Spatio-temporal analysis of school district dropout rate in MA, USA

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1. Introduction

A school district is an administrative unit responsible for managing primary and secondary schools, consisting of one or more public schools operated under the supervision of an elected or appointed school committee and a superintendent (MassGIS, 2019). A dropout is defined as a student in grade nine through twelve who leaves school prior to graduation for reasons other than transferring to another school and dropout rate is the number of students who drop out over a one-year period (DESE, 2023). Dropouts tend lead to lower economic opportunities, higher social costs, and socio-economic disparities in the future (Rumberger & Thomas, 2000). The OECD (2012, 2016, 2017) identifies several reasons behind dropout behaviors, including academic disaffection, socioeconomic stressors, and institutional failure in supporting at-risk students. Massachusetts' overall dropout rate of 2.1% makes significant differences, from 0.6% in wealthy suburbs like Weston to 3.3% in Gateway Cities such as Lawrence. These disparities are linked to the state's municipal-based school funding system, which causes resource inequities (DESE, 2023; Balfanz and Byrnes, 2019). The number of School Districts in this state are 399, Number of Schools 1,827, Enrollment 914,959, and Grades Served PK-12 (DESE, 2024). State education aid has increased $594 million in 2024 to enhance educational performance (DESE, 2023). There is a lack of information on whether these expenses have resulted in long-term gains or only temporary improvements. This study attempts to present the dropout rates across Massachusetts school districts and analyze their spatial and temporal patterns using ArcGIS Pro and statistical methods that can be helpful to policymakers, educators, as well as the community leaders.

Objectives

The objectives of the study are:

a. To represent the spatial patterns and temporal trends of school district dropout rates.
b. To present the dropout patterns across different grades, genders, and ethnicities over time.

2. Materials and Methodology

2.1. Study Area Description: The study area includes all school districts within the state of Massachusetts (Figure 1), that have significant demographic and socioeconomic diversity.

Massachusetts contains urban, suburban, and rural districts, all of which have different types of educational issues and resources. This state has a high education rate, with many residents holding bachelor's degrees or higher (Census Bureau, 2021).

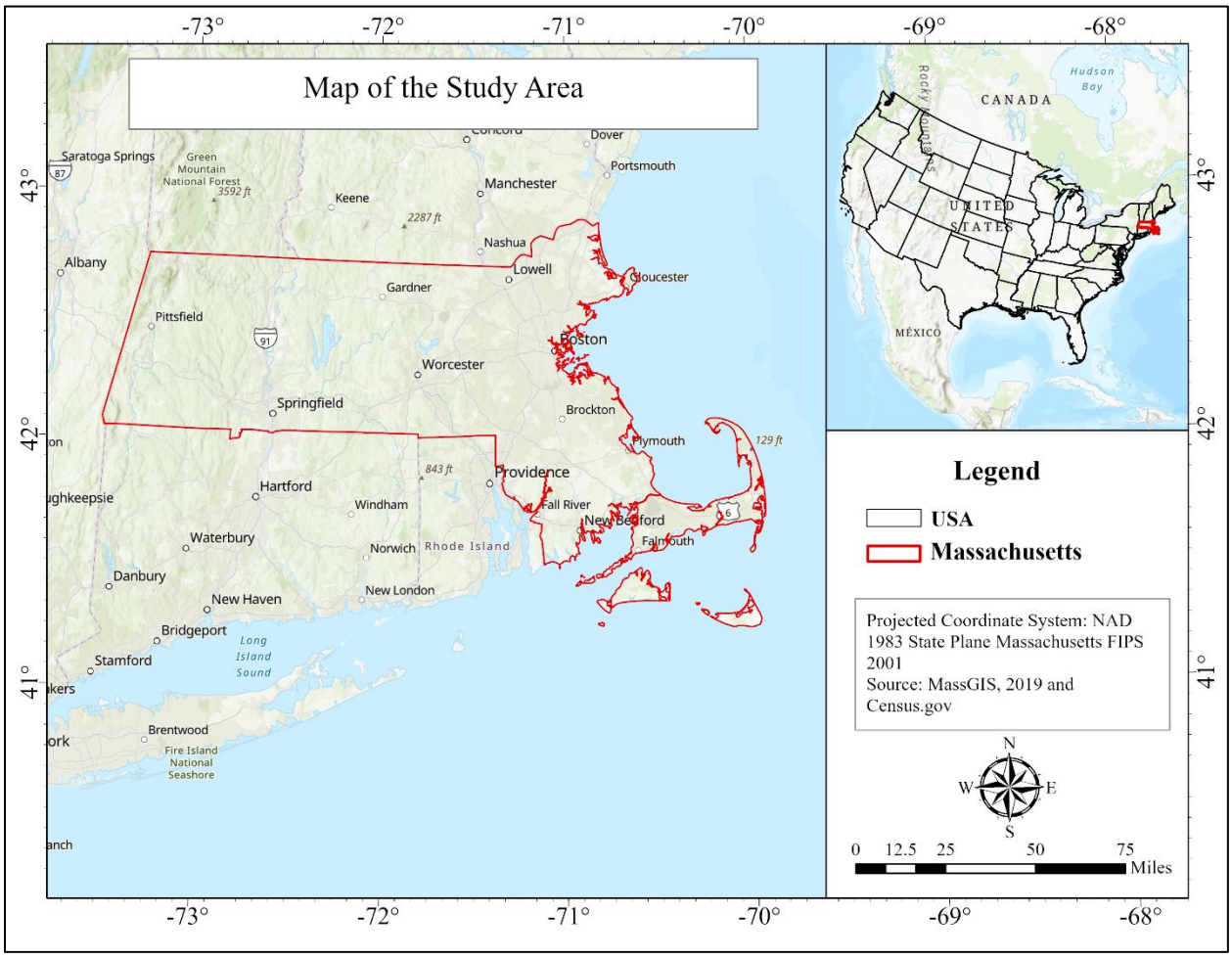


Figure 1: Study area map

2.2. Data Collection and Processing: The study uses a spatio-temporal approach to analyze Massachusetts school district dropout rates for 2009–10, 2015–16, and 2021–22. Data from the Massachusetts Department of Elementary and Secondary Education (DESE) and MassGIS were used, including dropout rates as per school districts, dropout rates as per grade, gender, and ethnicity and school district shapefiles. Data was cleaned, standardized, and exported to CSV for the analysis in ArcGIS Pro and creating maps of spatial distribution of dropout rates over time. Demographic trends were analyzed in R and Excel, with bar charts illustrating dropout differences by grade, gender, and ethnicity (Figure 2).

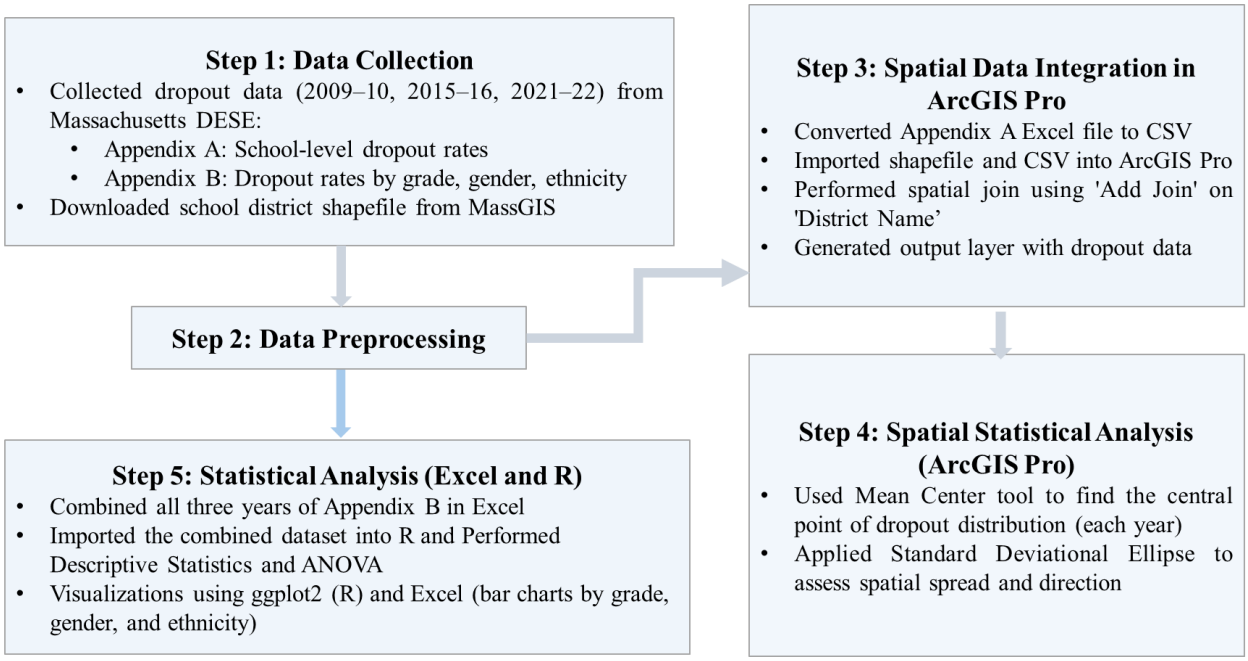


Figure 2: Working flowchart

3. Results and Discussion

3.1. Spatial distribution of School districts dropout

The geographical trend of dropout rates in Massachusetts schools reveals individualistic trends for the three selected academic years 2009–10, 2015–16, and 2021–22. In the academic year of 2009–2010 many school districts in western and center east Massachusetts experienced notably high dropout rates, with some reaching as high as 23.50% in 2009-10, particularly in the Provincetown, Springfield, Holyoke, Lawrence and Petersham areas. Much lower dropout rates were seen in eastern Massachusetts districts, especially around Westwood, Medfield, Hopkinton, Hingham and Duxbury areas (Figure 3).

By 2015–16, dropout rates had improved across most Massachusetts districts, with the majority falling between 0.60% and 2.80%, suggesting that local or statewide interventions may have been effective. Though some southeastern and rural west-central areas such as Wareham, Chelsea, New Bedford, Southbridge and Webster were struggling with higher dropout rates and lower dropouts seen in central and northeastern regions such as Ashburnham-Westminster, Longmeadow, Belmont, Needham, Lincoln-Sudbury (Figure 3). This progress was largely reversed by 2021–22 academic year, as the aftermath of the COVID-19 pandemic led to rising dropout rates again,

especially in the southeastern, south-center and western parts (North Brookfield, Winchendon, North Adams, Webster, and Southbridge) of the state.

Low dropout rate in northeastern (Groton-Dunstable), central (Lincoln-Sudbury, Acton-Boxborough) and southeastern (Freetown-Lakeville, Mansfield) regions (Figure 3). Overall, High dropout areas were concentrated in some part of western (Springfield, Holyoke) and southeastern (Fall River, New Bedford) in Massachusetts across the years. Lower dropout rates were observed in northeastern and central districts like Lexington and Newton.

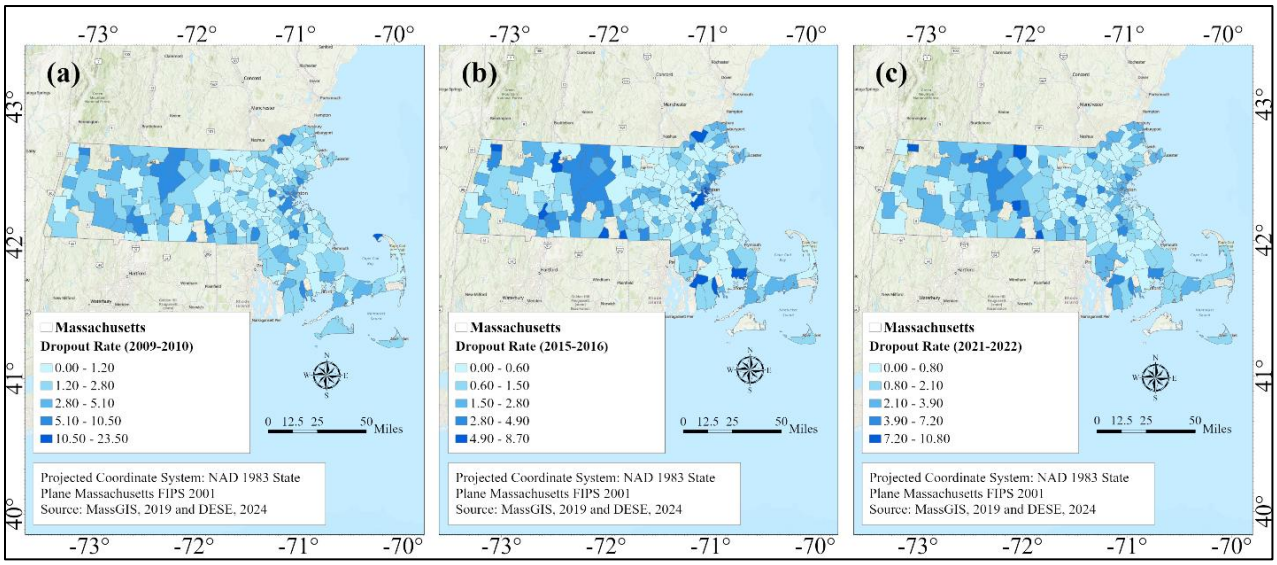


Figure 3: School District Dropout of (a) 2009-10, (b) 2015-16 and (c) 2021-22

Spatial statistical analysis using the Standard Deviational Ellipse (SDE) and Mean Center shows shifting patterns of concentrations of dropout rates in Massachusetts (Figure 4). In 2009–10, the mean center was located near central Massachusetts, with a wide ellipse extending eastward, indicating a dispersed and widespread pattern of dropout rates (Figure 4). In 2015–16, the mean center shifted slightly west, and the ellipse expanded westward and southward, reflecting increased variation and a growing concentration of dropout rates in western and south-central regions (Figure 4). By 2021–22, the mean center moved further west, and the ellipse stretched slightly westward but became narrower, suggesting that dropout rates became more concentrated in the western part of the state (Figure 4). Overall, the mean center shifted west over time, and ellipses narrowed, suggesting dropout rates became more regionally concentrated in the west by 2021–22.

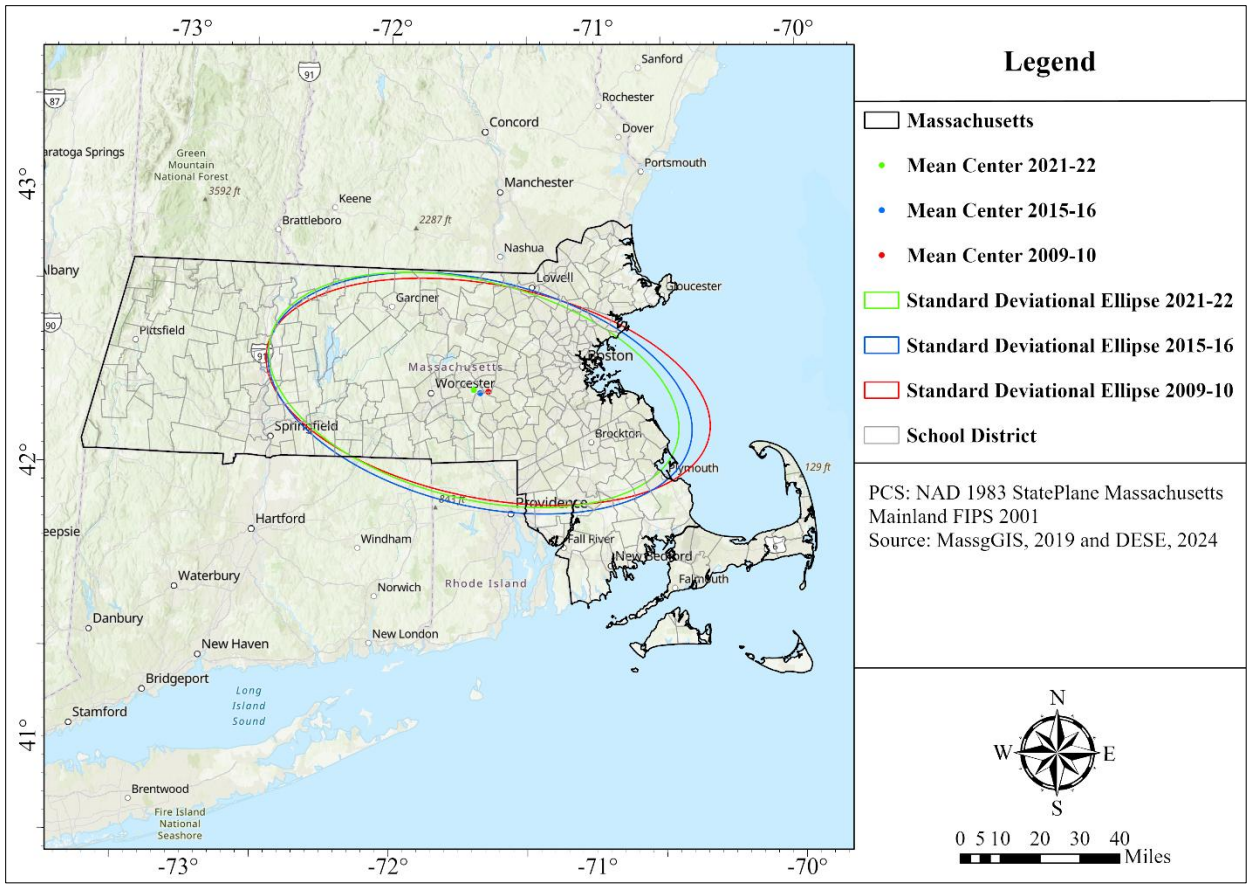


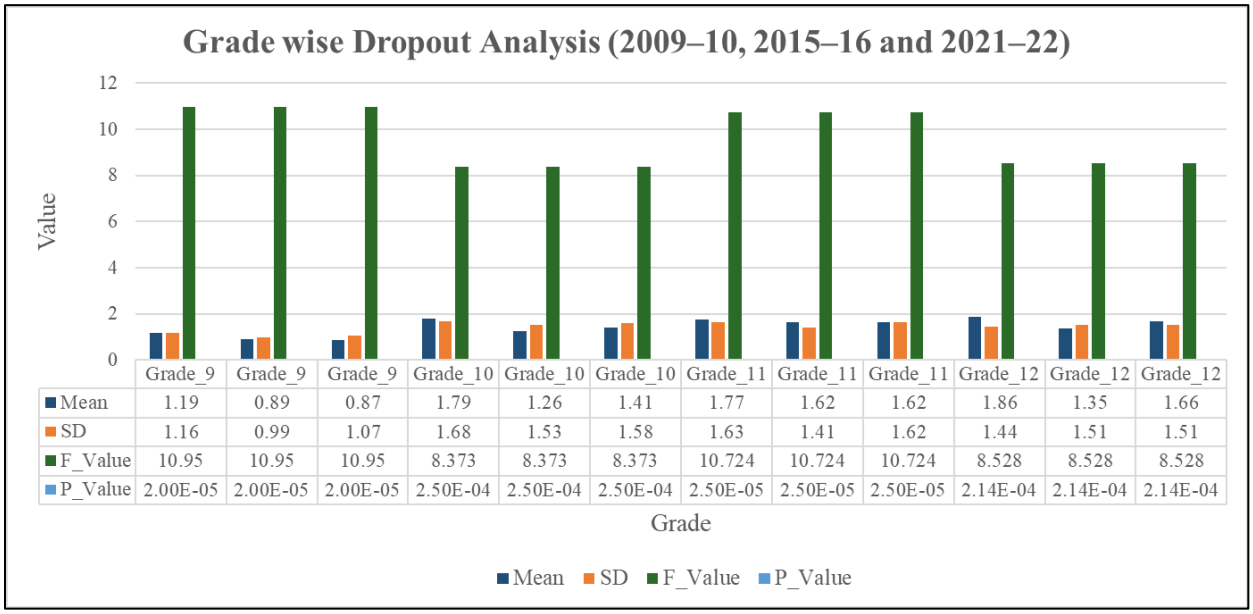
Figure 4: Standard Deviational Ellipse (SDE) of *School District Dropout*

3.2. Analysis of Dropout rate as per grade, gender and ethnicity

Analyzing the trends in school districts dropout over time is essential to overcome educational inequality and formulate proper policies. This study investigates the differences in dropout rates across grade levels (Grades 9–12), gender, and ethnic groups in the Massachusetts for three different academic years 2009–10, 2015–16, and 2021–22.

3.2.1. Grade Wise Dropout Rate Analysis: Descriptive statistics and ANOVA results reveal a consistent pattern across all grade levels, with dropout rates peaking in 2009–10, declining in 2015–16, and rising slightly again in 2021–22. Grade 9 had a notably higher dropout rate in 2009–10 (Mean = 1.19%) but showed improvement over time, dropping to 0.87% by 2021–22. Besides, Grade 10 had the highest dropout mean in 2009–10 (1.79%), which gradually decreased in later years. Grade 11 exhibited a fluctuating pattern, with a slight increase again in 2021–22 after a drop in 2015–16. Grade 12 consistently showed higher dropout rates than lower grades, especially in 2009–10 (1.86%). Standard Deviation (SD) indicates moderate variation in dropout rates within

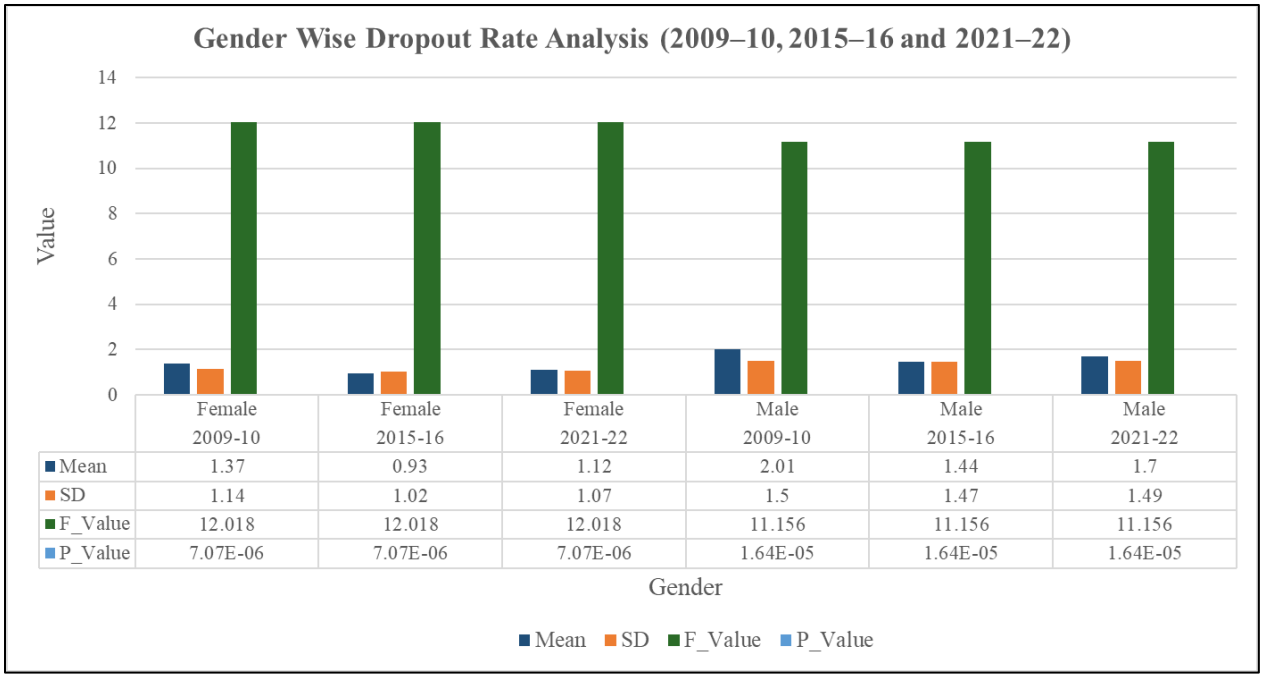
grades across years (ranges: ~0.99–1.68). F-Values range from 8.37 to 10.95, showing strong between-group variance. P-Values are consistently very low (2E-05 to 0.00021), confirming that the differences in dropout rates across the years are statistically significant for all grade levels (Figure 5). Overall, there is a significant reduction in dropout rates over time, particularly Grade 9 and Grade 10. However, attention may still be needed in Grades 11 and 12, where dropout rates remain relatively high in recent years.



	Grade_9	Grade_9	Grade_9	Grade_10	Grade_10	Grade_10	Grade_11	Grade_11	Grade_11	Grade_12	Grade_12	Grade_12
Mean	1.19	0.89	0.87	1.79	1.26	1.41	1.77	1.62	1.62	1.86	1.35	1.66
SD	1.16	0.99	1.07	1.68	1.53	1.58	1.63	1.41	1.62	1.44	1.51	1.51
F_Value	10.95	10.95	10.95	8.373	8.373	8.373	10.724	10.724	10.724	8.528	8.528	8.528
P_Value	2.00E-05	2.00E-05	2.00E-05	2.50E-04	2.50E-04	2.50E-04	2.50E-05	2.50E-05	2.50E-05	2.14E-04	2.14E-04	2.14E-04

Figure 5: Grade-wise dropout rate

3.2.2. Gender Wise Dropout Rate Analysis: Female Students Dropout rates declined significantly from 1.37% (2009–10) to 1.12% (2021–22). Standard deviation (SD) remained relatively low, showing stable dropout trends over time. F-value 12.018 and P-value 7.07E-06 indicate a statistically significant difference across the years (Figure 6). Besides, Male Students Dropout rates showed a modest decline, from 2.01% (2009–10) to 1.7% (2021–22). Despite the reduction, male dropout rates remained consistently higher than female rates in all years. F-value is 11.156 and P-value 1.64E-05 confirm that the change in male dropout rates is also statistically significant (Figure 6). Overall, both genders show a significant reduction in dropout rates, with greater improvement observed among female students.



	Female 2009-10	Female 2015-16	Female 2021-22	Male 2009-10	Male 2015-16	Male 2021-22
Mean	1.37	0.93	1.12	2.01	1.44	1.7
SD	1.14	1.02	1.07	1.5	1.47	1.49
F_Value	12.018	12.018	12.018	11.156	11.156	11.156
P_Value	7.07E-06	7.07E-06	7.07E-06	1.64E-05	1.64E-05	1.64E-05

Figure 6: Gender-wise dropout rate

3.2.3. Ethnicity Wise Dropout Rate Analysis: Hispanic students had the highest dropout rates across all years, peaking at 3.19% in 2009–10, though reduced in subsequent years. Black and White students also showed higher dropout means, though with improvement in 2015–16 and a slight rise in 2021–22. Asian and Native Hawaiian students consistently had the lowest dropout rates, under 0.5%, with very little variation. Native Hawaiian rates dropped significantly to 0.02% in 2021–22 (Figure 7 and Table 1). All ethnic groups show statistically significant changes across years ($p < 0.05$ in all cases) (Figure 7 and Table 1).

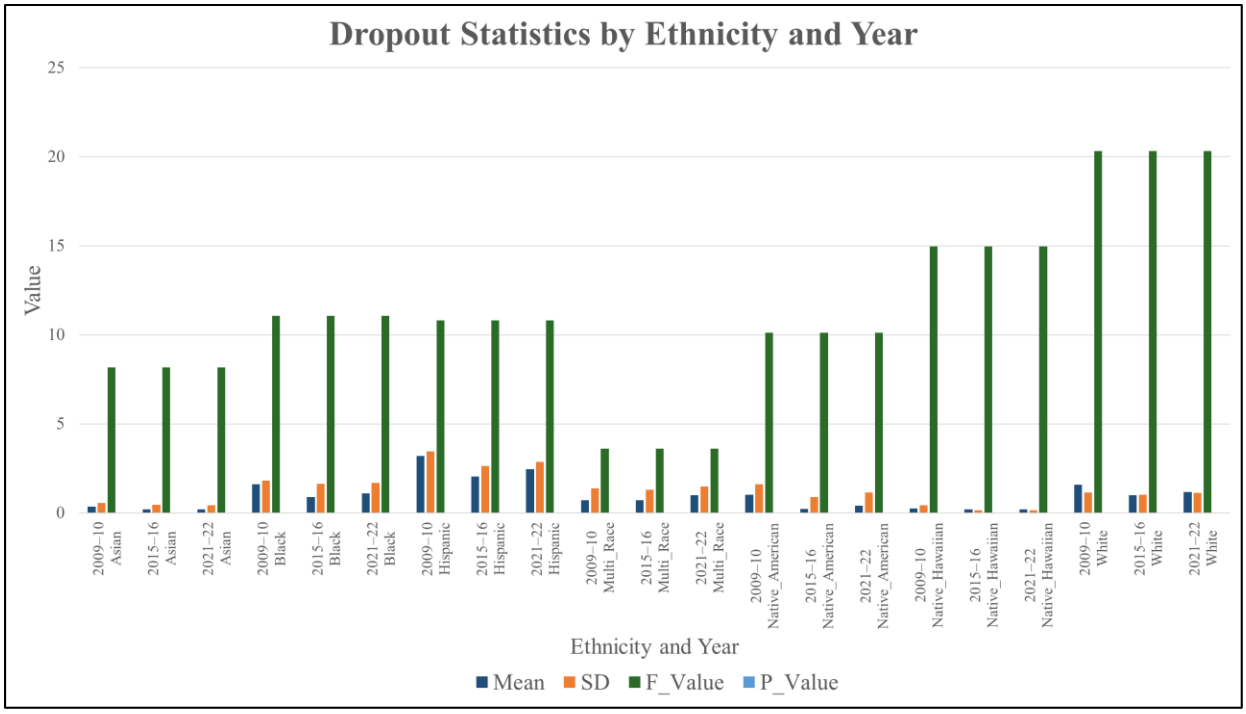


Figure 7: Ethnic Group Dropout Rate

These indicate strong variation across years within those groups. While dropout rates improved across most ethnic groups, disparities remain. Targeted interventions are still needed for Hispanic, Black, and white to ensure equitable outcomes.

Table 1: Ethnicity-Wise Dropout Rate Statistics in Massachusetts (2009–10, 2015–16, and 2021–22)

Ethnicity	**Year**	**Mean**	**SD**	**F_Value**	**P_Value**
Asian	2009–10	0.35	0.55	8.167	0.0003088
Asian	2015–16	0.2	0.45	8.167	0.0003088
Asian	2021–22	0.19	0.44	8.167	0.0003088
Black	2009–10	1.6	1.82	11.076	1.18E-05
Black	2015–16	0.9	1.63	11.076	1.18E-05
Black	2021–22	1.09	1.68	11.076	1.18E-05
Hispanic	2009–10	3.19	3.46	10.82	2.29E-05
Hispanic	2015–16	2.05	2.64	10.82	2.29E-05
Hispanic	2021–22	2.45	2.87	10.82	2.29E-05
Multi_Race	2009–10	0.72	1.37	3.608	0.027553

Multi_Race	2015–16	0.7	1.29	3.608	0.027553
Multi_Race	2021–22	0.98	1.47	3.608	0.027553
Native_American	2009–10	1.02	1.62	10.111	5.39E-05
Native_American	2015–16	0.23	0.88	10.111	5.39E-05
Native_American	2021–22	0.41	1.14	10.111	5.39E-05
Native_Hawaiian	2009–10	0.25	0.44	14.965	5.17E-07
Native_Hawaiian	2015–16	0.2	0.14	14.965	5.17E-07
Native_Hawaiian	2021–22	0.2	0.15	14.965	5.17E-07
White	2009–10	1.57	1.15	20.327	2.34E-09
White	2015–16	1	1.01	20.327	2.34E-09
White	2021–22	1.17	1.11	20.327	2.34E-09

3.3. Limitation

The analysis is limited to three academic years and relies on secondary data only, which may not capture all contextual factors influencing dropout rates.

3.4. Recommendation

Strengthen support programs in upper grades (11 and 12) where dropout rates remain high. Implement targeted interventions for male, Hispanic, white and Black students who show higher dropout patterns. Encourage early monitoring and allocate appropriate resources for high dropout districts to address underlying socioeconomic and academic challenges contributing to school dropouts.

4. Conclusion

This study reveals that High dropout areas were concentrated in western (Springfield, Holyoke) and southeastern (Fall River, New Bedford) Massachusetts across the years. Lower dropout rates were observed in northeastern and central districts like Lexington and Newton. The mean center shifted west over time, and ellipses narrowed, suggesting dropout rates became more regionally concentrated in the west by 2021–22. The study finds a declining trend in dropout rates across grades, genders, and ethnicities, with significant improvements in early high school years and

among females. However, persistent disparities particularly among Grades 11–12, male, Hispanic, White and Black students highlight the need for sustained and targeted educational interventions.

5. References

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