2



The regression models presented in table-2 are highly predictive as shown by the  $R^2$  values. Hence,  $CDRW^2$  and  $GFR^2$  values are calculated for the years 2001, 2011 and 2017 for all the 32 districts of Tamil Nadu State from censuses 2001 and 2011 and projected population for 2017 based on 2011 census and also using data published by SRS on age-specific mortality rates for Tamil Nadu. The regression models presented in table-2 along with the data elements, viz.  $CDRW^2$  and  $GFR^2$  were used to generate the Maternal Mortality Ratios for the 32 districts. Table-3 provides MMR estimates along with Confidence Intervals (CI, LL-Lower Limit, and UL-Upper Limit) and Relative Standard Error (RSE %) for all the 32 districts.

**Table-3**  
**DISTRICTWISE MMR ESTIMATES**

No.	NAME OF THE DISTRICT	2001				2011				2017			
		MMR	95% CI		RSE (%)	MMR	95% CI		RSE (%)	MMR	95% CI		RSE (%)
			LL	UL			LL	UL			LL	UL	
1	Ariyalur	144	128	160	5.1	128	99	157	10.5	92	76	107	8.1
2	Chennai	94	80	108	7.0	82	73	90	4.9	53	47	60	5.8
3	Coimbatore	103	93	114	4.8	88	74	103	7.4	55	48	62	5.8
4	Cuddalore	139	125	154	4.9	115	94	136	8.4	87	71	104	9.0
5	Dharmapuri	149	133	164	4.9	124	99	150	9.5	92	77	108	7.9
6	Dindigul	137	123	151	4.8	112	91	134	8.8	88	71	106	9.3
7	Erode	121	108	134	5.0	102	82	123	9.1	68	58	79	7.5
8	Kancheepuram	126	112	141	5.3	99	85	113	6.4	54	47	61	6.1
9	Kanniyakumari	100	90	111	4.9	86	74	99	6.7	54	47	61	5.8
10	Karur	136	122	151	5.0	110	88	131	9.1	90	72	108	9.6
11	Krishnagiri	149	133	164	4.9	123	100	145	8.4	89	75	103	7.5
12	Madurai	105	94	116	4.9	97	80	113	7.8	57	50	64	6.1
13	Nagapattinam	142	126	157	5.0	122	98	147	9.4	85	69	101	8.8
14	Namakkal	136	121	150	5.0	108	87	130	9.1	87	70	105	9.6
15	Perambalur	143	126	160	5.4	125	99	151	9.6	89	74	104	8.1

16	Pudukkottai	150	134	166	5.0	122	97	147	9.5	90	75	106	8.3
17	Ramanathapuram	141	127	156	4.9	118	97	140	8.4	87	71	102	8.5
18	Salem	124	111	137	4.9	103	85	122	8.3	70	61	80	6.1
19	Sivaganga	140	125	155	4.9	116	93	139	9.0	87	70	104	9.0
20	Thanjavur	137	123	152	4.9	113	91	135	9.1	88	71	106	9.4
21	Theni	117	105	129	4.9	101	84	119	8.2	57	50	64	6.0
22	The Nilgiris	120	107	133	5.0	96	77	115	9.1	56	49	63	5.9
23	Thiruvallur	128	114	143	5.3	97	83	111	6.6	57	49	64	6.0
24	Thiruvarur	143	127	159	5.2	123	97	149	9.8	86	69	102	9.4
25	Thoothukkudi	126	113	139	4.9	105	86	123	8.0	66	58	75	5.9
26	Tiruchirappalli	121	108	134	4.8	104	85	123	8.3	69	60	78	6.3
27	Tirunelveli	122	110	135	4.9	106	87	124	8.1	69	60	78	6.2
28	Tiruppur	88	75	100	6.5	97	81	113	7.7	53	47	60	5.8
29	Tiruvannamalai	143	127	158	5.0	125	102	148	8.6	93	79	108	7.3
30	Vellore	137	122	151	5.0	112	94	129	7.3	90	75	105	7.8
31	Viluppuram	141	126	156	4.9	128	104	152	8.7	86	72	101	8
32	Virudhunagar	135	121	150	5.0	104	86	123	8.1	68	59	77	6.4

Note: RSE-Relative Standard Error is computed as percentage of Standard Error over the Estimate.

Figure 1  
Comparison of MMR of Districts in 2001,2011,2017

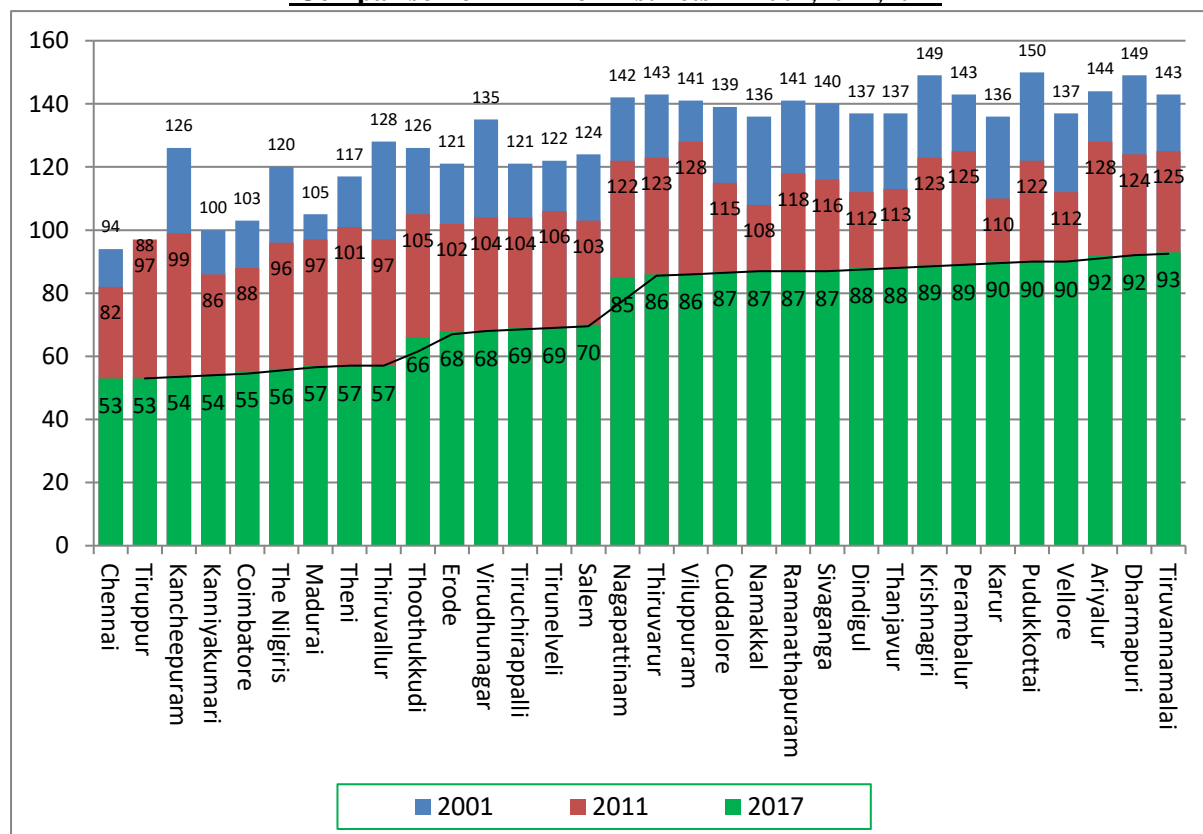


Table-4  
DISTRICTWISE PROGRESS (REDUCTION) IN MMR

No.	NAME OF THE DISTRICT	2001	2011	2017	Percentage reduction of MMR during 2001-2011	Percentage reduction of MMR during 2011-2017
1	Ariyalur	144	128	92	11	28
2	Chennai	94	82	53	13	35
3	Coimbatore	103	88	55	14	38
4	Cuddalore	139	115	87	17	24
5	Dharmapuri	149	124	92	16	26

6	Dindigul	137	112	88	18	21
7	Erode	121	102	68	15	33
8	Kancheepuram	126	99	54	22	45
9	Kanniyakumari	100	86	54	14	37
10	Karur	136	110	90	19	18
11	Krishnagiri	149	123	89	18	28
12	Madurai	105	97	57	8	41
13	Nagapattinam	142	122	85	14	30
14	Namakkal	136	108	87	20	19
15	Perambalur	143	125	89	12	29
16	Pudukkottai	150	122	90	18	26
17	Ramanathapuram	141	118	87	16	26
18	Salem	124	103	70	17	32
19	Sivaganga	140	116	87	17	25
20	Thanjavur	137	113	88	18	22
21	Theni	117	101	57	13	44
22	The Nilgiris	120	96	56	20	42
23	Thiruvallur	128	97	57	24	41
24	Thiruvarur	143	123	86	14	30
25	Thoothukkudi	126	105	66	17	37
26	Tiruchirappalli	121	104	69	14	34
27	Tirunelveli	122	106	69	14	35
28	Tiruppur	88	97	53	-11	45
29	Tiruvannamalai	143	125	93	12	26
30	Vellore	137	112	90	18	20
31	Viluppuram	141	128	86	9	33
32	Virudhunagar	135	104	68	23	35

## 5.0 Results:

It is apparent from Table-3, the MMR estimates predicted for the districts are accurate and precise as most of the Confidence Intervals are narrower and the relative standard error is almost less than 10% for all the districts and the high  $R^2$  values of the regression models. Hence, the regression models presented in table-2 can be applied to predict MMR for all other districts in the country due to the high predictability. From table-4, it is also clear that already 14 districts in Tamil Nadu have achieved sustainable development goal target of less than 70 and another 15 districts are on the threshold of reaching the goal soon. Sustained efforts are required in the remaining 3 districts to accomplish SDG target. The percentage reduction in MMR during 2011-2017 is significant compared to the previous decade i.e. 2001-2011 due to the universalisation of DMMBS covering almost all pregnant women, increase in maternity benefits from Rs.300 in 1987 to Rs.18000 in 2016, almost 100 percent institutional deliveries and the increased awareness among the antenatal women in Tamil Nadu. During 2001-11, Tiruppur district fared worse (-11%) in MMR due to the large influx of migrant labourers from other states and rest of Tamil Nadu posing huge stress on the public health management in the district.

**Table-5**  
**MMR Transition of the districts in Tamil Nadu**

MMR	2001	2011	2017
<=70	0	0	14
70-90	1	3	15
90-120	6	20	3
120-140	15	9	0
140-150	10	0	0
<b>Total</b>	<b>32</b>	<b>32</b>	<b>32</b>

Note: Figures denote the number of districts

Using indirect methods, Mari Bhat<sup>10</sup> estimates that Tamil Nadu had a MMR of about 372 in the mid-1980s and about 195 in the early 1990s. It is also very clear from Table-5 that the MMR transition from 2001 to 2017 is commendable. In 2001, there were 25 districts out of 32, had MMR more than 120 per 100,000 live births. But, in 2017, the MMR in these 25 districts have been reduced to below 100 due to

political commitment and proactive administration<sup>11</sup>, the continuous implementation of Dr Muthulakshmi Reddy Maternity Benefit Scheme<sup>12</sup> (DMMBS) over three decades. Even though the scheme was implemented from 1987, initially meant solely for agricultural labourers in rural areas, the scheme universally included all women below the poverty line from 2006 onwards.

## 6.0 Discussion:

In the absence of studies to estimate MMR at the district level due to huge costs and requirement of large sample sizes, this state based regression model provides a precise, cost effective and timely estimates for all the districts. The only requirement for estimating MMR is the general fertility rate (GFR) and the crude death rate for women aged 14-49 years (CDRW) for the districts. These two data elements can easily be collected and estimated from the SRS and census data. Now, it is possible that whenever SRS data on MMR is released, this regression model can be refined and the district level estimates can be generated simultaneously for all the districts in the country due to the high predictability of the regression model. From these constructed models, it is ascertained that 14 districts in Tamil Nadu have already achieved the SDG target and continuous efforts are required in the remaining 18 districts to achieve SDG target on time.

## 7.0 Conclusion:

The present study attempted to estimate MMR for all the districts of Tamil Nadu based on the State level regression Model. Three separate regression models for three different time points, viz.2001, 2011, and 2017 have been constructed and district level MMR estimates were generated. Fourteen districts have been identified for achieving the SDG target of less than 70 per 100,000 live births and for the remaining 18 districts, sustained and additional efforts are required to achieve the same. Comparing the levels of MMR of all the districts, a significant reduction in MMR is observed during 2011-17 compared to 2001-11 due to the universalization of the state's scheme, DMMBS covering all the pregnant women below the poverty line, higher levels of institutional deliveries and the increased awareness among the antenatal women in Tamil Nadu.

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**Declaration Note:** This study has been done by me and has not been published in any journal or newsletter. The views expressed in this paper are purely personal and on academic interest only and in no way connected to the organization which I belong to.

