Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/SA07.20260098
Published: August 4, 2026

Keeping Pace with Growth: Vehicle Counting Stations and Population Trends in Texas (2012–2021)

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Abstract

Effective traffic monitoring infrastructure is critical for managing mobility in rapidly growing states like Texas. However, vehicle counting stations require significant capital investment, maintenance, and operating expenses, demanding strategic placement. This study investigated the relationship between population growth and the deployment of vehicle counting stations in Texas from 2012 to 2021 to aid future strategic investment planning. Using a quantitative methodology, data was obtained from the U.S. Department of Transportation Federal Highway Administration and the Texas Department of Transportation. A Pearson correlation coefficient analysis was performed to measure the strength and direction of the linear relationship between population size and the number of counting stations. The results indicated that during the studied period, the Texas population increased steadily from approximately 26.0 million to 29.5 million. In contrast, the number of vehicles counting stations expanded in a stepwise pattern, rising from about 130 to 155 stations, with notable increments around 2014 and 2019 and intervening periods of limited growth. Ultimately, the analysis revealed a positive relationship between population size and the number of vehicles counting stations. These findings underscore the importance of proactive infrastructure planning to ensure vehicle monitoring capacity keeps pace with demographic changes. For rapidly growing regions, aligning infrastructure investment strategies with population trends can significantly enhance traffic data quality, support better transportation planning, and improve overall system efficiency.

Keywords
Traffic Monitoring Infrastructure, Vehicle Counting Station, Population Growth, Transportation Planning, Strategic Investment Planning

1. Introduction
The rapid urbanization and economic expansion of Texas have placed unprecedented demands on its transportation network. As the state's population continues to surge, the necessity for robust, data-driven infrastructure management becomes paramount. Central to this effort is the deployment and maintenance of vehicle counting stations, essential components of traffic monitoring systems that provide the fundamental data required for highway performance evaluation, congestion management, and log-term capital investment planning (Pande and Wolshon, 2015) However,

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the expansion of this monitoring network is not merely a technical challenge but a fiscal one. The installation of vehicle counting stations requires significant initial capital investment, while their continued operation requires ongoing maintenance and operational expenses.

Vehicle counting stations in Texas operate through both permanent and short-term monitoring programs. Permanent traffic count stations collect data continuously throughout the year, enabling transportation agencies to analyze seasonal traffic fluctuations, freight movement trends, and long-term roadway usage patterns (Federal Highway Administration, 2014). In contrast, short-duration monitoring stations provide targeted traffic data collection for specific corridors, intersections, or project areas. According to TXDOT Manual System (TXDOT, 2024) the statewide traffic monitoring program conducts more than 75,000 short-term traffic counts annually while maintaining over 350 continuous count stations that operates 24 hours per day, 365 days (about 12 months) per year (Texas Department of Transportation, 2026; TXDOT, 2024).

Effective traffic monitoring is mandated at both state and federal levels to ensure the reliability of the Highway Performance Monitoring System (HPMS) (Office of Highway Policy Information, 2016) These systems allow planners to quantify Annual Average Daily Traffic (AADT), which serves as the backbone for funding allocation and safety analysis (Qureshi and Al-Kaisy, 2025) Despite their importance, the deployment of physical counting stations often lags behind the immediate needs of a growing population due to budget constraints and the logistical complexities of statewide implementation. When monitoring infrastructure fails to keep pace with demographic shifts, the resulting data gaps can lead to suboptimal transportation planning, inefficient resources allocation, and a diminished ability to respond to emerging traffic patterns.

1.1 Objectives

The primary objective of this study is to investigate the quantitative relationship between population growth and the deployment of vehicle counting stations in Texas from 2012 to 2021 (while extending to 2024 as data permits). By establishing a clear correlation between these two variables, this study seeks to provide a foundational framework for future strategic investment planning. If population trends can serve as reliable predictor for infrastructure needs, planners can transition from a reactive catch-up model of deployment to a proactive strategy that anticipates demand before it manifests as critical congestion or data insufficiency.

Historically, traffic monitoring has relied on a variety of technologies, ranging from traditional inductive loops to advanced video-based sensors and millimeter-wave radar (Li et al., 2019; Yang et al., 2024). While technology itself has evolved, the spatial distribution of these assets remains a critical factor in their effectiveness. In a state as geographically diverse as Texas, the disparity between rapidly expanding metropolitan hubs and stable rural counties complicates the deployment strategy. This study addresses the complexity by analyzing county-level data to determine how closely infrastructure expansion mirrors human migration and growth patterns. By leveraging data from the TxDOT TPP statewide traffic count map and Federal Highway Administration, this research offers an empirical assessment of whether the state's eyes on the road are growing at the same rate as the residents who use them. Ultimately, aligning infrastructure investment with demographic trends is essential for enhancing traffic data quality and improving the overall efficiency of the Texas transportation system.

2. Literature Review

Transportation monitoring systems (TMS) play a critical role in supporting roadway planning, congestion management, and infrastructure investment decisions in rapidly urbanizing regions (Federal Highway Administration, 2023; Thabit et al., 2024). TMS's, such as continuous traffic monitoring stations, provide essential traffic volume and classification data that assist transportation agencies in forecasting roadway demand, improving highway safety, and supporting maintenance planning (Federal Highway Administration, 2022; Turner et al., 1998). Intelligent transportation systems depend heavily on reliable traffic count data for mobility analysis, traffic forecasting, and long-term transportation policy development (Tomar et al., 2022). As urban populations continue to grow, transportation infrastructure and monitoring systems must expand correspondingly to maintain roadway efficiency and support economic activity (Federal Highway Administration, 2021; Litman, 2002).

Texas has experienced significant population growth over the last decade, increasing from approximately 26.0 million residents in 2012 to about 29.5 million in 2021 (United States Census Bureau, 2021). Much of this growth has occurred

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within the Texas Triangle (see Figure 1) in major metropolitan areas such as Dallas–Fort Worth, Houston, Austin, and San Antonio, resulting in increased vehicle ownership, higher travel demand, and greater roadway congestion (Federal Highway Administration, 2021; Guo and Zhang, 2021). During the same period, the number of vehicle counting stations in Texas increased from roughly 130 in 2012 to approximately 155 stations in 2021, with notable infrastructure expansions occurring around 2014 and 2019 (Federal Highway Administration, 2022). These counting stations provide transportation agencies with critical data to monitor traffic patterns, identify congestion trends, and support infrastructure investment planning (Turner et al., 1998; Wang and Kockelman, 2009).

Despite continued population growth, traffic monitoring infrastructure expansion often occurs incrementally due to funding limitations, operational costs, maintenance requirements, and regional transportation priorities (Federal Highway Administration, 2022; Pande and Wolshon, 2015). Previous studies emphasize that aligning transportation monitoring infrastructure with demographic and mobility trends is essential for improving transportation system efficiency, enhancing traffic forecasting capabilities, and supporting long-term statewide transportation planning (Litman, 2002; Tomar et al., 2022).

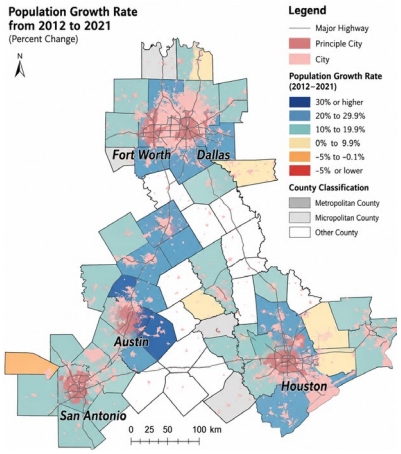


Figure 1. Population growth rate from 2012 to 2021 in the Texas Triangle (Adapted from Guo and Zhang, 2021; United States Census Bureau, 2021).

3. Methods

This study employed a quantitative research design to evaluate the alignment between demographic shifts and traffic monitoring infrastructure expansion. The analysis focused on the State of Texas, utilizing a longitudinal approach to track changes over a 13-year period (2012 – 2024). The methodology was structured into three primary phases: 1. Data acquisition, 2. Data processing and integration, and 3. Statistical analysis.

3.1 Data Acquisition

The data were sourced from two primary institutional repositories: 1. The infrastructure data regarding vehicle counting was obtained from TxDOT TPP statewide traffic count map (Texas Department of Transportation, 2026). 2. The population statistics and demographic data were retrieved from official census-linked records, detailing the annual population counts for each Texas county within the study period.

3.2 Data Processing and Integration

To ensure a consistent unit of analysis, the raw data underwent significant cleaning and transformation: 1. The infrastructure dataset was filtered to identify unique stations. Since the raw data often recorded multiple entries for different travel directions as a single location, the records were aggregated to determine the total number of physical counting stations per county per year. 2. The two-dataset emerged using county and year as the primary keys, allowing for the calculation of the stations-to-population ratio defined as number of counting stations per one million residents. This ratio serves as the normalized metric to assess whether infrastructure density was increasing or decreasing relative to the number of road users.

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3.3 Statistical Analysis

The core analysis utilized Pearson's correlation coefficient (r) to measure the strength and direction of the linear relationship between three core variables:
a. Year and Population: To confirm the consistency of growth.
b. Year and Station Count: To evaluate the expansion of infrastructure over time.
c. Population and Station Count: To determine if population is a variable predictor for infrastructure deployment. After the correlation analysis, a simple linear regression model was developed for each relationship. The models were used to quantify the rate of change and generate future projections. Specifically, the population-based model was utilized to forecast the required station count for the year 2030. Providing data-driven targets for state planners.

4. Results and Discussion

4.1 Datasets Information

The results were based on two datasets, both corresponding to the state of Texas during the period of analysis from 2012 to 2024. The first dataset consisted of 15,326 records, where each record represented a travel direction of a counting station for a given year within the study period. These records were processed to determine the number of unique stations in each county for each year. The second dataset consisted of 3,810 records, with each record representing the population of a specific county for each year of the analysis period. Both datasets were merged for the analysis.

4.2 Population and Vehicle Counting Station Over Time

Over the timeframe, the station count began at 381 in 2012, experienced slight fluctuations between 370 and 390 through 2018, then increased to 508 by 2019 and remained relatively stable until 2023, when the station count increased to 853 by 2024, as shown by the orange line in Figure 2. The noticeable increases in 2019 and 2023 in the number of counting stations indicated major expansion phases (perhaps due to the funding cycle) supporting large-scale traffic-monitoring infrastructure projects. Figure 2 also shows (with the blue line) that the population increased steadily from 26 million in 2012 to 31.3 million in 2024, reflecting a consistent upward trend each year. No sudden jumps or drops in the population were observed, indicating a stable growth likely driven by factors such as consistent urban expansion, migration, economic conditions, or natural population growth.

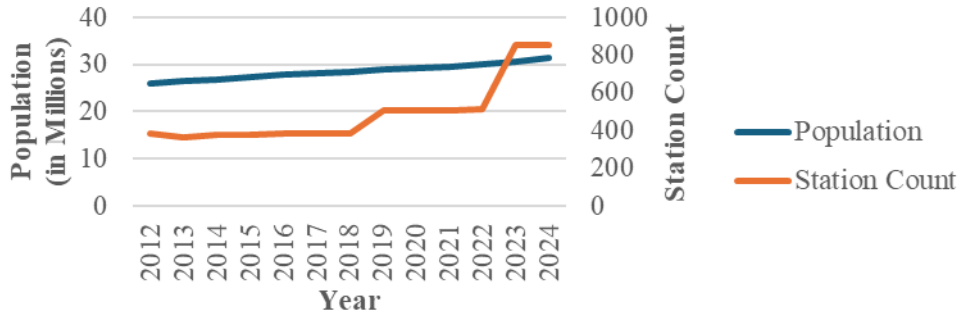


Figure 2. Population and Counting Station Numbers during the Studied Period

The same vehicle counting station and population data (from Figure 2) were then plotted one versus the other to visualize their relationship. Additionally, the ratio of the number of stations to the population was calculated. Figure 3 shows population (in millions) on the horizontal axis against two variables: station count (green line, left y-axis) and the stations-to-population ratio (purple line, right y-axis). As the population increased from 26.1 million to 31.3 million, the station count rose from 381 to 853. This increase in the number of stations was expected. However, what was not expected was that the ratio of stations per million people, which increased from 14.62 stations per million people in 2012 to 27.24 stations per million people in 2024. This increase was unexpected because higher population levels lead to a lower ratio, as more vehicles pass through each station. However, this increase in the ratio supports

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the earlier statement that major expansion phases occurred to support large-scale traffic-monitoring infrastructure projects.

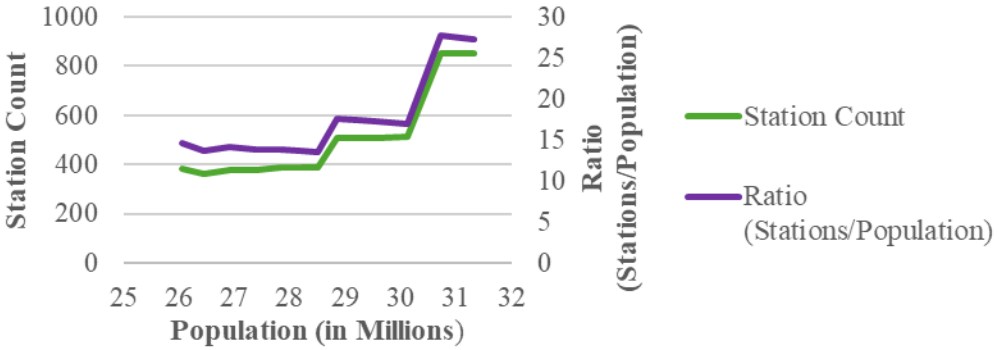


Figure 3. Counting Station Numbers vs Population Count during the Studied Period

When considering the analysis of both figures, it is worth mentioning that the population steadily and predictably rose 20% over the study period. This consistent growth suggests a stable expansion in demand. In contrast, the number of stations did not follow a smooth upward path. This mismatch between a steadily rising population and jumps in traffic monitoring infrastructure indicates that, during this early period, the system was gradually becoming more strained and less capable of determining traffic counts and congestion, among others, for proactive infrastructure planning. The number of stations remains relatively flat during some periods, with a significant increase in 2014 and 2019, with an increase of 123% in the number of stations. This resulted in an increase of 86% in the number of stations per million population.

4.3 Relationship between Population and Vehicle Counting Station

Three Pearson's correlation coefficients (Pearson's r) analyses were performed to examine the strength and direction of the linear relationship between (1) Year and Population, (2) Year and Station Count, and (3) Population and Station Count.

4.3.1 Linear Correlations Between Time (Year) and Population

The first Pearson's analysis was used to quantify the strength of the relationship between time (year) and population. Pearson's correlation between year and population was +0.9968, representing an extremely strong positive linear relationship (Schober and Schwarte, 2018). This indicates that from 2012 to 2024, population growth followed a highly consistent and near-linear upward trend over time. A correlation value this close to +1 implies that the year is a very strong predictor of population growth within this dataset, with minimal deviation from the overall upward trend. In practical terms, this reflects steady demographic growth over time with little fluctuation or reversal. This strong linear relationship justifies the use of a linear regression model (Equation 1) to represent population growth and support future predictions. Based on this model, for example, the population is projected to reach approximately 33.55 million by 2030, assuming the current trend continues without significant structural changes.

$$\boldsymbol{Population = Intercept + (Slope * Year)} \qquad \textbf{Equation 1}$$

Where: Intercept= -813.1 and Slope = 0.41708

4.3.2 Linear Correlations Between Time (Year) and Station Count

The second Pearson's r analysis focused on the correlation between year, and station count is 0.8223, indicating a strong positive relationship between time and the increase in the number of stations. This indicates that, overall, station count has tended to rise as years progress from 2012 to 2024, although the relationship is not as perfectly linear as observed for population. The lower correlation value compared to the population reflects noticeable fluctuations in infrastructure growth, including periods of stagnation and sudden expansion, particularly around 2019 and 2023. Despite these irregularities, the positive correlation confirms a general long-term upward trend in station count over time. This relationship can be further modeled using a linear regression model (Equation 2), where the slope (36.07692) represents the average annual increase in stations and the intercept (-72,310.5) defines the theoretical

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starting point of the trend line. Based on this model, station count is projected to reach approximately 926 stations by 2030, assuming the historical pattern continues without major structural changes.

$$\boldsymbol{Station\ Count = Intercept + (Slope * Year)} \qquad \textbf{Equation 2}$$

Where: Intercept= -72,310.5 and Slope = 36.07692

4.3.3 Linear Correlations Between Population and Station Count

The last Pearson's r analysis focused on the correlation between population and station count, which was 0.8477, indicating a strong positive relationship between the two variables. This indicates that, in general, increases in population are associated with increases in the number of stations, although the relationship is not perfectly proportional due to periods of uneven infrastructure expansion. The strength of this correlation highlights that station planning could be closely linked to population, but also influenced by additional factors such as funding cycles or strategic decisions, which may explain the observed fluctuations. This finding is particularly important for future planning, as it demonstrates that population growth can serve as a reliable indicator for infrastructure expansion needs. Planners can use this relationship to anticipate future station requirements, reduce the risk of under- or over-provision, and ensure that infrastructure development remains aligned with demographic changes. The corresponding regression model further supports this relationship, with a slope of approximately 88.88515, meaning that for each increase of one million people in population, station count rises. When the population reaches 33.55 million (estimated to be in 2030), this model produces a projected station count of around 938 stations, which is higher than the calculated based on the year.

$$\boldsymbol{Station\ Count = Intercept + (Slope * Year)} \qquad \textbf{Equation 3}$$

Where: Intercept= -2,044.8 and Slope = 88.88515

4.4 Discussion

The findings of this study demonstrate that Texas experienced substantial and sustained population growth of 20.4% from 2012 to 2024. At the same time, the number of vehicles counting stations increased by 123.9%, although the growth in monitoring infrastructure occurred in phases rather than through a continuous linear expansion. This trend supports previous transportation studies that identified population growth as a major driver of increased transportation demand, roadway congestion, and the need for expanded traffic monitoring systems (Federal Highway Administration, 2021; Litman, 2002). Similar observations were reported by Wang and Kockelman (2009), who emphasized the importance of expanding traffic count infrastructure in rapidly growing transportation networks to improve roadway planning and traffic forecasting accuracy.

The strong positive correlation between year and population (r=0.9968) indicates that population growth in Texas followed a highly stable, predictable upward trend throughout the study period. This trend aligns with reports from the United States Census Bureau (2021) and the Texas Demographic Center, which documented sustained demographic expansion driven by economic growth, migration, and urbanization across major metropolitan regions such as Dallas–Fort Worth, Houston, Austin, and San Antonio. Previous studies similarly concluded that population growth directly increases travel demand, vehicle ownership, and roadway utilization, creating additional pressure on transportation systems and monitoring infrastructure (Federal Highway Administration, 2021; Guo and Zhang, 2021; Tomar et al., 2022). Although the number of vehicles counting stations increased generally, the growth pattern was not linear. Instead, station expansion occurred in phases, particularly around 2019 and 2023, producing a strong but less consistent correlation between year and station count (r=0.8223). This finding suggests that population growth is not the only variable to consider when expanding transportation monitoring infrastructure; funding cycles, agency priorities, operational constraints, and infrastructure modernization efforts also matter. Similar findings were reported by (Turner et al., 1998), (Pande and Wolshon, 2015), (Federal Highway Administration, 2022), who noted that traffic monitoring systems often expand incrementally because of capital investment requirements and maintenance costs.
Another important finding from this study was an increase in the ratio of counting stations per million residents from 14.62 in 2012 to 27.24 in 2024. This increase suggests that Texas invested in traffic monitoring infrastructure at a rate exceeding population growth during certain expansion phases. The result may indicate a strategic effort by transportation agencies to improve statewide traffic data coverage, congestion detection capabilities, and roadway performance monitoring. Similar trends have been discussed in the intelligent transportation system literature, where researchers have emphasized that modern traffic management increasingly depends on higher-density traffic monitoring networks capable of supporting real-time decision-making and predictive transportation analytics (Federal Highway Administration, 2022; Thabit et al., 2024; Tomar et al., 2022). (Wang and Kockelman, 2009) also highlighted

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the importance of expanding traffic count coverage to improve forecasting accuracy and reduce uncertainty in transportation planning models.

The strong positive relationship between population and station count (r=0.8477) further confirms that demographic growth is closely associated with the expansion of transportation monitoring infrastructure in Texas. This finding is consistent with prior studies that identified population growth as a reliable indicator of future transportation infrastructure needs (Federal Highway Administration, 2021; Litman, 2002). The projected station counts for 2030, estimated between approximately 926 and 938 stations depending on the forecasting approach, suggesting that continued infrastructure investment will be necessary to support future transportation demand. Previous research similarly emphasized that proactive expansion of traffic monitoring improves traffic forecasting accuracy, congestion management, and the effectiveness of long-term transportation planning (Thabit et al., 2024; Tomar et al., 2022; Turner et al., 1998). Therefore, the findings of this study reinforce the importance of aligning traffic monitoring infrastructure development with long-term demographic and mobility trends to support sustainable transportation system management in rapidly growing regions such as Texas.

6. Conclusion

This study successfully established a strong positive correlation (r=0.8477) between population growth and the deployment of vehicle counting stations in Texas. The analysis revealed that while the population of Texas grew at a remarkably steady and linear rate (r=0.9968), the expansion of traffic monitoring infrastructure followed a more sporadic, stepwise pattern. Significant surges in station counts in 2019 and 2023 suggest that infrastructure growth is often driven by periodic funding cycles and large-scale project phases rather than a continuous, incremental responses to demographic changes.

The most striking finding was the unexpected increase in the stations-to-population ratio, which nearly doubled from 14.62 to 27.24 stations per million people over the study period. While high-growth areas typically see a lower ratio due to increased efficiency, this trend indicates a proactive shift in Texas towards higher-density monitoring. The regression models developed in this study provide a predictive tool for planners, projecting a need for approximately 938 stations by 2030 to maintain the current trajectory. Ultimately, the results underscore that while Texas is making significant strides in expanding its monitoring capabilities, the lack of a perfectly linear alignment between population and stations suggest that some period experienced data strain where infrastructure lagged demand.

While this research provides a macro-level view of the relationship between demographics and infrastructure, several avenues for future investigation remain. Future research should move beyond county-level totals to incorporate Geographic Information Systems (GIS) through spatial analysis. This would allow for a more granular analysis of whether stations are being placed in high-congestion corridors versus rural areas, ensuring that the quality of placement matches the quantity of stations. Alternative future study and data sources would be from the rise of Connected and Automated Vehicles (CAVs) and crowdsourced data (e.g., Waze, Google Maps, Apple Map). Investigating virtual counting stations or event-based data from traffic signals can supplement physical stations (An et al., 2018; Tsapakis et al., 2025). By integrating these future directions, transportation authorities can move towards a more integrated, responsive, and technologically diverse traffic monitoring ecosystem.

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Biographies

Dr. Tulio Sulbaran is a tenured professor in the School of Civil and Environmental Engineering and Construction Management at The University of Texas at San Antonio (UTSA). With over 23 years of experience, he was also the founder and director of the Center for Logistics, Trade, and Transportation (CLTT) at the University of Southern Mississippi. An accomplished researcher, Dr. Sulbaran has submitted over 170 proposals and secured more than 70 externally funded projects totaling millions of dollars as PI/Co-PI. His research primarily focuses on transportation innovation assessment, decision support, multimodal freight networks, and workforce development. He has received extensive funding from prominent organizations, including the National Science Foundation (NSF), U.S. Department of Transportation (DOT), U.S. Department of Defense (DoD), U.S. Department of Homeland Security (DHS), various state DOTs, the Transportation Research Board (TRB), and Northrop Grumman. A widely published academic, Dr. Sulbaran has authored over 130 peer-reviewed publications, written several books, and delivered more than 280 professional presentations. His work appears in top-tier journals such as the International Journal of Virtual Reality, IEEE, and American Society of Engineering Education Proceedings.

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Dr. Billy Gray is a tenured associate professor in Engineering Technology at Tarleton State University. Dr. Gray holds a Ph.D. in Industrial Engineering and has extensive experience in systems engineering, manufacturing systems, cost analysis, and lifecycle evaluation, including research on sensor integration, RFID technologies, and operational performance metrics. In his industry roles, he led engineering and operations teams with responsibility for product design, manufacturing, process improvement initiatives, quality management systems, and cost control efforts. He also holds professional certifications in Lean Six Sigma and RFID technologies.

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