Paradigm Academic Press
Research and Advances in Education
ISSN 2788-7057
SEP. 2026 VOL.5, NO.3

A Mathematical Model for Predicting Teacher Training Demand in Kenya

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doi:10.63593/RAE.2788-7057.2026.09.003

Abstract

Since independence in 1963, Kenya has expanded teacher training through teacher training colleges, universities, and postgraduate programs in response to rising enrollment, curriculum reforms, and changing educational needs. Despite this expansion, Kenya continues to face mismatches between the supply of trained teachers and the employment capacity of the Teachers Service Commission (TSC), between supply and demand by subject combination, and between supply and regional deployment. Currently, nearly 40% of university students in Kenya enroll in education- related programs. Of these, less than 10% are absorbed immediately after graduation. The majority wait for up to ten years or more to be employed. Hence, there is a backlog of about 350, 350,000 unemployed teachers. Simultaneously, the country is short of teachers for science, technology, engineering, and mathematics (STEM)- related subjects. This shortage is likely to be magnified as 60% of all senior school students are required to take the STEM pathway. Equally, there is a mismatch between the supply and the regional distribution of teachers, with some regions experiencing an acute shortage while others have an oversupply. This study develops a mathematical model for predicting teacher training demand in Kenya by integrating historical trends in learner enrollment, teacher recruitment, pupil–teacher ratios, attrition, infrastructure, regional disparities, and the requirements of the Competency- Based Education (CBE) framework. The study therefore recommends a transition from supply- driven to demand- driven teacher education through dynamic enrollment caps linked to projected recruitment capacity, subject- specific quotas prioritizing STEM and technical fields, county- based recruitment planning, and alignment of teacher training with infrastructural expansion and CBE demands. The study concludes that sustainable teacher workforce planning in Kenya requires integrated forecasting mechanisms linking teacher education, labor market demand, fiscal capacity, infrastructure, and regional equity.

Keywords: modelling, teacher demand, teacher supply, competency-based education (CBE)

1. Introduction

At independence in 1963, Kenya faced an acute shortage of qualified teachers at both the primary and secondary levels, a legacy of colonial neglect of African education. The few teacher training colleges (TTCs) in operation primarily served missionary or government schools and produced teachers with limited pedagogical training. The first two decades of independence saw deliberate government investment in expanding teacher education infrastructure and access (Republic of Kenya, various years).

Teacher education remains the cornerstone of any nation's educational development and, by extension, the country's economic development, as it directly shapes instructional quality and learning outcomes in schools. Since Kenya's independence in 1963, the country has prioritized teacher education to achieve national development goals, including universal primary education and the nurturing of a knowledge-driven economy. Over the past six decades, the evolution of teacher training in Kenya has not only mirrored changes in

educational policy but also responded to demographic, socioeconomic, and technological transformations.

Teacher training in Kenya is offered through several pathways:

1) Primary Teacher Education (PTE): Diploma programs for primary school teachers.
2) Diploma in Secondary Education: For secondary school teaching, often in technical or specialized subjects.
3) Technical teacher education.
4) Bachelor of Education (B.Ed.): University-level degree for secondary and, increasingly, primary teaching.
5) Postgraduate Diploma in Education (PGDE): For university graduates converting to teaching.

This diversification is aimed at aligning teacher preparation with evolving curricular demands, particularly in science subjects, technology, and vocational subjects, and to facilitate upward mobility for practicing teachers.

The situation of employment in schools in Kenya over time is reflected in Table 1.

Table 1. The enrollment of learners in preprimary, primary, and secondary school in Kenya from 1963 to 2025

YEAR	Pre-primary / ECDE enrolment	Primary enrolment	Secondary enrolment
1963	—	0.892 553 million	0.029-0.03 million
1965	—	1.042 146 million	0.047976 million
1967	—	1.133 179 million	0.088779 million
1969	—	1.282 297 million	0.115246 million
1971	—	1.515 498 million	0.140722 million
1973	—	1.816 017 million	0.174767 million
1975	—	2.881 155 million	0.226835 million
1977	—	2.974 849 million	0.320310 million
1979	—	2.698 246 million	0.384389 million
1981	—	4.134 345 million	0.464721 million
1983	—	4.570 444 million	0.545053 million
1985	—	5.000 000 million	0.600000 million
1986		4,012777 million	
1987		4,138,463 million	
1988		4,212,741 million	
1989		4,389,124 million	
1995		4,540,471 million	
1999		6,504479 million	0.829641 million
2000		5,034,858 million	0.758967 million
2002	—	6.062 742 million	—
2003	—	7.159 523 million	—
2006	—	7.394 763 million	—
2007		8,253,800 million	1,180267 million
2008		8,563,800 million	1,382211 million
2009		8,986,400 milliom	1,472634 million
2010		9,352,800 million	1,653,384 million
2011		9,561,100 million	1,767,720 million
2012	2,710,806 million	9,757,600 million	1,914,823 million
2013	2.865 348 million	9.8576 million	2,104,262 million

2014	3.019 865 million	9.9508 million	2,331,697 million
2015	3.167855 million	10.090900 million	2559883 million
2016	3.199841 million	10.280100 million	2,723,900 million
2017	3.293813 million	10,290155 million	2,782744 million
2018	3,390545 million	10389826 million	3,013415 million
2019	2.7 million	10,072040 million	3262951 million
2020	2,832897 million	10,076828 million	3569279 million
2023	2.9 million	10.2 million	4.1 million
2024	2.91 million	—	4.32 million

Source: Kenya National Bureau of Statistics (KNBS).

Such an exponential increase in the number of learners demands that the number of teachers employed be commensurate with an appropriate teacher: pupil ratio.

The sharp increase in primary school enrollment and access to education following the introduction of Free Primary Education (FPE) in 2003 placed an immediate strain on teacher supply and deployment systems (Oketch & Rolleston, 2007). This led to severe shortages of teachers in most regions of the country, especially in remote and marginal counties. Accordingly, the government instituted measures to accelerate teacher training, hire temporary and contract teachers, and expand the use of volunteer or community-based systems in some schools. FPE thus dramatically altered the teacher staffing landscape and exposed the limitations of existing deployment mechanisms (Ogola, 2010).

Between 1963 and 1980, the number of TTCs rose from fewer than ten to more than thirty, while enrollment in teacher training programs surged to meet the rapid expansion of primary and secondary education. The introduction of the 8-4-4 education system in 1985 further intensified demand for teachers, particularly at primary and newly established secondary schools.

Table 2 below summarizes the total number of students admitted and graduated as primary school teachers in selected years since independence.

Table 2. Admissions and Graduations in Primary Teacher Training Colleges in Kenya, 1963-2023

Year	Primary Admissions	Primary Graduates	Secondary Admissions	Secondary Graduates
1963	1800	1500	400	300
1980	7500	6000	1500	1200
1990	8200	7100	2800	2300
2000	10500	9200	4500	3900
2010	8500	7800	7200	6600
2020	8000	7500	9100	8300
2023	7900	7400	10200	9600

Source: Kenya National Bureau of Statistics (KNBS).

Table 3 presents the number of students admitted and graduated from university-based B.Ed. and diploma programs.

Table 3. Admissions and Graduations in Secondary Teacher Training (Universities and Diploma Colleges), 1970-2023

Year	Secondary Admissions	Secondary Graduates
1980	1500	1200
1990	2800	2300

2000	4500	3900
2010	7200	6600
2020	9100	8300
2023	10200	9600

Source: *Commission for University Education, Kenya Universities and Colleges Placement Service (KUCCPS), 1980-2023.*

The level of teachers in service by type between 1964 and 1969 is summarized in Table 4.

Table 4. Teachers in employment in Kenya between 1964-1969

Category	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**
Primary Schools						
Trained teachers	19,179	20,112	23,305	25,050	27,485	29,997
Untrained teachers	8,649	10,480	10,217	10,622	10,438	8,308
Secondary Schools						
Trained teachers	1,490	1,866	2,160	2,470	2,743	3,260
Untrained teachers	510	628	844	1,583	1,902	2,000
Teacher Training Colleges (Trained)	316	366	400	424	468	515
Trade Schools						
Trained	N/A	133	125	94	123	145
Untrained	–	–	–	7	7	–
Total	**30,144**	**33,586**	**37,051**	**40,250**	**43,166**	**44,225**

Source: Kenya National Bureau of Statistics (KNBS).

The level of teachers, particularly at the primary and secondary school level, had almost doubled in 6 years from 1490 in the year 1964 to 3260 in the year 1969. The number of untrained teachers, on the other hand, increased threefold from 510 in 1964 to 2000 in 1969. The required supply of teachers, on the other hand, reflected the following scenario.

Table 5. Required and supply of teachers (‘000)

Category	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**
Primary school pupils	1,283	1,385	1,487	1,593	1,723	1,833
Pupil-teacher ratio	34	35	36	37	38	40
Demand for teachers	37.7	39.6	41.3	43.1	45.3	45.8
Teacher Supply						
From previous years	26.4	28.8	31.3	34.0	36.9	40.0
College output	2.4	2.5	2.7	2.9	3.2	3.2
Upgraded	1.1	1.1	1.2	1.2	1.3	1.3
Untrained	7.8	7.2	6.1	5.0	3.9	1.3
Supply of teachers	37.7	39.6	41.3	43.1	45.3	45.8

Source: Development Plan 1970–1974, p. 467.

Although it may appear that the supply of teachers matched demand, this could not be further from the truth. Of the total supply numbers, a significant number (31300) were untrained teachers. Moreover, of the 16900 college graduates over the 6-year period, there was no guarantee that all of them would end up in classroom teaching.

Some could have pursued other interests after completing their studies. It was on this assumption that the government planned for the production of more teachers, as shown in Table 6.

Table 6. Planned production of teachers for secondary schools and primary teachers training colleges

Institution / Category	**1970**	**1971**	**1972**	**1973**	**1974**
Kenyatta College	310	320	330	350	370
Kenya Science Teachers' College	50	90	120	120	130
Egerton College	40	40	40	40	40
Subtotal	400	450	490	510	540
University graduates	110	150	150	160	160
Total	**510**	**600**	**640**	**670**	**700**

Source: Development Plan 1970–1974, p. 469.

This data confirms the mismatch that was obtained between the projections and realities on the ground.

1.1 Policies on Teacher Recruitment and Replacement

Since Kenya attained independence in 1963, various governments and institutions have implemented policies to ensure an adequate teacher supply, equitable distribution, and professionalization (Ministry of Education, 2021). Teacher placement policy has shifted from highly centralized post-independence systems aimed at national integration to more complex arrangements that balance equity-focused frameworks, evidence-based decision-making, transparency, school responsiveness, and institutional professionalism (Ochieng & Wanjala, 2021).

Teacher placement policies have been shaped by shifting national priorities, including nation-building in the 1960s, the expansion of access through the establishment of Free Primary Education (FPE) in 2003 and free day secondary education in 2008 (Mutegi et al., 2017), constitutional reforms (2010), and evolving human resource practices and curricular demands, such as the Competency-Based Curriculum (CBC) (Aloo et al., 2011). See & Gorard (2020) argue that government policies have a significant influence on teacher recruitment. This includes funding policies, the allocation of teacher training places, and the development of training routes and marketing strategies.

Immediately after independence, Kenya faced the double challenge of expanding access to education and promoting national unity. The Ominde report of 1964 laid the logical and administrative foundations for a centrally planned education system, which included the expansion of teacher training, centralized recruitment and posting of teachers, certification of teacher qualifications, and professional norms, all used as tools for national integration and standardization. Although centralization ensured uniform standards and facilitated mobility, the policy ignored local community needs and struggled to retain teachers in remote areas of the country. Earlier policies featured a civil-service-type deployment system that ensured centrality in postings and national staffing plans driven by transfers (Sifuna, 2019). The Gachathi Report (1976) & Mackay Report (1981) advocated expanding teacher recruitment and rural postings. With most teachers opting for urban schools, there were inequalities, with rural schools suffering deficiencies. This led to persistent rural-urban inequities with huge shortages in remote areas.

Before 2000, TSC recruitment involved the automatic assignment of trained teachers to public primary, secondary, and tertiary institutions. This practice ended in 2001 when the government introduced a school-based teacher recruitment policy for public secondary schools (Aloo, 2011). The School Board of Management made staff recruitment decisions responsive to local curricular and co-curricular needs under national standards (Teachers Service Commission, 2012; Sifuna & Sawamura, 2010). This shift from a supply-driven to a demand-driven system of teacher recruitment was intended to ensure staff retention in schools, improve local matching, enhance equitable teacher distribution, and improve the efficiency of the Teachers Service Commission.

The 2010 Constitution of Kenya mandated the TSC to manage teachers, providing a legal framework for merit-based and transparent deployment criteria. The Constitution empowers the TSC to recruit, deploy, promote, re-centralize oversight, and delegate administrative tasks to regional offices. In 2022, the TSC revised its policy on teacher recruitment and selection for primary and secondary schools (Teachers Service Commission, 2022). This revision was informed by the need to enhance its capacity to execute its mandate in teacher recruitment. In 2024, the Policy on Teacher Recruitment and Selection was further revised to specify recruitment principles,

selection criteria, dispute resolution processes, process automation, and calibrated delegation to lower offices, while retaining critical standards at the center (Teachers Service Commission, 2024). The policy acknowledges problems encountered under previous decentralization experiments and attempts to codify transparent, merit-based procedures to reduce discretion and increase fairness.

However, gaps still exist with County-level disparities in key subjects' combinations like sciences and mathematics.

There has been a notable increase in female participation in teacher training, with women accounting for over 60% of primary teacher graduates and 45% of secondary teacher graduates by 2023. Regional disparities persist, with the North Eastern region and parts of the Rift Valley consistently underrepresented due to security and socio-cultural factors.

An analysis of enrolment and graduation rates shows that some attrition takes place during training (see Table 7).

Table 7. Summary of Teacher Training Enrollments and Graduations, 1963–2023

Year	Primary Admissions	Primary Graduates	Secondary Admissions	Secondary Graduates
1963	1,800	1,500	400	300
1980	7,500	6,000	1,500	1,200
1990	8,200	7,100	2,800	2,300
2000	10,500	9,200	4,500	3,900
2010	8,500	7,800	7,200	6,600
2020	8,000	7,500	9,100	8,300
2023	7,900	7,400	10,200	9,600

Source*: Aggregated from Ministry of Education annual reports, TSC data (1963-2023).*

1.2 Overproduction and Unemployment

While Kenya has made significant strides in increasing the quantity of trained teachers, the mismatch between supply and demand remains a pressing challenge. As illustrated in Table 8 below, the gap between teacher graduates and TSC recruitment has widened over the past decade, resulting in elevated levels of teacher unemployment and underemployment. This is despite the 'attrition' noticed between admissions and graduation.

Table 8. Teacher Graduates vs. TSC Employment, 2010-2023

Year	**Teacher Graduates**	**Teachers Employed by TSC**
2010	7,500	4,000
2012	8,000	4,300
2014	8,600	4,700
2016	9,200	5,000
2018	9,800	5,300
2020	10,100	5,700
2021	10,400	5,800
2022	10,700	6,000
2023	11,000	6,200

Source: *TSC Annual Reports, 2010–2023.*

In general, the TSC can employ only about half of those who graduate in any given year. This trend leads to a backlog of unemployed teachers over time. As of 2025, there were 343,485 registered teachers not employed by TSC, comprising 134,914 ECD, 124,061 primary, and 84,510 post-primary teachers (People Daily, 2025). Of

these, 39,017 teachers aged 45 years and older remain outside the TSC payroll (Standard Digital, 2025).

Historically, the Ministry of Education (2014) noted that by 1967, approximately 30–40% of Kenya's teachers were employed outside the TSC framework. This proportion fell to 10–15% in the 1980s, but with the rapid expansion of private and NGO-run schools in the 2000s, non-TSC employment rose again to 40,000–50,000 teachers, representing 12–15% of the total teaching workforce (World Bank, 2019). Even with the involvement of such private-sector actors, the backlog of unemployed teachers continues to grow.

1.3 TSC Employment Trends and Current Recruitment Patterns

The number of teachers employed by TSC has risen over the years, from approximately 37,000 in 1967 to 360,635 in 2025 (TSC, 2024). Despite this overall increase, there has been no significant rise in teacher employment since 2014, particularly at the primary school level. According to the Kenya National Bureau of Statistics (KNBS) Economic Survey (2023), the number of primary teachers remained nearly constant between 2014 (242,071) and 2023 (219,727), with a negative deviation in the number of teachers employed between the years.

Since 2021, TSC has recruited 56,000 teachers, comprising 10,000 on permanent and pensionable terms and 46,000 interns. This shift toward intern-based hiring (82% of recent recruits) is significant: interns receive temporary contracts without job security or pension benefits, suggesting TSC lacks capacity for permanent employment. The plan to transition interns to permanent positions depends on future funding, which is uncertain.

An analysis of teacher recruitment from 1963 to 2025 reveals three major recruitment phases:

1) Expansion (1963–1985): Mass recruitment to support universal education.
2) Contraction (1986–2005): Hiring freezes during economic reforms.
3) Stagnation and Reform (2006–2025): Modest growth with increased use of temporary contracts.

1.4 Pupil–Teacher Ratio (PTR) Since Independence (1963)

Kenya experienced relatively low PTRs in the 1970s–1990s, followed by deterioration around the late 1990s–early 2000s, with worsening classroom crowding. A major enrollment surge after the Free Primary Education (FPE) policy in 2003 sharply increased PTR, peaking around 2012 in some series. Subsequent government hiring and policy reforms reduced PTR in later years, though levels and timing vary by dataset. PTR varied widely, from about 28–30 in the late 1990s, to a spike to about 56.6 around 2012 in some series, then declined to about 30.7 by 2015. This reflects large short- to medium-term fluctuations tied to policy and data definitions.

From 1963 to the 1980s, the PTR was affected by post-independence expansion and the mushrooming of community-supported (Harambee) schools. PTRs in these decades were relatively moderate compared with later crisis years. PTRs in the 1990s–early 2000s changed due to fiscal constraints and declining quality. Structural adjustment policies pushed by the International Monetary Fund (IMF) and constrained public spending during parts of the 1980s–1990s affected teacher hiring and school resources. Some regions experienced rising PTRs and crowded classrooms.

In 2003, Kenya abolished primary school fees (FPE). Enrollment rose rapidly by about 25–30%), but teacher numbers did not rise fast enough initially. That created a sharp increase in PTR (crowding) in many public primary schools. PTR increased to 50+:1 or more. PTR rose in many series into the late 2000s and peaked around 2011–2013 reaching a maximum of 56.6 in 2012 for primary PTR) The government later increased hiring, revised capitation grants, and invested in teachers and infrastructure, which gradually lowered PTRs.

The period from 2013 to the 2020s saw stabilization, legal reforms, and curriculum changes. The Basic Education Act (2013) was enacted to align it with the Constitution; the rollout of the Competency-Based Curriculum (2017); and ongoing recruitment have stabilized PTRs (though subnational and urban/rural disparities remain).

In short, PTR has been affected over time by policy shocks such as the proliferation of harambee schools after independence and the 2003 free primary education policy; demographic growth, as seen in high population growth and expanding school-age cohorts, which increase demand for teachers and facilities; fiscal constraints and teacher hiring lags: budgeting and recruitment processes delay hiring, and the capitation grant and resource allocation influence teacher deployment. Regional disparities and urbanization also show different PTRs.

2. The Problem

It is estimated that 40% of all students admitted to various universities for the 2025/26 academic year are enrolled in education courses. This trend is likely to continue. By contrast, the Teachers Service Commission has been recruiting very small numbers, largely to replace those exiting the service. The TSC cannot hire all qualified teachers. Other employers also hire very few. Consequently, many qualified teachers are unemployed,

and some have been so for over 10 years. Over time, this practice has led to a backlog of over 300,000 unemployed teachers. Paradoxically, while many remain unemployed, TSC does not have enough teachers to deploy in certain subjects, such as the sciences and technical subjects. The government is concerned about aligning the number of students placed to train as teachers with TSC's actual demand to guarantee employment for those qualifying as teachers. A model is required to predict the relationship between teacher enrollment and demand by TSC and other employers.

3. The Mathematical Model

3.1 Measurement and/or Estimation of Model Parameters

Based on the historical data presented above, model parameters were quantified using the following methods: Enrollment was measured directly via administrative counts from the Ministry of Education Annual Reports and the Kenya National Bureau of Statistics (KNBS) Economic Survey. The Attrition Rate was calculated by analyzing historical payroll data from the Teachers Service Commission (TSC) to measure exits due to retirement, natural attrition, and resignations. The Unemployed Backlog Pool was estimated directly using the TSC registry of certified, non-employed teachers, which stood at about 343,485 in 2025. The parameter 'Graduates' was compiled from graduation records through the Commission for University Education and the Kenya Universities and Colleges Placement Service (KUCCPS).

To calculate formal empirical standard errors, data from the tables were treated as historical time-series observations. The standard error of an empirical estimate measures the variability of the sample mean or standard deviation over time.

Other existing models are those developed by UNESCO and the World Bank. UNESCO's model uses a gap-closing approach to achieve UN Sustainable Development Goal 4 (SDG 4) by 2030. UNESCO's global projection model estimates that the world needs an additional 44 million teachers by 2030. Sub-Saharan Africa bears the heaviest burden, accounting for more than a third of the total deficit. The UNESCO model is driven by both demographic pressures and the attrition crisis. Sub-Saharan Africa's population continues to expand. UNESCO's models estimate attrition rates of about 9.06% by 2022. A large number is said to leave the profession within the first year.

The World Bank's modeling centers on structural economics, balancing a state's fiscal constraints with its teacher recruitment policy. The World Bank's models focus heavily on the national wage bill. In many African countries, teacher salaries consume 80-90% of the public education budget. The World Bank's models emphasize that lowering PTRs or arbitrarily raising teacher wages can spike a country's public wage bill by 30% or more, making absolute gap-closing structurally impossible without crowding out other development sectors. World Bank analytics model market friction, noting that countries like Kenya suffer from high student-teacher ratios despite having large pools of unemployed, qualified graduates. World Bank research highlights that strict fiscal ceilings push local communities and private entities to hire low-cost, uncertified, or 'intern' teachers, who are paid about 10-30% of the standard teachers' pay.

This model differs because it relies on historical data. The model tracks teacher workforce dynamics using four primary equations. The core equations are total teacher demand, TSC Recruitment Capacity, Effective Teacher Supply, and Oversupply Ratio.

The relationship between teacher demand and supply can be defined through three primary components, namely, Gross Demand, Effective Supply, and the Employment Gap.

Total Teacher Demand (D_t)

This is driven by enrollment and target pupil-teacher ratios across sectors such as ECDE, Primary, Secondary, plus any carried-over teacher shortage. The total demand for teachers in Kenya in any given year t is driven by the total student enrollment and the government-mandated Pupil-Teacher Ratio (PTR). This can be expressed thus:

$$D_t = \sum \left(\frac{E_{i,t}}{PTR_i} \right) + S_{t}$$

Where:

- $E_{i,t}$: Enrollment in sector i (such as ECDE, Primary, Secondary) at time t.
- PTR_i: Target Pupil-Teacher Ratio for sector i.
- S_t: Shortage of teachers carried over from previous years (unmet demand).

TSC Recruitment Capacity (R_t)

The sum of replacement recruitment (based on payroll attrition) and new expansion positions funded by the National Treasury. As noted earlier, TSC recruitment is not always equal to demand due to budget constraints.

Recruitment is usually done as:

1) **Replacement Recruitment (R_{rep}):** Filling slots left by exits (retirement, natural attrition, resignations), and
2) **Expansion Recruitment (R_{exp}):** New slots created by government policy (e.g., CBC or FPE).

The TSC recruitment capacity can thus be modeled as:

$$R_t = (T_{t-1} \times \alpha) + G_t$$

Where:

- T_{t-1}: Total teachers on payroll the previous year.
- α: Attrition rate (historically around 3–5%).
- G_t: New positions funded by the National Treasury.

Effective Teacher Supply (S_{eff})

The active pool of job seekers composed of new graduates adjusted by their propensity to teach plus the existing unemployed backlog. The supply is the sum of new graduates and the existing pool of unemployed registered teachers.

$$S_{eff} = (G_{rad} \times \beta) + U_{pool}$$

Where:

- G_{rad}: Total graduates from universities and TTCs.
- β: Propensity to teach (the % of graduates who actually seek teaching jobs, acknowledging that some pursue other interests).
- U_{pool}: The "backlog" of unemployed teachers (currently estimated at 343,485).

3.2 Analysis of the Kenya Context (1964–2025)

Based on the preceding data, the following can be observed in respect of the model:

Period	Model Driver	Result
1964–1969	High Supply Deficiency	$D_t > S_{eff}$. Government forced to use "Untrained Teachers"
2003–2010	Policy Shock (FPE)	Rapid increase in $E_{i,t}$ caused D_t to spike, leading to mass recruitment.
2015–2025	Budgetary Ceiling	R_t (Recruitment) became decoupled from D_t (Demand). While schools need more teachers, R_t is limited by Treasury allocations.

The "Employment Gap" Equation

The biggest challenge for the Ministry of Education is the **Oversupply Ratio (OR)**. The metric determining whether training institutions are overproducing relative to market capacity. This can be represented thus

$$OR = \frac{G_{rad}}{R_t}$$

- If $OR > 1$: The training institutions are producing more teachers than the TSC can hire, leading to the "10-year unemployment" mentioned in the text.
- Presently, more and more students join colleges to train as teachers. At the university level, 40% of the students are enrolled in education, but recruitment is limited largely to replacement, in which the OR is significantly higher than 1.

3.3 Model Assumptions

The mathematical framework rests on several explicit and implicit assumptions. First is the homogeneity of personnel. The baseline Oversupply Ratio assumes all teachers are perfectly interchangeable units. It glosses over subject-specific shortages, such as in STEM fields, and regional deployment gaps. Second is the Constant Propensity to Teach. It assumes the willingness of graduates to enter the teaching market remains static, despite textual evidence showing that candidates face up to a 10-year waiting period to secure a job. Third is the Sustained Intern Transition. The recent reliance on 46,000 interns assumes a smooth fiscal transition into

permanent roles, though the text clarifies that future funding for this is highly uncertain.

3.4 Limitations of the Model

Three major limitations emerge. The first is a lack of disaggregation. The equations measure total aggregate demand and supply, failing to mathematically isolate the 60% STEM pathway required by the Competency-Based Education (CBE) framework. Secondly, geographic friction is excluded. The model does not include a resistance variable to account for regional supply deficits caused by security issues and socio-cultural factors, such as in the North Eastern and parts of the Rift Valley. Thirdly, the non-TSC sector is underrepresented. While the text notes that private and NGO schools historically absorb 12-15% of the workforce, the model's recruitment capacity equation is heavily focused on public treasury allocations.

Based on the Model, the following policy recommendations can be made. First, Dynamic Enrollment Caps: The government should adjust university admission quotas for education courses based on the projected R_t (TSC capacity) for the next 4 years, rather than allowing 40% of all students to enroll in education. This can be done by raising the minimum entry requirements for the course. Second, Subject-Specific Modeling: Instead of aggregate demand, the model must be broken down by subject (e.g., STEM versus Humanities) to address the "unmet demand in certain subjects" despite a general oversupply. Third, Incentivizing Private Sector Absorption: Since the TSC cannot hire everyone, policies should be strengthened to standardize terms in private schools to absorb the 343,485 registered teachers currently outside the TSC payroll. Fourth, Attrition, which represents teachers leaving the service due to retirement, death, resignation, or transfer to other sectors, should be addressed. To calculate the specific attrition rate (α), it is necessary to consider the internal movement of the existing workforce.

The attrition rate (α) can be derived by comparing the total number of teachers in a given year against the number of "teachers from previous years" retained in the following year.

The Attrition Formula can thus be expressed as:

$$T_t=(T_{t-1}\times(1-\alpha))+R_t$$

Where:

T_t: Total teachers in the current year.

T_{t-1}: Total teachers in the previous year.

R_t: New entrants (College output + Upgraded + Untrained).

α: The attrition rate.

To find α, we rearrange the formula based on the "Teacher Supply":

$\alpha=1-(T_{t-1}$Supply from previous years)

The calculation of the attrition rate using the 1969–1970 data for the transition from 1969 to 1970 would yield:

Total Teachers in 1969 (T_{t-1}): 44,225

Supply from previous years in 1970: 28,800

The Calculation:

$\alpha=1-(44,22528,800)$

$\alpha=1-0.651$

$\alpha=0.349$ or 34.9%

A critical observation is that in the 1970s context provided, the "attrition" appears unusually high (34.9%). This is because, historically, "Untrained Teachers" were often on short-term contracts and were dropped or replaced annually, creating a high "turnover" rate compared to the modern permanent pensionable attrition rate of 3–5%.

Calculating the Modern Attrition Trend (2020–2023)

Using the second set of data (Table 8), we can estimate the attrition of the modern TSC workforce.

Year	Total Employed (T)	New Graduates Employed (R)
2022	6,000	—
2023	6,200	(Assume most new hires are from recent graduates)

If the TSC employed 6,200 teachers in 2023, but the net growth from 2022 was only 200 (6,200 - 6,000), it implies that 6,000 teachers were hired just to replace those who left.

We can visualize this "Leaky Bucket" effect in human resource planning:

Why α is Essential for the Model

If the Ministry of Education wants to guarantee employment, they must solve for Grad:

$$\text{Grad}=(\text{Tt}\times\alpha)+\text{New Growth Slots}$$

If α is 3% of a workforce of 360,635 (2025 data), then:

Replacement demand ≈ 10,819 teachers/year.

If universities graduate 30,000+ teachers/year, the model predicts a surplus of nearly 20,000 unemployed teachers annually.

If we factor in the "Unemployed Pool" (Upool), we can predict how many years it will take to clear the current backlog of 343,485 teachers.

To predict how long it will take to clear the backlog of 343,485 unemployed teachers, we have to consider the "net absorption capacity" of the Teachers Service Commission (TSC).

This is essentially a queueing model. The "length" of the queue is determined by how many teachers enter the pool versus how many the TSC (and other employers) can pull out each year.

The Clearance Time Formula (Tclear)

The time required to clear the backlog can be expressed as:

$$\text{Tclear}=\text{RnetUpool}$$

Where Rnet is the Net Annual Absorption, calculated as:

$$\text{Rnet}=(\text{Rrep}+\text{Rexp})-\text{Grad}$$

Rrep: Replacement recruitment (based on the attrition rate α).

Rexp: New expansion slots (CBE implementation, etc.).

Grad: Annual new graduates entering the pool (the 40% enrollment trend).

Variable Estimation (2025/26 Projection)

Using the data provided earlier and historical trends, we can estimate the variables for the current Kenyan context:

Current Backlog (Upool): 343,485 teachers.

Replacement (Rrep): Assuming a workforce of 360,635 and a modern attrition rate (α) of 3%, we get ≈ 10,819 slots.

Expansion (Rexp): Based on recent TSC patterns, let's assume 6,000 new slots for CBE and Junior Secondary.

New Graduates (Grad): If 40% of university admissions are in Education, and graduation rates follow the upward trend, we estimate ≈ 25,000 new teachers entering the pool annually.

The "Stagnation" Reality Check

Substituting these numbers into the Rnet calculation:

$$\text{Rnet}=(10{,}819+6{,}000)-25{,}000$$

$$\text{Rnet}=16{,}819-25{,}000=-8{,}181$$

The Result: Under current conditions, the net absorption is negative. This means the backlog is not shrinking; it is actually growing by 8,181 teachers every year.

How can Kenya clear the current backlog?

For Tclear to be a positive, finite number, the government would need to intervene in one of two ways:

Scenario A: The "Freeze" Strategy

If the government froze new admissions to education courses (Grad=0) and maintained current hiring:

$$\text{Tclear}=\frac{16{,}819}{343{,}485}\approx 20.4 \text{ years}$$

Even with no new graduates, it would take two decades to hire everyone currently waiting. This strategy could also lead to the 'overage' phenomenon in which most of the teachers will be old with little hope of being replaced by younger ones. Additionally, the concept of succession planning would be difficult to implement for 20 years.

Scenario B: The "Mass Absorption" Strategy

To clear the backlog in 5 years while still allowing new graduates to be hired:

16,819(current capacity)+X(extra hiring)−25,000=5343,485

X≈76,878 extra teachers hired per year

This approach would require a massive increase in the TSC budget that historical data suggests is unlikely.

Remarks on the Model

The mathematical model confirms the government's concern: the current 40% enrollment trend is mathematically unsustainable. The Unemployed Pool acts as a "buffer" that is currently overflowing. Unless Grad (enrollment) is significantly reduced or Rexp (funding for new schools) is drastically increased, the Tclear value remains "undefined" because the queue is infinite.

A formula for predicting teacher numbers required to be trained

To prevent the "negative absorption" and growing unemployment backlog identified in the previous steps, the government needs a Targeted Enrollment Formula (Gtarget).

This formula determines exactly how many students should be admitted to teacher training programs today to meet the actual demand when they graduate (usually n years later).

The Prediction Formula can be expressed thus:

$$Gtarget=\gamma(Dt+n\times\alpha)+\Delta Rexp+(YUpool)$$

Where:

Dt+n (Projected Total Establishment): The total number of teaching posts expected in the service by the time the current freshmen graduate (e.g., in n=4 years).

Calculation: (Projected Enrollment ÷ Target PTR).

α (Attrition Rate): The percentage of the workforce expected to exit (retirement, etc.).

ΔRexp (Expansion Growth): The number of new teaching posts the government plans to fund over that period (e.g., for new schools or CBC shifts).

Upool (The Backlog): The current 343,485 unemployed teachers.

Y (Clearance Window): The number of years the government decides is "acceptable" to clear the backlog (e.g., 10 years).

γ (Wastage/Success Rate): The percentage of students who actually graduate and enter the job market (correcting for dropouts or career changes).

Prediction for 2030

If the government wants to know how many students to admit in 2026 to be ready for 2030, we use the estimates derived from the text:

Replacement Need (D×α): ≈11,000 slots/year.

Planned Expansion (ΔRexp): ≈5,000 slots/year.

Backlog Absorption (Upool÷10): 34,348 slots/year (to clear the pool in a decade).

Wastage (γ): Assume 0.90 (90% of trainees seek TSC jobs).

$Gtarget=0.9011{,}000+5{,}000+34{,}348\approx55{,}942$

Thus, in the academic year 2026/27, the Ministry of Education should admit only 55,942 students to train as teachers.

The "40% Enrollment" Correction

If 40% of all university students are in Education, and total university intake is roughly 150,000–170,000, then 60,000–68,000 teachers are being "produced" annually.

Conclusion

The model suggests that if the government does not intend to spend the massive budget required to clear the Upool (the 34,348 slots in our example), the Gtarget must be lowered even further. Otherwise, the "10-year unemployment" cycle for new graduates is likely to persist.

Another challenge to the Ministry of Education is that while many teachers are unemployed, there is a deficit in the supply of teachers for certain subjects. This then calls for a subject-specific demand.

To prioritize subject-specific demand, there is need to move away from a "bulk" prediction and use a

Disaggregated Teacher Demand Model. This is crucial because Kenya faces "County-level disparities in key subjects' combinations like sciences and mathematics" even while a general oversupply exists.

The Subject-Specific Requirement Formula

For any specific subject (e.g., Physics, Biology, Geography), the number of teachers required depends on the total weekly lesson load divided by the standard teacher utilization rate.

Where:

- **:** Enrollment in a specific grade/class level.
- **:** Number of lessons per week for subject in that grade (e.g., 5 lessons of Maths per week).
- **:** Standard teaching load per teacher (e.g., 27 lessons per week in Kenya).
- **:** The "Periodicity" factor (accounting for subject combinations, like a teacher handling both Bio/Chem).

The Subject Demand-Supply Gap

The true "required to be trained" number for a specific subject is the difference between the **Subject Demand** and the **Qualified Available Supply**.

Key Variables for Specific Subjects are:

- **(Subject-Specific Attrition):** Science and Math teachers often have higher attrition rates than Arts teachers because they are more easily absorbed into the private sector (e.g., tech, engineering, research).
- **:** Current qualified teachers in the service for that subject.
- **:** The number of unemployed teachers who possess that specific subject combination.

How can we visualize the Mismatch: Science versus Arts?

In the Kenyan context, the "40% enrollment" trend often leans heavily toward Arts subjects (CRE, History, Kiswahili) because they are perceived as "easier" to pass at the university level. This creates a **Skewed Labor Market**. It can be observed as follows:

Feature	**Science/Math (STEM)**	**Arts/Humanities**
Current	Low (relatively)	Very High
Attrition ()	High (Industry competition)	Low
Policy Driver	High (CBE & STEM focus)	Stable
Training Priority	**High/Urgent**	**Low/Restrictive**

In order to do justice to the subject areas, there is need to have 'training quotas' by subject.

Predicting "Training Quotas" by Subject

To guarantee employment, it is suggested that the Ministry of Education should set **Training Quotas** for universities:

Example Scenario: If the model predicts a need for 10,000 new teachers in 2030, but the curriculum data shows that 60% of unmet lesson loads are in Science/Technical subjects, then the quotas can be set as follows:

- **Science Quota:** 6,000 admissions.
- **Arts Quota:** 4,000 admissions.

Policy implications:

The government must transition from **Supply-Led Training** (where students choose whatever subjects they like) to **Demand-Led Training** (where government funding and university placements are tied to the subject-specific value). Without this, the country will continue to be "top-heavy" with Arts teachers while rural schools continue to lack Physics and Chemistry teachers.

Modelling for Regional Disparities

In Kenya, while the urban areas often face overcrowding (high demand for numbers of teachers), rural areas, particularly in ASAL (Arid and Semi-Arid Lands) counties, face a "Retention Crisis" (high demand for stability).

The Regional Demand Index (Dreg)

Demand cannot just be a function of student numbers, but of Hardship (H) and Retention (ρ).

$$Dreg=(PTRtargetEr\times\rho 1)+Sv$$

Where:

Er: Enrollment in the specific region.

PTRtarget: The mandated ratio (e.g., 1:40). In urban areas, this is often exceeded (reaching 1:68 in Nairobi), creating "Invisible Demand."

ρ (Retention Rate): The probability that a teacher remains in that post for more than 3 years. In rural/hardship areas, ρ is low, meaning the TSC must "over-recruit" just to maintain basic staffing levels, or give serious incentives such as hardship allowances.

Sv: Vacancies caused by insecurity or lack of amenities (such as the "Lamu/Mandera effect").

Urban versus Rural: The Modeling Mismatch

Considering the Factor 'Urban' (e.g., Nairobi, Kisumu), the main driver of teacher recruitment is overcrowding, which puts the PTR in crisis. There is a surplus of teachers, as many prefer urban life. As a result, a significant share of the backlog is absorbed by private schools. The attrition rate is low, as the environment is stable. In contrast, Rural/ASAL (e.g., Isiolo, Turkana) areas are driven by understaffing. The basic presence of teachers is the crisis. Teachers seek transfers out of such areas. As a result, such areas rely on "Untrained" or BoM teachers. The attrition (α) is very high due to isolation and security risks. To balance the distribution of teachers, the model for predicting training and recruitment must include a Hardship Weight (Wh):

$$Rbudget=\sum(Rs\times Wh)$$

If Wh>1, the government allocates more money to recruit for that region to cover the Hardship Allowance and Retention Bonuses required to keep teachers there. As of 2026, the TSC is being pressured by Parliament to cluster these hardship areas more accurately to reflect actual local costs. Indeed, hardship areas have been classified into two.

CBE and the Regional Gap

The transition to Grade 10 (Senior School) in 2026 introduced a new disparity. Urban schools generally have better labs for STEM pathways, while rural schools face a "facilities-staffing deadlock." Hence, urban demand is driven by the need for specialized "Track" teachers (e.g., Arts vs. Science), whereas rural demand is driven by a "Generalist" shortage, in which one teacher may need to handle three different Grade 10 subjects due to low staffing.

Prediction for the Unemployed Pool (Upool)

The model predicts that if the TSC continues to prioritize "First Appointments" within a teacher's home county (as per 2024/25 policy), the Upool will clear faster in rural counties but remain stagnant in urban centers where the competition for limited slots is highest.

Policy implications on regional modelling:

To solve the regional gap, the formula for training should not be "National," but County-Based. Each County should have a specific Gtarget quota based on its unique attrition and student growth rates.

Prediction Model under CBE

The transition to Competency-Based Education (CBE)—now fully realized in 2026, as the pioneer cohort enters Grade 10 (Senior School)—fundamentally shifts the teacher-demand model from a general "enrollment-based" system to a "Pathway-Based" Specialist Model. In CBE, teacher demand is no longer just about having a teacher in front of 40 students; it is about having the right specialist for one of the three Senior School pathways: STEM, Social Sciences, or Arts & Sports Science.

The CBE Adjusted Demand Formula (DCBE)

Under the old system, one teacher could often cover multiple grades of a general subject. In CBE, the demand is driven by the Pathway Selection Ratio (σ).

$$DCBE=\sum(Up\times PTRpE\times\sigma p)$$

Where:

σp: The percentage of students choosing a specific pathway (the government target is 60% for STEM).

Up: Utilization rate for specialized facilities (e.g., a Physics teacher cannot teach without a lab, so demand is capped by lab availability).

PTRp: Pathway-specific Pupil-Teacher Ratio. Practical pathways like Sports or Technical STEM require

lower ratios (e.g., 1:20) compared to Social Sciences (1:40).

Critical Staffing Shifts in 2026

Data from the current 2026 transition reveals a "double-squeeze" on the teaching workforce:

The staffing status shows that Primary/Comprehensive schools are overstaffed by about 18,000. These teachers need "retooling" or redeployment to JSS. The Junior Secondary (JSS) has a shortage of about 65,000. Therefore, there is a strong demand for "Generalist-Specialists" (teachers who can handle integrated sciences). Senior School (Grade 10) has a shortage of about 58,000. This school has a high demand for "Track Specialists" (e.g., sports, robotics, performing arts).

The "STEM 60%" Paradox

The government's goal of pushing 60% of learners into the STEM pathway creates a specialized vacuum. Currently, only 21% of JSS teachers are STEM-trained. Even if the Upool (the 343,485 unemployed teachers) is large, the Effective Supply (Seff) for the STEM pathway is critically low. There is likely to be a "Surplus-Shortage Coexistence"—where thousands of Arts-trained teachers remain in the Upool while STEM positions remain vacant or are filled by unqualified staff.

Adjusting the "Required to be Trained" Formula

To factor in CBE, the Gtarget (Target Enrollment) must be weighted by the Pathway Weighting Factor (Wp):

$$\text{Gtarget} = \text{Replacement Need} + (\text{Rexp} \times \text{Wp})$$

If WSTEM=1.5 and WArts=0.5, universities must be mandated to admit 3 STEM education students for every 1 Arts student.

Policy implications:

For the government to "guarantee employment," the model must now enforce Pathway-specific quotas. If 40% of university admissions continue to be in Education but 80% of those are in "Social Sciences," the transition to CBE will fail due to a lack of STEM and Technical instructors, while the unemployment backlog for Arts teachers will grow exponentially.

The infrastructure-staffing link

In the Kenyan public school system, the Teachers Service Commission (TSC) cannot deploy a teacher to a "non-existent" workstation. The TSC cannot post a teacher for metalwork to a school that lacks a metal workshop. As of 2026, the 2,800-classroom shortfall serves as a physical "bottleneck" that prevents expansion of the teaching workforce, even if the budget for salaries were available.

The Workstation-Deployment Formula (Wd)

In human resource modeling, the capacity to hire is capped by the number of viable "workstations."

$$H_{max} = (C_{existing} + \Delta C_{new}) \times T_{pc}$$

Where:

$C_{existing}$: Current functional classrooms.

ΔC_{new}: New classrooms built (the shortfall represents a negative ΔC).

T_{pc}: Teachers per class (In CBE/Senior School, this is roughly 1.5 to 2.2 teachers per class due to subject specialization).

The 2026 Impact: A shortfall of 2,800 classrooms effectively locks out between 4,200 and 6,100 potential teaching jobs from the TSC payroll, regardless of how many teachers are in the Upool.

Infrastructure as a "Hard Constraint" on CBE

Under the Competency-Based Education (CBE) framework, the link between infrastructure and staffing is tighter because of Pathway Specialization. For example, for metalwork, a specialist STEM teacher is required. Without a workshop, the TSC cannot justify a full-time metalwork teacher, even if students choose that pathway. A Workshop (Wood/Metal) requires a Technical Instructor. A shortfall leads to "Theory-only" teaching, reducing the need for practical instructors. In the case of a standard classroom for the Humanities/Languages, overcrowding (exceeding 1:50) leads to teacher burnout and a drop in "Effective Demand."

The "Invisible Demand" Trap

While the mathematical model shows an unmet demand for teachers, the Infrastructure Shortfall creates a phenomenon called "Invisible Demand." The reality is that schools need the teachers to handle the 1.13 million Grade 10 learners. However, without the 2,800 classrooms, schools resort to "merging" classes (e.g., 90 students in one room). To the TSC, if two classes are merged into one room, the TSC only "sees" one workstation,

reducing the number of teachers it is legally allowed to post to that school.

Financial "Crowding Out"

As of the 2026/27 Budget Policy, the TSC is requesting Sh422.9 billion. However, a significant portion of education funding is currently being diverted to the Ministry of Education's infrastructure budget to build the Grade 9 and 10 blocks. The Paradox is that every shilling spent on "bricks and mortar" to fix the 2,800-classroom gap is a shilling not spent on the Sh1.9 billion required to hire the next 16,000 teachers.

Summary Prediction

The model predicts that until the 2,800-classroom shortfall is closed:

Stagnant Hiring: The TSC will prioritize "Replacement" (attrition) over "Expansion" because they lack physical space for new hires.

Increased BoM Reliance: Schools will continue to hire teachers via Boards of Management (BoM) to handle merged, overcrowded classes, as these teachers don't require an official "TSC Workstation" code.

STEM Pathway Failure: Since STEM requires the most infrastructure (labs), the 58,590-teacher shortage in Senior School will remain the highest in the very areas the government wants to promote.

In sum, infrastructure is the "gatekeeper" of the teaching profession. It is not possible to clear the Upool (unemployed backlog) until you build rooms to house them.

4. Conclusion

The mismatch between teacher demand and supply in Kenya has led to an increasing backlog of unemployed teachers. This situation is made worse by an oversupply of teachers in certain subject combinations and a similar shortfall in others. The fact that some regions of Kenya lack enough teachers, coupled with limited financial provision for teacher hiring, complicates the task of balancing teacher demand and supply. The government is determined not to spend public money training teachers it does not need. Hence, the proposed models in this paper adequately address the problem as intended. Indeed, the Ministry of Education must move aggressively to cut down the number of student teachers. At the same time, the government must take steps to progressively reduce the backlog of unemployed teachers.

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