

# Python-Based Mapping of Productive Technical Teachers Using Google Colab in Tuban's Vocational High Schools

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## ABSTRACT

The availability of productive subject teachers is a crucial factor in ensuring the quality of vocational education, particularly at the level of Vocational High Schools (SMK). This report presents the results of a mapping study on the adequacy of productive teachers in technical departments at public SMKs in Tuban Regency, under the supervision of the Regional Education Office of Bojonegoro. The study aims to identify the distribution of productive teachers across departments, assess their adequacy based on the ideal minimum requirements, and determine whether there is a shortage or surplus relative to the ideal maximum needs. Data were obtained from official school reports and analyzed using descriptive quantitative methods. The findings show that 96% of the 25 mapped departments have met the minimum required number of productive teachers, while one department still faces a shortage. On the other hand, 36% of the departments have a surplus of teachers, as the number exceeds the ideal maximum threshold. The distribution of teachers also reveals disparities both within schools (between departments) and among different schools. This mapping provides valuable insight for schools and the regional education authority in planning teacher redistribution, recruitment, and dual-skill training. Furthermore, the results underscore the importance of developing a more dynamic and integrated teacher data system to support sustainable human resource planning in vocational education.

**Keywords:** Mapping, productive teacher, teacher adequacy, vocational education, vocational high school (SMK)

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## 1. INTRODUCTION

Teacher quality and comprehensive competencies are essential for effective vocational education and preparing graduates to meet industry needs (Fatimah et al., 2024). Furthermore, teacher professionalism and discipline have been shown to significantly influence performance, which ultimately impacts the quality of education in vocational high schools (SMK) (Rosmawati et al., 2020). Additional studies indicate that the teacher's multifaceted role in the learning process, whether as a manager, facilitator, or motivator, contributes substantially to learning effectiveness and student achievement in vocational settings (Dewi & Yuniarsih, 2020; Ilahi & Imaniyati, 2016). Teachers are also responsible for developing contextual curricula, managing workshops and laboratories, and fostering students' soft skills and entrepreneurial character (Efendi et al., 2022; Yoto et al., 2020). Moreover, a dual-expertise program designed to convert "adaptive" (general subjects) teachers into "productive" (vocational subjects) teachers has demonstrated positive outcomes in enhancing both teacher competency and the quality of instruction (Widayana, 2022). Consequently, the teacher functions not merely as an instructor but as a strategic agent in developing vocational graduates who are competent, professional, and prepared to compete in the modern industrial workforce. Despite the pivotal role of teachers, the shortage of "productive" (vocational subject-matter) teachers in Indonesian Vocational High Schools (SMK) presents a critical issue that adversely affects the quality of vocational training and graduate employability. The study by Wibowo & Lyau (2021) found a national shortage of 93,542 specialized vocational teachers, with the deficit being larger in private schools (66,378) than in public schools (27,164). This scarcity stems from several factors, including a mismatch between the educational backgrounds of teachers and the required

vocational competencies, alongside a lack of specific and continuous professional development programs (Widayana, 2022). Another challenge is the limited capacity of the Vocational Teacher Professional Education (PPGV) program, which has not yet been able to meet the national demand for professionally qualified vocational educators (Handayani & Djohar, 2020). Teacher competency gaps also contribute to the ineffective management of workshops and laboratories, which are essential for supporting students' hands-on vocational practice (Yoto et al., 2020). The shortage of vocational teachers leads to an inequitable distribution of vocational course instruction, thereby diminishing the quality of learning and the job readiness of graduates (Rosmawati & Meilani, 2019). Meanwhile, initiatives such as the dual-expertise training program have yielded positive contributions, yet their implementation has not been uniform across all regions (Widayana, 2022). Additionally, deficiencies in the technological literacy and competence of vocational teachers widen the gap between the curriculum and the demands of industry (Wardoyo et al., 2024). Moreover, inadequate pedagogical competence and outdated teaching methodologies further exacerbate poor student learning outcomes in vocational subjects (Tilaar et al., 2024).

To date, productive teacher mapping has been conducted primarily at the national level, while in-depth studies at the district level, particularly in Tuban, remain minimal. To address the aforementioned shortage of vocational teachers, this article reports on a project involving the mapping of teacher adequacy across various engineering departments within vocational high schools under the jurisdiction of the Tuban Regency Education Branch Office. Given the strategic role of teachers in vocational education, particularly in creating contextual, practice-based learning environments that align with industrial requirements, this mapping initiative represents a critical first step toward understanding the actual, on-the-ground availability of vocational educators in the region. The project employed a data-driven approach to identify the distribution, qualifications, and number of available vocational teachers for each field of study. Furthermore, it aimed to analyze the discrepancy between the existing teacher supply and the ideal demand. The findings from this mapping are expected to provide an empirical overview of the distribution and competency challenges concerning vocational teachers. This data will serve as a foundational basis for formulating policy recommendations regarding teacher recruitment, placement, and capacity development, intended to enhance the quality of vocational instruction and better prepare vocational high school graduates for the challenges of the modern workforce.

## 2. LITERATURE REVIEW

### 2.1. VOCATIONAL EDUCATION: A PATHWAY TO WORK READINESS

Historically, vocational education in Indonesia has undergone significant development, with its roots traceable to the pre-independence era under the Dutch colonial administration (Suharno et al., 2020). The primary objective of vocational education is to cultivate a skilled workforce capable of contributing to national economic development by reducing unemployment rates and fostering entrepreneurship (Subiyantoro et al., 2023; Sunyoto & Andri, 2021). This educational stream emphasizes practical training over theoretical mastery, thereby preparing students for specific professions and alleviating pressure on higher education pathways (Poedjiastutie, 2019). The curriculum in Vocational High Schools (SMK) is generally aligned with industrial needs, ensuring that graduates possess the soft skills and hard skills required by the modern workforce (Rosina et al., 2021). Furthermore, vocational education plays a crucial role in human development by enhancing critical thinking, emotional intelligence, and proficiency in science and technology (Ichwanto et al., 2020). Recognizing its importance for sustainable economic growth, the Indonesian government has implemented policies to increase the ratio of vocational high schools to general high schools (Suharno et al., 2020). Despite facing challenges such as limited infrastructure and variable support from the industrial sector, vocational education remains a primary strategy for preparing a competent workforce ready to meet future challenges (Fairman et al., 2020; Muharam & Afrilia, 2024).

Vocational education prioritizes the mastery of practical skills that are directly relevant to the demands of industry and the labor market (Rosina et al., 2021; Subiyantoro et al., 2023). The curriculum in vocational schools is designed to develop both the hard and soft skills that align with business and industry requirements, enabling graduates to adapt rapidly to professional environments (Ahmad et al., 2023; Rosina et al., 2021). The competency-based approach within vocational education aims to enhance student proficiency through work-relevant learning, although its implementation is still in the early stages and confronts various challenges (Ahmad et al., 2023). The "link and match" concept is key to bridging the gap between education and industrial needs, involving industry in the educational process through dedicated industry-led classes, internships, and training programs (Gholibi et al., 2024; Irwanto, 2021; Koehler et al., 2020; Saryadi et al., 2024). This model allows students to gain direct experience in authentic work environments, significantly improving their readiness for employment (Fania et al., 2024; Saryadi et al., 2024). Moreover, government support and robust industry collaboration are essential to ensure the successful implementation of this policy (Fairman et al., 2020; Saryadi et al., 2024). Consequently, vocational education in

Indonesia plays a vital role in creating a skilled and job-ready workforce, which in turn supports sustainable economic growth (Rosina et al., 2021).

In addressing the challenges of Industry 4.0 and Society 5.0, vocational education plays a critical role. These eras are characterized by rapid technological advancements, such as artificial intelligence, the Internet of Things (IoT), and automation, which are significantly transforming the world of work (Hastutiningsih et al., 2024; Nugraha et al., 2021; Sudarmana et al., 2022). Vocational education must adapt to these changes by upgrading student skills to meet modern industrial requirements. For instance, Muhammadiyah Piyungan Vocational School has implemented information technology training to prepare students for the rapid changes in the workplace (Sudarmana et al., 2022). Furthermore, industry-based experiential learning models have been shown to increase student motivation and learning outcomes, although their implementation necessitates strong collaboration among schools, government, and industry (Fania et al., 2024). In another example, a training program at SMK Master Indonesia Bogor helped students understand the skills needed to overcome unemployment among vocational graduates (Rizky et al., 2023). The Indonesian government has also actively worked to strengthen vocational education by updating curricula and promoting partnerships with the industrial sector (Zukna & Sassi, 2024). As such, vocational education in Indonesia strives to produce graduates who not only possess technical skills but also the competencies required in the Industry 4.0 era, including critical thinking, collaboration, communication, and creativity (Nugraha et al., 2021; Wahjusaputri & Bunyamin, 2022).

## 2.2. TEACHERS AS THE MAIN PILLAR OF VOCATIONAL LEARNING

Teachers fulfill a pivotal role in vocational education, serving as the primary determinant of learning quality, character development, and students' work readiness. Their function extends beyond instruction; they also act as character mentors, skills trainers, and liaisons to the industrial sector (Affandi et al., 2023; Murniawan et al., 2024). The pedagogical and social competencies of teachers significantly influence learning success and the preparedness of graduates for the workforce (Tilaar et al., 2024; Wardoyo et al., 2024). Within the Indonesian vocational education system, teachers in Vocational High Schools (SMK) are classified into three main categories: normative, adaptive, and productive. Normative teachers are responsible for general subjects such as Indonesian language and civics, while adaptive teachers cover foundational sciences like mathematics and physics that support vocational fields. The most crucial role is held by productive teachers, who deliver subjects directly related to students' specific vocational competencies and the world of work (Widayana, 2022). Productive teachers are required not only to possess teaching abilities but also to have practical experience and strong connections with industry (Wardoyo et al., 2024). Furthermore, their primary duty involves managing practical instruction, including the planning, implementation, and evaluation of hands-on activities in workshops or laboratories that adhere to industry standards (Lapian et al., 2024).

To effectively execute their duties and responsibilities, productive teachers are required to possess two equally important core competencies: technical skills and pedagogical skills. Technical skills enable teachers to master vocational subject matter and practical equipment in accordance with industry standards, which is key to developing practice-based learning and real-world projects (Atmono et al., 2022). Concurrently, pedagogical skills are essential for delivering material effectively, guiding students with appropriate methods, and adapting teaching styles to meet diverse learning needs (Mamahit et al., 2023; Tilaar et al., 2024). The combination of these two skill sets significantly impacts the learning outcomes and job readiness of vocational students, as evidenced by the significant correlation between teachers' instructional skills and student academic results (Ruata et al., 2024). Productive teachers also need to develop innovative learning media, such as smartphone-based videos, to make content more accessible to the digital native generation (Kurniawan et al., 2023). Additionally, they must strengthen students' technological literacy and soft skills through approaches such as Flipped Learning and STEM (Nurwidodo et al., 2022; Sunarto et al., 2023). Therefore, the synergy of technical and pedagogical skills forms the essential foundation for productive teachers to cultivate competent and work-ready vocational graduates.

## 2.3. THE IMBALANCE OF PRODUCTIVE TEACHERS: A THREAT TO VOCATIONAL SCHOOL QUALITY

The disparity in the adequacy of productive vocational teachers represents one of the foremost challenges in Indonesian vocational education, as it directly impacts the quality of practical learning and the job readiness of graduates. A primary cause of this issue is the limited recruitment of teachers with industry backgrounds or specific technical expertise, particularly for new and rapidly evolving fields such as information technology and tourism (Widayana, 2022). Furthermore, the uneven distribution of productive teachers, with a high concentration in major urban centers and a scarcity in underdeveloped regions, exacerbates inequities in access to quality vocational education (Nur, 2021). Without an adequate number of productive teachers, many vocational high schools struggle to deliver practice-based learning that meets industry standards, resulting in a lower quality of student skills (Nur, 2021;

Widayana, 2022). Consequently, students do not receive optimal guidance in developing the vocational competencies required by industry (Sugiyarto et al., 2024). The shortage of productive teachers also increases the workload of adaptive (general science) teachers, who are often compelled to teach vocational subjects without the requisite expertise, leading to a reduction in the effectiveness of knowledge transfer (Gusnan et al., 2023). Collectively, these impacts hinder the overarching goal of vocational education to produce competent and work-ready graduates.

### 3. RESEARCH METHOD

This activity was implemented in the form of a mapping of productive (vocational) teacher adequacy within the engineering departments of public vocational high schools in Tuban Regency, under the coordination of the Bojonegoro Region Education Branch Office. The primary objective of this project was to provide an empirical overview of the current availability of productive teachers and to support the formulation of policy recommendations for the strategic placement and fulfillment of educator needs in the vocational sector.

#### 3.1. APPROACH AND ACTIVITY TYPE

This project utilized a quantitative descriptive approach with a methodology centered on documentary study and data analysis. The activity was non-interventional, focusing on mapping the real-world situation based on data obtained from the schools. Through this approach, the project focused on identifying issues in the distribution of productive teachers and classifying their status based on a comparison between the actual number of teachers and the ideal minimum and maximum requirements.

#### 3.2. DATA COLLECTION

Data were acquired through the documentation and recapitulation of reports from each school, which had been previously collected by the Bojonegoro Region Education Branch Office. The collected data included school names, total teaching hours, names of engineering departments, the number of existing teachers, and the ideal teacher requirement figures.

#### 3.3. DATA ANALYSIS

The data were analyzed descriptively by directly comparing the total number of teachers in each department with the ideal minimum and maximum requirement figures. Departments were classified into one of three categories:

- a. Deficit, if the total number of teachers was less than the ideal minimum requirement.
- b. Sufficient, if the number of teachers fell within the range of the minimum to maximum requirement.
- c. Surplus, if the number of teachers exceeded the ideal maximum requirement.

Table 1. Libraries Used in Google Colab

Library	Function
pandas	Reading and processing data from Excel files.
matplotlib	Creating visualizations such as bar charts and line plots.
seaborn	Generating heatmaps to visualize the status of teacher availability.
numpy	Managing index data and positioning elements within plots (e.g., bar positions in a chart).
openpyxl	Serving as a backend engine for reading .xlsx Excel files via the pandas.read_excel() function.
folium	Creating interactive maps featuring markers and regional boundaries.
geopandas	Reading and managing spatial data (e.g., GeoJSON files for Tuban Regency boundaries).
shapely	Applying masking effects (e.g., a blur) to areas outside the Tuban Regency boundary.
google.colab.files	Facilitating the upload and download of files within the Google Colab environment.

The analysis was performed using data processing software such as Microsoft Excel, supported by visualizations like bar charts and distribution maps created with Google Colab. Utilizing Python and Google Colab for data processing and visualization offers significant advantages. Python's open-source nature, simple syntax, and extensive libraries make it highly accessible for both beginners and advanced users, enabling efficient data analysis, machine learning, and visualization tasks across various domains (Hernández Aguilar & Hernández Pérez, 2023; Kuroki, 2021; Pandey & Panchal, 2020; Vidal-Silva et al., 2022). Google Colab enhances this experience by providing a cloud-based environment that requires no installation, offers free computational resources, and supports easy sharing and collaboration, making it ideal for both individual and group projects (Canesche et al., 2021; Febby et al., 2024; Hewitt, 2024; Kuroki, 2021). The libraries utilized for data processing in Google Colab are detailed in Table 1, while the complete codes used are shown in Figure 1 (a) and (b).

```

# Instalasi dan Import Library
!pip install matplotlib seaborn openpyxl pandas --quiet

import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns

# Baca Data dari File Excel
excel_file = "Data fix.xlsx"
sheet_names = pd.ExcelFile(excel_file).sheet_names
df = pd.read_excel(excel_file, sheet_name=sheet_names[0])

# Cek Isi Data
print(df.head())

# Visualisasi 1: Sebaran Jumlah Guru Produktif (Clustered Bar Chart)
schools_jurusan = df[["SEKOLAH"] + " - " + df["JURUSAN"]]
x = np.arange(len(schools_jurusan))
bar_width = 0.35

fig, ax = plt.subplots(figsize=(18, 9))
rects1 = ax.bar(x - bar_width/2, df["GURU PNS"], bar_width, label="Guru PNS")
rects2 = ax.bar(x + bar_width/2, df["GURU NON PNS"], bar_width, label="Guru Non PNS")

ax.set_xlabel("Sekolah - Jurusan")
ax.set_ylabel("Jumlah Guru")
ax.set_title("Sebaran Jumlah Guru Produktif (PNS dan Non PNS) per Jurusan di SMK Negeri Kabupaten Tuban", fontsize=15)
ax.set_xticks(x)
ax.set_xticklabels(schools_jurusan, rotation=45, ha='right', fontsize=10)
ax.legend()
plt.subplots_adjust(bottom=0.38, top=0.92, left=0.05, right=0.98)
plt.show()

# Visualisasi 2: Kecukupan Guru terhadap Kebutuhan Ideal (Stacked Bar Chart + Line)
fig, ax = plt.subplots(figsize=(18, 9))
pns = df["GURU PNS"]
non_pns = df["GURU NON PNS"]
kebutuhan_ideal_min = df["GURU IDEAL MINIMUM"]
kebutuhan_ideal_max = df["GURU IDEAL MAKSIMUM"]

ax.bar(x, pns, bar_width, label="Guru Non PNS", color="lightgray")
ax.plot(x, kebutuhan_ideal_min, color="red", marker='o', linestyle='-', linewidth=2, label="Kebutuhan Guru Ideal Minimum")
ax.plot(x, kebutuhan_ideal_max, color="green", marker='o', linestyle='-', linewidth=2, label="Kebutuhan Guru Ideal Maksimum")

ax.set_xlabel("Sekolah - Jurusan")
ax.set_ylabel("Jumlah Guru")
ax.set_title("Kecukupan Guru Produktif terhadap Kebutuhan Ideal per Jurusan", fontsize=15)
ax.set_xticks(x)
ax.set_xticklabels(schools_jurusan, rotation=45, ha='right', fontsize=10)
ax.legend()
plt.subplots_adjust(bottom=0.38, top=0.92, left=0.05, right=0.98)
plt.show()

# Visualisasi 3: Heatmap Status Ketersediaan Guru
def status_ketersediaan(row):
    total = row["TOTAL GURU"]
    min_ideal = row["GURU IDEAL MINIMUM"]
    max_ideal = row["GURU IDEAL MAKSIMUM"]
    if total < min_ideal:
        return "Kekurangan"
    elif min_ideal <= total <= max_ideal:
        return "Cukup"
    else:
        return "Kelebihan"

df["STATUS"] = df.apply(status_ketersediaan, axis=1)
status_map = {"Kekurangan": 0, "Cukup": 1, "Kelebihan": 2}
df["STATUS_NUM"] = df["STATUS"].map(status_map)

plt.figure(figsize=(14, 10))
heatmap_data = df.pivot(index="SEKOLAH", columns="JURUSAN", values="STATUS_NUM")
ax = sns.heatmap(
    heatmap_data,
    annot=df.pivot(index="SEKOLAH", columns="JURUSAN", values="STATUS"),
    fmt="",
    cmap=sns.color_palette(["#e74c3c", "#f7b731", "#27ae60"]),
    cbar=False,
    linewidths=1, linecolor='white'
)

plt.title("Heatmap Status Ketersediaan Guru Produktif per Sekolah dan Jurusan", fontsize=14, pad=20)
plt.ylabel("Sekolah")
plt.xlabel("Jurusan")
plt.tight_layout()
plt.show()

```

```

# Instalasi dan Import Library
!pip install folium geopandas openpyxl shapely --quiet

import pandas as pd
import geopandas as gpd
import folium
import json
from shapely.geometry import box, shape, mapping
from folium.features import DivIcon

# Baca Data Sekolah
df = pd.read_excel("Data Sekolah.xlsx")
df.columns = [col.upper().strip() for col in df.columns]

if "KOORDINAT" in df.columns:
    df[["LAT", "LON"]] = df["KOORDINAT"].str.split(",", expand=True).astype(float)
elif "LAT" in df.columns and "LON" in df.columns:
    df["LAT"] = df["LAT"].astype(float)
    df["LON"] = df["LON"].astype(float)
else:
    raise ValueError("Kolom 'KOORDINAT' atau 'LAT' dan 'LON' tidak ditemukan.")

# Baca Batas Kabupaten Tuban
with open("tuban_geojson", "r") as f:
    tuban_json = json.load(f)
tuban_geom = shape(tuban_json["features"][0]["geometry"])

# Buat Masking Wilayah di Luar Tuban
world_bounds = box(109.8, -8.0, 113.5, -6.0)
mask_geom = world_bounds.difference(tuban_geom)
mask_geojson = mapping(mask_geom)
mask_feature = {
    "type": "FeatureCollection",
    "features": [
        {
            "type": "Feature",
            "geometry": mask_geojson,
            "properties": {}
        }
    ]
}

# Buat Peta
m = folium.Map(location=[df["LAT"].mean(), df["LON"].mean()], zoom_start=10.5)

# Tambahkan Blur Luar Tuban
folium.GeoJson(mask_feature, style_function=lambda x: {
    "fillColor": "#999999", "color": "#999999", "weight": 1, "fillOpacity": 0.5
}).add_to(m)

# Tambahkan Batas Tuban
folium.GeoJson(tuban_json, style_function=lambda x: {
    "fillColor": "#00000000", "color": "#FF0000", "weight": 2, "dashArray": [5, 5]
}).add_to(m)

# Deteksi Kolom Nama Sekolah
nama_kolom_sekolah = None
for col in df.columns:
    if "sekolah" in col.lower() and "nama" in col.lower():
        nama_kolom_sekolah = col
        break
if not nama_kolom_sekolah:
    raise ValueError("Kolom nama sekolah tidak ditemukan.")

# Tambahkan Marker Sekolah dan Label
for _, row in df.iterrows():
    folium.Marker(
        location=[row["LAT"], row["LON"]],
        popup=row[nama_kolom_sekolah],
        icon=folium.Icon(color="blue", icon="graduation-cap", prefix="fa")
    ).add_to(m)

folium.map.Marker(
    [row["LAT"] - 0.005, row["LON"]],
    icon=DivIcon(
        icon_size=(150,36),
        icon_anchor=(0,0),
        html='''
<div style="
font-size:10pt;
font-weight:bold;
color:black;
text-align:center;
transform: translateX(-50%);
position: relative;
left: 50%;>
{row[nama_kolom_sekolah]}
</div>
'''
    )
).add_to(m)

# Simpan Sebagai HTML
html_file = "peta_sekolah_tuban.html"
m.save(html_file)

```

(a)

(b)

Figure 1. Code Used, (a) Analysis Visualization, and (b) Schools Map Visualization

## 4. RESULT AND ANALYSIS

### 4.1. PRODUCTIVE TEACHERS DISTRIBUTION

Table 2. Productive Teachers Availability Data

No	School Name	Instructional Hours	Number of Teachers			Ideal		Departments	
			Civil Servant	Non Civil Servant	Total	Retired Teachers	Min		Max
1	SMKN 1 SINGGAHAN	63	2	1	3	-	2	2	Teknik dan Bisnis Sepeda Motor
2	SMKN RENGEL	154	5	-	5	-	4	6	Teknik dan Bisnis Sepeda Motor
3	SMKN 1 TUBAN	228	7	2	9	-	6	9	Teknik Instalasi Tenaga Listrik
4	SMKN TAMBAKBOYO	63	3	-	3	-	2	2	Teknik Instalasi Tenaga Listrik
5	SMKN 1 SINGGAHAN	126	5	-	5	-	4	5	Teknik Kendaraan Ringan Otomotif
6	SMKN 1 TUBAN	152	3	2	5	-	4	6	Teknik Kendaraan Ringan Otomotif
7	SMKN 3 TUBAN	231	7	2	9	-	6	9	Teknik Kendaraan Ringan Otomotif
8	SMKN JATIROGO	228	7	1	8	-	6	9	Teknik Kendaraan Ringan Otomotif
9	SMKN PALANG	121	5	1	6	-	4	5	Teknik Kendaraan Ringan Otomotif
10	SMKN RENGEL	154	3	-	3	-	4	6	Teknik Kendaraan Ringan Otomotif
11	SMKN TAMBAKBOYO	189	5	1	6	-	5	7	Teknik Kendaraan Ringan Otomotif
12	SMKN WIDANG	152	8	-	8	-	4	6	Teknik Kendaraan Ringan Otomotif
13	SMKN 1 TUBAN	152	5	2	7	-	4	6	Teknik Komputer dan Jaringan
14	SMKN RENGEL	154	5	1	6	-	4	6	Teknik Komputer dan Jaringan
15	SMKN TAMBAKBOYO	126	6	1	7	-	4	5	Teknik Komputer dan Jaringan
16	SMKN WIDANG	152	5	2	7	-	4	6	Teknik Komputer dan Jaringan
17	SMKN 1 TUBAN	152	6	1	7	-	4	6	Teknik Pemesinan
18	SMKN 3 TUBAN	231	6	3	9	-	6	9	Teknik Pemesinan
19	SMKN TAMBAKBOYO	126	4	1	5	-	4	5	Teknik Pemesinan
20	SMKN WIDANG	152	4	1	5	-	4	6	Teknik Pemesinan
21	SMKN TAMBAKBOYO	126	5	-	5	-	4	5	Teknik Pemesinan Kapal
22	SMKN 3 TUBAN	77	1	1	2	-	2	3	Teknik Pendinginan dan Tata Udara
23	SMKN WIDANG	12	1	-	1	-	1	1	Teknik Pendinginan dan Tata Udara
24	SMKN RENGEL	154	5	1	6	-	4	6	Teknik Pengelasan
25	SMKN 1 TUBAN	228	8	7	15	-	6	9	Teknik Pengolahan Minyak, Gas dan Petrokimia

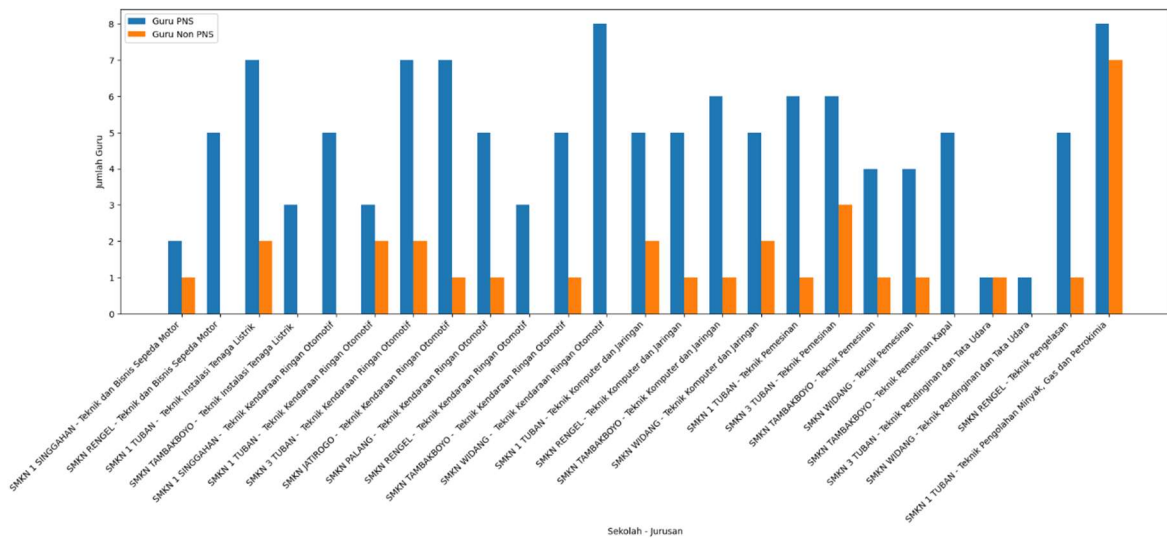


Figure 2. Productive Teachers Distribution Graph

The analysis was performed using data processing software such as Microsoft Excel, supported by visualizations like bar charts and distribution maps created with Google Colab. Utilizing Python and Google Colab for data processing and visualization offers significant advantages. Python’s open-source nature, simple syntax, and extensive libraries make it highly accessible for both beginners and advanced users, enabling efficient data analysis, machine learning, and visualization tasks across various domains (Hernández Aguilar & Hernández Pérez, 2023; Kuroki, 2021; Pandey & Panchal, 2020; Vidal-Silva et al., 2022). Google Colab enhances this experience by providing a cloud-based environment that requires no installation, offers free computational resources, and supports easy sharing and collaboration, making it ideal for both individual and group projects (Canesche et al., 2021; Febby et al., 2024;

Hewitt, 2024; Kuroki, 2021). The libraries utilized for data processing in Google Colab are detailed in Table 1, while the complete codes used are shown in Figure 1 (a) and (b).

Table 2 presents summary data on the adequacy of productive teachers in the engineering departments of public Vocational High Schools (SMK) across Tuban Regency for the year 2025. The information displayed includes the total number of instructional hours, the number of available teachers categorized by employment status (PNS/Civil Servant and Non-PNS/Non-Civil Servant), the number of teachers scheduled for retirement in the current year, and the estimated ideal teacher requirement for each area of expertise. This dataset forms the basis for analyzing the actual conditions of productive teacher adequacy and for formulating strategies for a more equitable and sustainable redistribution of educational human resources in Tuban Regency. This summary is also illustrated in Figure 2.

As shown in Table 2 and Figure 2, the distribution of productive teachers in Tuban Regency varies significantly among schools and departments. This variation reflects differences in departmental needs, the number of student cohorts, and the specific management policies of each institution. The schools included in this study are geographically mapped in Figure 3.

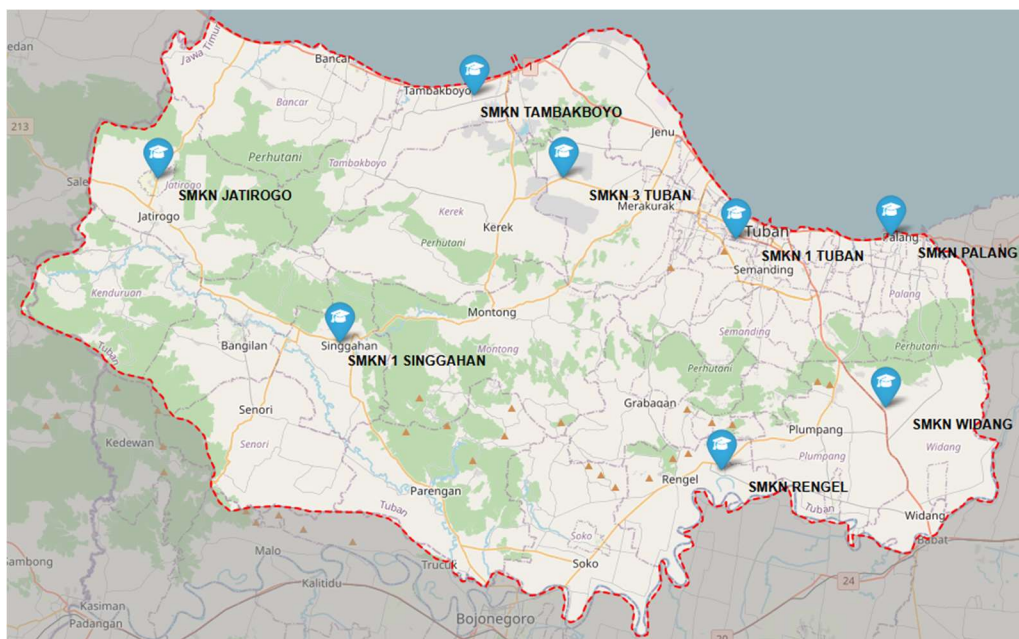


Figure 3. Schools Map

#### 4.2. ADEQUACY ANALYSIS

The adequacy analysis was conducted by considering the range between the minimum and maximum ideal requirements, as illustrated in Figure 4. The departments in this mapping were classified into three categories: deficit if the total number of teachers was less than the minimum requirement, sufficient if the total fell within the ideal range, and surplus if the number exceeded the maximum requirement.

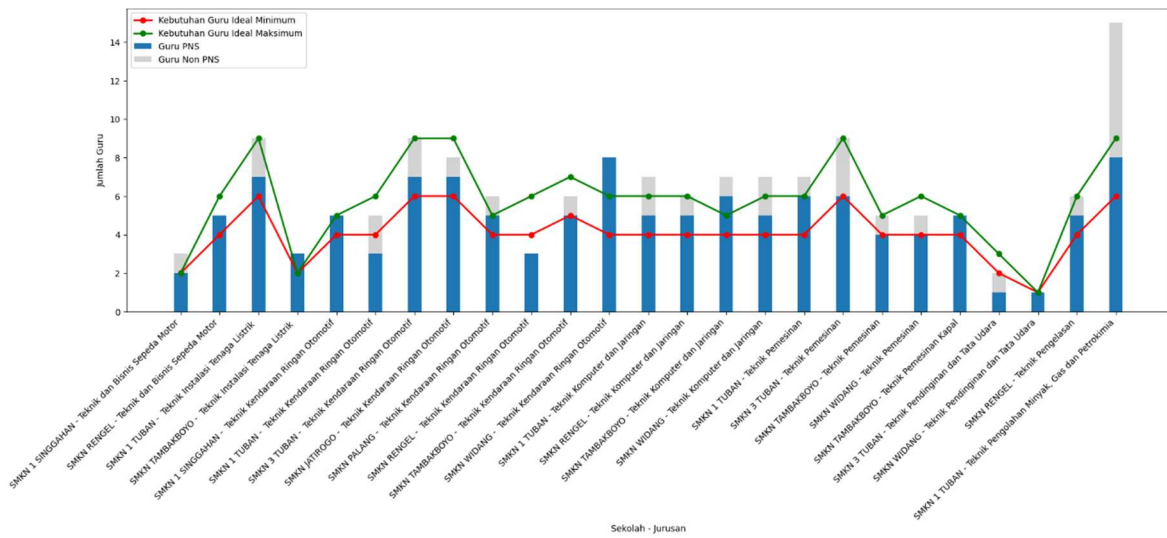


Figure 4. Productive Teacher Adequacy versus the Ideal Requirement

The results of the analysis indicate that 1 department (4%) experiences a deficit, 15 departments (60%) are within the sufficient range, and 9 departments (36%) have a surplus of productive teachers. This condition suggests that, overall, the schools in Tuban Regency have successfully provided an adequate number of instructors to support productive learning processes at a fundamental level. The results of this analysis are further illustrated in the form of a heatmap in Figure 5.



Figure 5. Productive Teacher Status Heatmap

A surplus of teachers in several departments presents an opportunity for optimization. These educators could be redistributed to other departments experiencing teacher shortages or be involved in dual-expertise programs, internal training, or the strengthening of school production units. However, if not managed properly, a teacher surplus

can also lead to inefficiencies in assignments, workload imbalances, and decreased motivation due to insufficient teaching hours.

Meanwhile, the "sufficient" category encompasses the majority of departments across various schools, where the number of teachers falls within the ideal requirement range. These departments can serve as a benchmark for identifying effective human resource management practices, such as scheduling, teacher needs planning, and data-driven recruitment strategies.

Overall, these findings provide a robust basis for policymaking related to the redistribution of productive teachers, recruitment prioritization, and training for dual-expertise development. Such measures are essential to ensure that every department has the quantity and quality of teachers appropriate for the actual needs of vocational instruction in Tuban Regency.

### **4.3. HOW TO ADDRESS THE IMBALANCE IN PRODUCTIVE TEACHER DISTRIBUTION**

To address the inequitable distribution of productive teachers in Tuban Regency, the following strategies warrant serious consideration.

#### **4.3.1. OPTIMIZING THE UTILIZATION OF NON-CIVIL SERVANT (NON-PNS) TEACHERS**

Non-PNS teachers can be dynamically allocated to fill vacancies in departments or schools that are experiencing a shortage of productive teachers. This placement must be based on real-time data on needs and must consider welfare aspects to maintain motivation and performance.

#### **4.3.2. STRENGTHENING DUAL-EXPERTISE PROGRAMS**

Qualified adaptive or normative teachers can be enrolled in dual-expertise training programs to enable them to teach productive subjects. This strategy has proven effective in filling vacancies in specific fields of expertise while simultaneously enhancing the overall competency of the teaching staff.

#### **4.3.3. UTILIZING MULTI-COMPETENCY TEACHERS AND INTERNAL MOBILITY**

Teachers who hold more than one certification or competency can be maximally utilized to teach across interrelated departments. Additionally, a system of rotation or internal mobility between departments within a single school should be encouraged to increase the flexibility of human resource management.

#### **4.3.4. CROSS-INSTITUTIONAL AND INDUSTRY COLLABORATION**

Schools experiencing a surplus of teachers in certain departments can implement a teacher-sharing scheme with schools that have a deficit, particularly for practical programs and competency assessments. Collaboration with the industrial sector also needs to be enhanced, especially through guest lecturers or industry practitioner instructors.

#### **4.3.5. CONTINUOUS MONITORING BY THE REGIONAL EDUCATION BRANCH OFFICE**

Periodic monitoring must be conducted by the regional education branch office to map actual needs, changes in staffing due to retirement, and trends in departmental development. This will enable teacher procurement and redistribution policies to be implemented swiftly and responsively.

#### **4.3.6. ENHANCING THE ATTRACTIVENESS OF THE PRODUCTIVE TEACHER PROFESSION**

Long-term efforts should focus on increasing the appeal of the productive teacher profession, for instance, by providing scholarships for teacher professional education, incentives, and clear career pathways for new graduates or industry experts transitioning into teaching.

## **5. CONCLUSION**

This study mapped the adequacy and distribution of productive technical teachers in the engineering departments of public Vocational High Schools (SMK) in Tuban Regency. The findings reveal that 96% of the 25 departments surveyed have met the minimum requirement for productive teachers, indicating a generally sufficient teacher supply to support practice-based vocational learning. However, one department (Teknik Kendaraan Ringan Otomotif at SMKN Rengel) remains in deficit, and 36% of departments experience a surplus, highlighting ongoing distributional imbalances.

A key academic contribution of this study is the demonstration of a systematic, data-driven mapping method for assessing teacher adequacy at the departmental level. By leveraging quantitative analysis and visualization tools

(such as Python and Google Colab), this approach provides a replicable model for other regions seeking to monitor and optimize the distribution of vocational teachers. The mapping framework can serve as a practical tool for regional education authorities to inform policy decisions on teacher recruitment, redistribution, and professional development. Furthermore, the integration of real-time administrative data and visualization enhances transparency and supports evidence-based human resource planning in vocational education.

Despite its strengths, this study has several limitations: the mapping was limited to public vocational high schools (SMK Negeri) in Tuban Regency, excluding private schools and other regions, which may affect the generalizability of the findings. The analysis relied on administrative data provided by the regional education office, and any inaccuracies or delays in data reporting could impact the results. Additionally, the study focused solely on the quantitative adequacy of teachers, such as headcount relative to minimum and maximum requirements, without assessing their actual competency, quality, or professional development needs. Future research should address these limitations by expanding the scope to include private institutions, incorporating qualitative assessments of teacher competency, and exploring the impact of teacher distribution on student outcomes.

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