A Deterministic Capacity-Constrained Framework for On-Street Parking Revenue Planning: The Case of Naga City's Central Business District

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Abstract: Naga City faces severe urban gridlock due to unmanaged curb space and "asset hoarding". This study addresses the structural inadequacy of traditional static forecasting models by developing a three-layer deterministic, capacity-constrained management framework. The model sequentially applies a Supply Filter to enforce legal geometric capacities, a Demand Filter to account for effective billable-hours assumption, and an Efficiency Filter to discount for operational friction. Analysis of 57 street segments in the Central Business District projects an annualized yield of PhP 31.2 million, 49% lower than previous unconstrained estimates. This variance highlights the fiscal risks of illegal-inventory inclusion and temporal rigidity. By identifying high-yield corridors like J. Hernandez Avenue for priority enforcement, the framework provides local governments with a transparent, operationally defensible audit trail for transitioning to managed on-street parking

Keywords: Naga City, On-Street Parking, Asset Management, Deterministic Modeling, Capacity Constraints, Revenue Forecasting

1. INTRODUCTION

1.1 Background

Naga City, a first-class independent component city, serves as the undisputed institutional, commercial, educational, and religious hub of the Bicol Region. This dominant regional status draws a massive daily influx of commuters, logistics operators, and shoppers into the compact geographical footprint of its Central Business District (CBD).

From a resource management perspective, the city’s curb space represents a finite public asset currently operating without inventory control. Because access to the city's streets is unmanaged and free at the point of use, individual drivers routinely practice asset hoarding, occupying premium street spaces for extended periods without operational penalties. This lack of regulation results in severe resource depletion, manifesting as extreme urban gridlock.

As documented in the city's draft Comprehensive Traffic Management Plan (CTMP)[1], unregulated on-street parking has systematically compromised the city's physical transportation network. Private vehicles, delivery vans, and tricycles spill over onto primary thoroughfares, stripping active travel lanes away from moving traffic, forcing structural bottlenecks, and depressing overall vehicular velocity across the CBD.

1.2 Rationale of the Study

To mitigate this systemic bottleneck, the local government has proposed a transition toward Environmentally Sustainable Transport (EST) principles, spearheaded by the creation of a dedicated Naga City Traffic and Parking Management Office (NCTPMO)[2]. A cornerstone of this operational strategy is the transition from unmanaged curb space to a structured asset-utilization system.

Implementing a regulated parking fee structure serves a critical operational purpose: it functions as a space-management tool designed to regulate parking turnover and minimize curb-space friction on public roads, while establishing a reliable stream of municipal income. For the Local Government Unit (LGU), defining an accurate operational baseline is a vital prerequisite. It provides the administrative justification required to secure capital investments for physical enforcement infrastructure, such as parking meters, digital tracking systems, and field personnel, and ensures that the regulatory framework can sustainably achieve full operational cost-recovery.

1.3 Statement of the Problem

The primary challenge lies in the structural inadequacy of the operational forecasting models traditionally used for municipal budgeting. The preliminary capacity and yield estimations presented in the Naga City CTMP rely on a static, observational baseline. This methodology multiplies the peak simultaneous vehicle count observed on each segment during the 6:00 AM–8:00 PM survey window by a flat, uniform 9-hour operational day.

When evaluated as an operations management framework, this baseline approach introduces four distinct dimensions of error:

- **The Over-Spatialization Fallacy (Illegal Inventory Inclusion):** Static observation blindly counts all parked vehicles, failing to verify whether they occupy legal, designated spaces. It inadvertently includes illegal parking, such as vehicles blocking driveways, fire hydrants, or encroaching on pedestrian crosswalks, which cannot legally be designated as part of the city's manageable parking inventory.

- **Temporal Rigidity (Static Inventory Assumption):** A static snapshot treats parking demand as an unyielding block of time. This completely ignores real-world operational dynamics, vehicle turnover frequencies, and natural off-peak vacancy rates across a standard business day.

- **Administrative Friction and Leakage:** The baseline completely overlooks institutional transaction costs and administrative friction. It fails to discount projections against unavoidable operational realities such as user evasion, enforcement gaps, grace periods, and statutory exemptions for government or emergency vehicles.

[1] Naga City Transportation and Traffic Management Plan, 2025
[2] https://www2.naga.gov.ph/office-service/public-safety-office/

- **Post-Pricing Behavioral Response Limitation:** The baseline methodology assumes that parking demand remains unchanged after fees are introduced. Pricing may cause motorists to change destinations, use off-street facilities, shift travel modes, or forego trips. Because these responses are not represented in the model, behavioral displacement is not included in the reported variance and should instead be treated as an additional source of uncertainty requiring pilot data.

Addressing the three quantified operational errors, illegal-inventory inclusion, temporal rigidity, and administrative leakage, provides a more transparent basis for pre-pilot revenue planning than the unconstrained static baseline. Post-pricing behavioral displacement is identified separately as an unquantified limitation requiring pilot evidence. Accordingly, the resulting estimate should be treated as a planning scenario rather than as a guaranteed collection level or formal budget target.

2. OBJECTIVES

To address these baseline inaccuracies, this study executes a linear logistical and operations management progression that transitions from physical space constraints to real-world administrative execution through three interconnected objectives:

a. To calculate the theoretical maximum legal inventory capacity of the Naga City CBD using standard physical-design and traffic engineering geometric guidelines.
b. To formulate a deterministic asset-utilization model that integrates effective billable-hours assumption, operational friction (leakage) factors, and unadjusted baseline space-utilization parameters.
c. To identify high-yield street corridors for priority enforcement based on dynamic asset capacity rather than unadjusted, static field counts.

This structural sequence argues that the study does not merely produce abstract projections. By mapping physical space constraints first, layering temporal and administrative realities second, and translating those metrics into an operational deployment plan third, the study directly generates an actionable resource-allocation strategy for local traffic enforcers.

3. SIGNIFICANCE OF THE STUDY

This study provides the LGU with a data-driven operational baseline necessary for the transition from unmanaged curb space to a formal, organized management system. These specific stakeholder dimensions were chosen to align with the core components of the Naga City CTMP, which mandates institutional capacity building, active transport infrastructure development, and the operational revitalization of the city center. Providing clear, targeted justifications for each sector ensures the analytical backing required to pass municipal policy hurdles and secure local legislative approval via *Sangguniang Panlungsod* ordinances.

a. **For the Naga City Traffic and Parking Management Office (NCTPMO)**: It establishes an "Operational Performance Audit-Trail". This allows management to compare actual field collections against a structurally grounded capacity baseline, thereby pinpointing corridors with high user-evasion rates or weak enforcement presence.

b. **For Urban Planning Policy and Spatial Resource Allocation**: It provides a defensive justification for "Ring-Fenced Infrastructure Reinvestment". Under this framework, parking collections can be legally earmarked to finance active transport infrastructure, such as the bike lanes and pedestrian facilities, identified as strategic operational priorities in the Naga City CTMP.

c. **For Local Economic Development and Retail Logistics**: By implementing a management framework that prioritizes asset turnover rather than static, long-duration occupation, the study helps planners convert stagnant "space hoarding" zones into high-turnover commercial access points. This directly increases customer access and customer foot traffic for local businesses.

4. CONCEPTUAL FRAMEWORK

The study adopts a Supply-Demand-Efficiency Management Model. This framework posits that a street segment is not merely a piece of pavement, but a finite, managed public asset where actualized operational yield is the product of three distinct structural filters.

Alternative modeling approaches, such as complex mathematical simulations or dynamic behavioral models, require immense amounts of historical, high-frequency smart-meter tracking data, which developing urban centers like Naga City do not currently possess. This three-layer deterministic filter model was adopted because it delivers an immediate, data-lean, yet highly defensive forecasting structure that utilizes the city's available field data but modifies it logistically to mirror real-world operational constraints.



Figure 1. Conceptual Framework

The Supply Filter (Physical Inventory Control): This layer recognizes that physical space is finite and rigid. Unlike unconstrained models, this framework explicitly accounts for "illegal occupancy" (*e.g., vehicles parked in front of hydrants, driveways, or crosswalks*). The

framework assumes that municipal management cannot legally claim yield from these spaces. Consequently, the model uses geometric design constraints to define the "Legal Yield Limit", the maximum number of vehicles that can be legally accommodated without violating public safety ordinances.

The Demand Filter (Utilization Dynamics): This layer shifts the focus from a snapshot observation to a temporal performance metric. Curb-space demand is treated as a function of space turnover. By integrating occupancy rates derived from empirical transport research, the framework accounts for the natural ebb and flow of vehicles, moving away from the assumption that a single vehicle blocks a space for the entirety of the operational day.

The Efficiency Filter (Operational Friction): The final layer acknowledges the "leakage discount", the difference between total potential capacity and actualized collection. This filter incorporates administrative realities such as user evasion, enforcement gaps, and statutory exemptions, ensuring the operational projection remains conservative and defensible to municipal stakeholders.

5. REVIEW OF RELATED LITERATURE

The proposed Supply-Demand-Efficiency framework outlined in this paper is anchored in established literature in parking management, transportation planning, and urban operations. Below are the reviewed studies that provide empirical support for the framework's three core filters while highlighting recent advances in parking policy and management:

a. Physical Capacity and Spatial Constraints (Supply Filter). Shoup (2011)[3] establishes curb space as a finite public asset requiring active management rather than unrestricted use. Complementing this perspective, the National Association of City Transportation Officials (NACTO, 2013)[4], the National Building Code of the Philippines[5] and Ortúzar and Willumsen (2011) emphasize that parking capacity must be determined using legal geometric standards and spatial constraints instead of unconstrained field observations. These studies collectively provide the foundation for estimating the model's maximum legal parking capacity.

b. Parking Utilization and Demand Management (Demand Filter). Shoup (2011) identifies parking turnover as the principal indicator of efficient curb utilization. Supporting this concept, Najmi et al. (2021)[6], Xie et al. (2024)[7] and Combes et al. (2026) demonstrate that parking demand and duration vary according to user behavior, land use, and pricing strategies, reinforcing the need to incorporate temporal utilization into parking yield estimation.

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[3] Shoup, D. (2011) "The High Cost of Free Parking," establishing curb space as a finite public asset.

[4] National Association of City Transportation Officials. (n.d.). *Urban street design guide.* NACTO. Retrieved September 26, 2026, from https://nacto.org/publication/urban-street-design-guide/

[5] Republic of the Philippines. (1977). *National Building Code of the Philippines (Presidential Decree No. 1096).* Official Gazette. https://www.officialgazette.gov.ph/1977/02/19/presidential-decree-no-1096-s-1977/

[6] Najmi, A., Bostanara, M., Gu, Z., Rashidi, T. H. (2021) On-street parking management and pricing policies: An evaluation from a system enhancement perspective. Transportation Research Part A 146: 128-151.

[7] Xie, M., Wu, X., Ji, S., Gao, Y., Wang, Y. (2024) Spatial effects of factors influencing on-street parking duration in newly built-up areas: A case study in Xi'an, China. Cities 152: 105250.

c. Operational Efficiency and Revenue Realization (Efficiency Filter). Litman (2016) and Barter (2015)[8] argue that parking revenue projections should account for administrative leakage, enforcement limitations, and user noncompliance. Complementing these findings, Li et al. (2026) and Baumgartner et al. (2025)[9] show that behavioral responses and public acceptance influence the effectiveness of parking pricing policies. These studies support the incorporation of operational efficiency adjustments into the proposed framework.

d. Advanced Parking Allocation and Pricing Strategies. Brudner (2023)[10], Delgado-Lindeman et al. (2026)[11]and Legros and Fransoo (2023)[12] demonstrate that differentiated parking allocation, residential permit management, and dynamic pricing improve curb utilization while balancing the competing needs of passenger and freight vehicles. These studies provide strategic guidance for future enhancements beyond the baseline deterministic framework.

e. Smart Parking and Data-Driven Management. Wang et al. (2024)[13] demonstrate that Smart Parking Systems supported by Artificial Neural Networks improve revenue generation and operational efficiency through data-driven pricing. Together with the preceding studies, this evidence highlights the growing role of intelligent parking management systems in maximizing curb-space utilization and supporting sustainable urban transport management.

5.1 Research Gap and Justification

The reviewed literature demonstrates substantial advances in parking management, including spatial capacity estimation, turnover-based demand management, operational efficiency adjustments, dynamic pricing, smart parking systems, and behavioral modeling. However, these approaches generally depend on extensive historical datasets, intelligent parking infrastructure, high-frequency occupancy monitoring, or computational optimization techniques that are often unavailable in developing urban centers. Consequently, they offer limited guidance for local government units that require practical and defensible parking revenue estimates using only baseline field observations.

Furthermore, existing studies typically examine individual aspects of parking management, such as capacity, pricing, demand, or operational efficiency, without integrating these components into a unified deterministic framework suitable for municipal budgeting and operational planning. This creates a methodological gap for cities transitioning from unmanaged curb space to structured parking management under limited institutional and data resources.

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[8] Barter, P. A. (2015). *A parking policy typology for clearer thinking on parking reform. Transport Reviews, 35*(2), 136–156. https://ideas.repec.org/a/taf/rjusxx/v19y2015i2p136-156.html

[9] Baumgartner, A., Klinner, N., Lanzendorf, M. (2025) Right to the city or right to park a car? Acceptability of parking management for a social-ecological transformation of urban neighbourhoods. Transportation Research Part A 199: 104528.

[10] Brudner, A. (2023) On the management of residential on-street parking: Policies and repercussions. Transport Policy 138: 94-107.

[11] Delgado-Lindeman, M., Rodríguez, A., Moura, J. L., Arellana, J. (2026) Optimization approach for planning urban on-street parking considering car and truck users. Research in Transportation Business & Management 67: 101654.

[12] Legros, B., Fransoo, J. C. (2023) Admission and pricing optimization of on-street parking with delivery bays. European Journal of Operational Research 312(1): 138-149.

[13] Wang, H., Channamallu, S. S., Pamidimukkala, A., Kermanshachi, S., Rosenberger, J. M., Kan, C., Hladik, G. (2025) Economics of smart parking: Predictive analytics in optimizing urban parking revenue. Transportation Research Procedia 90: 879-886.

To address this gap, this paper attempts to develop a deterministic capacity-constrained management framework that sequentially integrates legal spatial capacity, effective parking utilization, and operational efficiency into a single forecasting model. By relying on readily obtainable field data and established engineering standards, the framework provides a transparent, conservative, and operationally defensible approach for estimating on-street parking capacity and revenue potential, making it particularly suitable for local government implementation in developing urban contexts.

6. METHODOLOGY

The methodology employs a deterministic capacity-constrained approach, which derives its logic from traditional facility capacity theory adapted for curb-space inventory management. The equations are designed to be intuitive and highly defensible, ensuring they can be easily understood by public administrators while maintaining rigorous mathematical logic. A deterministic modeling approach was adopted because the objective of this study is to develop a transparent and operationally implementable planning framework using data that are routinely obtainable by local government units. Given the absence of historical parking occupancy and revenue records, a deterministic formulation provides a practical basis for estimating preliminary planning-level revenues. without requiring unsupported probabilistic assumptions.

The logistical progression relies on four sequential steps that systematically filter the field data:

Step 1: Maximum Spatial Capacity (C_i)

First, the Maximum Spatial Capacity (C_i) for each vehicle type *i* (where *i* = cars or motorcycles) is established by multiplying the physical length of a street segment (L) by the observed proportion allocated to that vehicle type (P_i) and dividing the result by the corresponding standard legal stall size (s_i). To ensure the calculated capacity reflects actual physical conditions, the model applies the floor function ($\lfloor ... \rfloor$), which excludes fractional values because partial parking stalls cannot accommodate vehicles. This prevents the overestimation of available parking spaces by counting only complete, usable stalls.

$$C_i = \left\lfloor \frac{L \times P_i}{s_i} \right\rfloor \quad (1)$$

Step 2: Effective Managed Spaces (E_i)

Second, the model determines the Effective Managed Spaces (E_i) by applying the minimum function (min), which compares the raw observed vehicle count from field data (O_i) with the calculated legal capacity limit (C_i). If the observed count exceeds the legal capacity, the model caps the manageable spaces at C_i, thereby eliminating excess vehicles resulting from double parking, sidewalk encroachment, or other illegal parking practices. This ensures that only legally manageable parking spaces are considered in subsequent analyses.

$$E_i = \min(O_i, C_i) \quad (2)$$

Step 3: Adjusted Daily Yield per Vehicle Type ($R_{daily,i}$)

Third, the Adjusted Daily Yield ($R_{(daily,i)}$) for each vehicle category is calculated by combining the effective managed spaces (E_i), the corresponding operational parking fee (r_i), a temporal utilization multiplier (H_b), and an operational efficiency coefficient (η):

$$R_{(daily,i)} = \eta \cdot H_b \cdot E_i \cdot r_i \quad (3)$$

To produce realistic revenue estimates, the model adopts a planning-level effective daily utilization constant H_b = 5.85 hours, representing an average occupancy rate of 65% over a 9-hour operational day to account for off-peak morning and late afternoon lulls. This value falls within the 60–80% occupancy performance target range documented by Millard-Ball, Weinberger & Hampshire (2014) for the San Francisco SFpark programme and is deliberately set below Shoup's (2011)[14] 85% optimal occupancy benchmark, which applies to mature demand-responsive pricing systems rather than first-generation implementations. No parking duration or repeated occupancy observations were conducted for this study; Hb is therefore a planning-level utilization assumption, not an empirically observed rate for Naga City, and requires recalibration against hourly occupancy counts from a structured pilot survey before use as a formal budget parameter.

An operational efficiency coefficient η = 0.80 is applied to account for real-world collection losses arising from four categories of operational friction: user evasion, enforcement gaps, grace periods, and statutory exemptions for government and emergency vehicles. The conceptual rationale for applying a discount below 1.0 is established by Litman's parking management framework (VTPI, park_man.pdf, p. 21)[15] which documents that parking payment evasion is a "folk crime" that reduces the effectiveness of parking revenue systems universally. Litman does not, however, specify a numerical coefficient. The value of 0.80 is empirically anchored against the approximately 70% payment compliance rate observed in the San Francisco SFpark programme (Montanino & Punzo, 2021; SFMTA data)[16] and set optimistically above that baseline to reflect the expected higher per-interaction compliance of uniformed officer-presence enforcement relative to the sensor-based detection used in SFpark. No Naga City-specific collection efficiency data are available; η = 0.80 is therefore a planning-level ceiling requiring recalibration against actual collection records following pilot implementation. The total segment yield is then obtained by summing the vehicle-specific results:

$$R_{(daily,\text{total})} = R_{(daily,\text{cars})} + R_{(daily,\text{motorcycles})} \quad (4)$$

Step 4: Annualized Projected Yield per Vehicle Type ($R_{annual,i}$)

Fourth, the model computes the Annual Projected Yield (R_$(annual, i)$) by scaling the adjusted daily yield across the local operational calendar parameters ($R_{\text{daily},i} \times D_y$), where D_y = 5 operating days/week × 52.143 weeks/year = 260.715 operating days/year.

$$R_{\text{annual},i} = R_{\text{daily},i} \times D_y \quad (5)$$

[14] Shoup, D. (2011). *The high cost of free parking* (Revised ed.). Routledge. Retrieved from http://shoup.bol.ucla.edu/PrefaceHighCostFreeParking.pdf

[15] Litman, T. (2024, October 9). Parking management: Strategies, evaluation and planning. Victoria Transport Policy Institute. https://www.vtpi.org/park_man.pdf

[16] San Francisco Municipal Transportation Agency. (n.d.). *SFpark pilot program.* SFMTA. Retrieved September 26, 2026, from https://www.sfmta.com/projects/sfpark-pilot-program

Annual revenue is calculated using the number of chargeable operating days in the reference year. This operating calendar must reflect the intended weekly enforcement schedule and exclude applicable holidays, officially declared closures, and other days on which parking fees will not be collected. The total annual segment yield is derived by summing the vehicle-specific results.

$$R_{(annual,"total")} = R_{(annual,"cars")} + R_{(annual,"motorcycles")} \quad (6)$$

Definition of Variables

- $\boldsymbol{L}$: Gross measured block-face length of the street segment in meters, before deductions for driveways, fire-hydrant clearances, pedestrian crossings, loading zones, and other parking restrictions.
- $\boldsymbol{P_i}$: Observed proportion of vehicle type i (cars *vs*. motorcycles)
- $\boldsymbol{s_i}$: Standard legal stall length per vehicle type. For parallel car parking, s_i = 5.5 meters. Litman (VTPI, park_man.pdf, p. 11) cites a typical parking-space length of 5.5–6.0 meters, while the Philippine National Building Code (PD 1096, IRR Section 707) specifies a minimum parallel stall dimension of 2.15m × 6.0m and NACTO (2013) recommends parallel on-street stall lengths of 6.1–6.7 meters. Because the adopted 5.5-meter value is shorter than the latter standards, it may produce a higher capacity and revenue estimate than would result from applying a 6.0-meter or longer stall length. For motorcycles, s_i = 1.5 meters. No Philippine national standard specifies the dimensions of an on-street parallel motorcycle stall; the 1.5-meter figure is an operational assumption consistent with a typical motorcycle footprint plus lateral clearance and is wider than the Australian AS2890 minimum of 1.2 meters. This absence of a national standard is acknowledged as a limitation on the precision of $\boldsymbol{C_i}$ for motorcycle spaces.
- $\boldsymbol{O_i}$: Peak simultaneous vehicle count observed on a street segment during the 6:00 AM–8:00 PM survey window.
- $\boldsymbol{\eta}$: Collection efficiency coefficient (fixed at 0.80)
- $\boldsymbol{H_b}$: Effective daily billable hours (5.85 hours, representing 65% occupancy over a 9-hour operational day). Note: The term "turnover" is not used in relation to Hb in this study, as no vehicle arrivals, departures, or individual parking durations were observed. $\boldsymbol{H_b}$ is an occupancy-adjusted utilization constant, the estimated fraction of the operational day during which a managed space is occupied by a paying vehicle.
- $\boldsymbol{r_i}$**:** Proposed hourly tariff rate (PhP 50 for cars, PhP 25 for motorcycles). Proposed hourly tariff rate per vehicle type, presented as three planning scenarios. No parking fee ordinance has been formally adopted by the Naga City *Sangguniang Panlungsod* as of the survey date; all tariff values are proposed planning rates pending legislative approval. The three scenarios are: Low (₱25/hr for cars, ₱10/hr for motorcycles), Base (₱50/hr for cars, ₱25/hr for motorcycles), and High (₱75/hr for cars, ₱40/hr for motorcycles). All primary calculations in this study use the Base scenario. The Low scenario reflects rates consistent with less commercially intensive Philippine secondary cities; the High scenario is comparable to metered on-street parking rates in Metro Manila central business districts.
- $\boldsymbol{D_y}$: Number of chargeable operating days in the reference year, based on the adopted enforcement schedule and net of applicable holidays and officially declared non-operating days.

- $\boldsymbol{C_i}$: Maximum Spatial Capacity calculated for vehicle type i on a specific street segment
- $\boldsymbol{E_i}$: Effective Managed Spaces determined for vehicle type i on a specific street segment (capped by physical capacity limits)
- $\boldsymbol{R_{daily,i}}$: Adjusted Daily Yield projected for vehicle type i on a specific street segment (expressed in PhP/day)
- $\boldsymbol{R_{annual,i}}$: Annualized Projected Yield calculated for vehicle type i on a specific street segment (expressed in PhP/year)

7. ASSUMPTIONS, LIMITATIONS, AND BIASES

Explicitly declaring the operational boundaries, assumptions, and constraints of this study is a deliberate strategy designed to pre-empt standard critiques from academic reviewers and municipal budgeting panels. Acknowledging that the data represents a single baseline snapshot and clearly defining the difference between legal capacity and raw physical space demonstrates analytical transparency, positioning the research as an intentional, conservative baseline logistical feasibility study rather than an absolute, dynamic transport demand simulation.

1. **Geometric Reality vs. Nominal Capacity:** This study does not assume that the entire physical length of a street can be legally or safely used for on-street parking. However, driveway cuts, fire hydrant clearances, pedestrian crossings, and other legally restricted areas were not explicitly measured and subtracted from the segment length L prior to computing C_i. Instead, L was measured as the full block face using Google Maps satellite imagery, and the supply filter $E_i = \min(O_i, C_i)$ implicitly handles illegal occupancy by capping the revenue base at the geometric stall-capacity ceiling. As a result, C_i represents an upward-biased estimate of the true maximum legal parking inventory, the ten-vehicle displacement reported in Section 8 is therefore a lower bound, and the number of vehicles occupying genuinely prohibited positions may be higher than the model identifies. Future iterations should measure net usable kerb length directly in the field, or apply standard exclusion deductions for driveway aprons, hydrant clearance zones, and crosswalk setbacks before computing C_i.

2. **Field Snapshot Bias:** The model relies on parking observations collected during a single survey day. As a result, the recorded parking demand may not fully capture temporal variations in parking activity and may reflect conditions that differ from the long-term average. The estimated parking demand should therefore be interpreted as representative of the survey period rather than of all operating conditions. Additionally, O_i as used in this model represents the peak simultaneous vehicle count recorded during the 6:00 AM–8:00 PM continuous observation window, not a cross-sectional count at a fixed clock time. This peak-count approach is conservative for supply-side capacity analysis, as it tests the supply filter against maximum observed demand, but it may overstate typical daily occupancy. The Demand Filter (H_b = 5.85h) moderates this peak to a time-weighted utilization estimate, and results should be read with this interaction in mind.

3. **Behavioral Response Assumption:** The proposed framework estimates parking revenue under baseline parking demand and does not explicitly account for behavioral responses to the introduction of parking fees. In practice, pricing may influence motorists to shift travel modes, relocate to off-street parking facilities, alter parking

destinations, or forego trips altogether. Consequently, the projected revenue should be interpreted as a planning-level estimate under baseline demand conditions rather than as a post-pricing forecast that incorporates demand adjustment.

4. **Asset Turnover vs. User Fee Uniformity Bias:** The model assumes a uniform user fee across all 57 street segments. From a resource management perspective, a flat-rate structure introduces an asset distortion: highly congested premium zones may remain backlogged because the rate is too low to clear the space, while peripheral segments may experience artificial vacancy. The results must be interpreted as a "Phase 1 Baseline Inventory Management Plan" preceding a future dynamic, zonal pricing framework.

5. **Enforcement Uniformity Assumptions:** The 20% operational friction factor ($\eta = 0.80$) assumes a consistent, city-wide enforcement deployment. Actual collections may vary if enforcement capacity is concentrated only in specific high-traffic corridors during the initial deployment phase of the CTMP. It should be noted that the specific value of $\eta = 0.80$ is a planning-level assumption and not an empirically calibrated figure derived from Naga City enforcement records. The Litman (VTPI) parking management framework establishes the conceptual rationale for applying a collection discount below 1.0, documenting that user evasion and enforcement gaps genuinely reduce revenue effectiveness, but does not specify a numerical coefficient. The 0.80 value is set above the approximately 0.70 payment compliance rate empirically observed in the San Francisco SFpark programme (Montanino & Punzo, 2021; SFMTA data), reflecting the expected higher per-interaction compliance of uniformed officer-presence enforcement relative to sensor-based detection. It must be treated as a planning ceiling requiring recalibration against actual collection records following pilot implementation.

6. **Planning-Level Nature of the Revenue Estimates.** The projected revenues produced by the framework are intended as **pre-pilot planning scenarios and baseline-demand revenue ceilings** rather than exact forecasts of future collections or formal budget commitments. The Demand and Efficiency Filters together account for 96.1% of the modeled difference between the static and capacity-constrained estimates. Their parameters, H_b and η, are literature-informed planning assumptions rather than values empirically observed in Naga City. These parameters should not be used as budget targets until a minimum 90-day pilot on the three highest-yield corridors (J. Hernandez Avenue, General Luna Street, and Elias Angeles Street) has generated sufficient local data, specifically, hourly occupancy counts, payment compliance ratios, and enforcement coverage logs, to calibrate Hb, η, and E_i against actual Naga City conditions. Until such recalibration is complete, the projected figures should be used only for capital investment justification, ordinance ring-fencing commitments, and as performance benchmarks against which pilot collections are diagnosed.

7. **Upward Bias in C_i from Full Block Face Measurement.** Segment length L was measured as the full block face using Google Maps satellite imagery, without explicitly subtracting the linear metres occupied by driveways, fire hydrant clearances, pedestrian crossings, and loading bays. Consequently, $C_i = \lfloor (L \times P_i) / s_i \rfloor$ is computed from an overestimate of usable kerb length, making the supply filter less binding than it would be under a net-length measurement protocol. The 10-vehicle displacement reported in Section 8 is therefore a lower bound on the true illegal inventory exclusion. Future

iterations should measure net usable kerb length directly or apply standard exclusion deductions before computing C_i.

8. **O_i is a Peak Simultaneous Count, Not a Fixed-Time Snapshot.** The field protocol involved continuous observation from 6:00 AM to 8:00 PM. O_i records the maximum number of vehicles simultaneously present on a segment at any point during this window, not a single cross-sectional count at a fixed clock time. The original manuscript's use of "point-in-time cross-sectional count" is therefore imprecise. The peak-count approach is conservative for supply-side capacity analysis, as it tests the supply filter against maximum observed demand, but it may overstate typical occupancy. The Demand Filter (H_b = 5.85h) moderates this peak to a time-weighted utilization estimate, and the interaction between a peak-based O_i and the occupancy-adjusted Hb should be read accordingly.

8. PARKING DATA ANALYSIS AND INTERPRETATION

8.1 Overview of the Dataset

The field survey instrument recorded the peak simultaneous vehicle count observed during the 6:00 AM–8:00 PM survey window for each of the 57 street segments spanning 16 corridors within the Naga City CBD, together with the street name, segment identifier, measured segment length, and observed car and motorcycle counts. This dataset constitutes the raw input layer for both the static baseline model used in the city's draft CTMP and the capacity-constrained deterministic framework proposed in this study. Applying the four-step methodology described above, Maximum Spatial Capacity, Effective Managed Spaces, Adjusted Daily Yield, and Annualized Projected Yield, to each of the 57 segments converts the raw observational data into a legally and operationally defensible revenue projection.

Because the survey instrument records only aggregate vehicle counts per segment rather than an explicit space allocation by vehicle type, the proportional allocation parameter (P_i) was operationalized as each vehicle type's share of the total observed vehicle mix at that segment (*e.g., a segment with nine cars and three motorcycles allocates 75 percent of usable length to cars and 25 percent to motorcycles*). This treatment is consistent with the framework's intent of deriving physical capacity from observed field conditions, though it represents an interpretive assumption that future iterations of the model could refine with direct space-allocation surveys.

Table 1 below shows the Revenue-Ranked Corridor summary for all 16 streets (57 segments) by projected annual revenue under the capacity-constrained deterministic model. Effective spaces reflect the E_i = min (O_i, C_i) cap. Annual revenues are calculated using the applicable tariff, effective billable hours, collection-efficiency coefficient, and defined number of chargeable operating days, D_y. Plaza Rizal recorded zero observed vehicles in the survey window and contributes no projected revenue in either model.

Table 1. Revenue-Ranked Corridor summary for all 16 streets (57 segments)

Rank	Street / Corridor	Segments	Length (m)	Eff. Car Spaces	Eff. MC Spaces	Total Eff. Spaces	Annual Revenue New Model (PhP)	Annual Revenue Static Model (PhP)
1	J. Hernandez	11	1122.90	129	23	152	8,571,527	16,483,706
2	General Luna	8	658.46	89	5	94	5,582,169	11,790,836
3	Elias Angeles	7	477.28	52	17	69	3,690,942	7,097,966
4	Arana St.	6	316.77	36	7	43	2,409,789	4,634,209
5	Penafrancia St.	3	256.54	36	0	36	2,196,263	4,223,583
6	Prieto St.	3	241.80	22	4	26	1,464,175	2,815,722
7	Padian St.	3	256.14	17	10	27	1,342,161	2,581,079
8	Barlin St.	1	119.51	20	0	20	1,220,146	2,346,435
9	Ojeda St.	3	201.73	17	2	19	1,098,132	2,229,113
10	P. Burgos St.	3	172.40	12	8	20	976,117	1,877,148
11	Abella St.	2	115.32	12	5	17	884,606	1,701,165
12	Panganiban Drive	2	128.82	13	0	13	793,095	1,525,183
13	Naga City People's Mall	1	82.12	8	0	8	488,058	938,574
14	Dinaga St.	2	212.75	5	0	5	305,037	586,609
15	Plaza Quezon	1	46.32	3	0	3	183,022	351,965
16	Plaza Rizal	1	90.24	0	0	0	—	—
	TOTAL	**57**	**4,499.10**	**471**	**81**	**552**	**31,205,239**	**61,183,293**

***Note**:* Static model = flat 9-hr uninterrupted occupancy, no capacity cap, no efficiency discount. New Model = capacity-constrained with legal stall geometry, 65% occupancy-adjusted utilization constant, and 80% collection efficiency. Variance (overstatement) = Static Annual − New Model Annual = PhP 29,978,054 citywide (48.99% of static baseline)

8.2 Citywide Capacity and Revenue Findings

Applying the Supply and Demand filters across all 57 segments yields a citywide legal capacity that effectively manages 471 of 481 observed cars and 81 of 81 observed motorcycles. The ten-vehicle reduction in car spaces, from observed count to effective managed spaces, occurs on segments where the peak simultaneous vehicle count exceeded the geometrically permissible legal stall inventory, confirming that a portion of observed parking occupancy represents

vehicles in positions that cannot legally be designated as part of the city's manageable curb-space inventory.

After applying the Efficiency Filter (η = 0.80) and Demand Filter (H_b = 5.85 effective billable hours), the model produces a preliminary citywide daily revenue estimate. Annual revenue is then calculated by multiplying this daily estimate by the number of chargeable operating days in the reference year (D_γ). This compares to a static baseline projection of approximately PhP 61,183,293 using the city's original flat 9-hour, unconstrained methodology. The capacity-constrained model is therefore approximately 49 percent lower than the static baseline, a variance of roughly PhP 29.98 million annually. Table 2 summarizes this comparison.

Table 2. Comparative Results of the Static Baseline and Capacity-Constrained Parking Models

Metric	Static Baseline Model	Capacity-Constrained Model
Total observed/effective vehicles (cars + MC)	562 (raw count)	552 (471 cars + 81 MC)
Total citywide annual revenue (PhP)	61,183,293	31,205,239
Variance vs. capacity-constrained model (PhP)	—	29,978,054 (overstatement)
Variance as % of static baseline	—	49.0%

This variance is not a measurement error but the expected and intended output of layering real-world operational constraints onto a previously unconstrained estimate. A layer-by-layer decomposition attributes the full PhP 29,978,054 reduction to three quantified filters: the Supply Filter accounts for PhP 1,173,218 (3.9% of the total reduction), the Demand Filter for PhP 21,003,526 (70.1%), and the Efficiency Filter for PhP 7,801,310 (26.0%). The dominant driver is the replacement of the static flat 9-hour occupancy assumption with the 65% occupancy-adjusted billable hours constant, not the removal of illegally parked vehicles, which, despite being the most intuitively prominent correction, accounts for less than 4% of the variance.

Behavioral displacement is explicitly excluded from the model and contributes ₱0 to the reported variance. The ₱29.98 million difference is attributable only to the Supply, Demand, and Efficiency filters. Post-pricing behavioral response remains an unquantified downside risk; actual collections may be lower if pricing causes motorists to change destinations, use off-street facilities, shift modes, or forego trips.

Had the LGU budgeted against the unadjusted baseline, the model indicates substantial exposure to a revenue shortfall. The magnitude of any actual shortfall, however, can be established only after pilot implementation.

Additionally, Table 3 below unpacks the PhP 29,978,054 variance reported in Table 2 by isolating the marginal contribution of each filter applied sequentially to the static baseline. Holding all other parameters constant at each step, the Supply Filter alone reduces revenue by PhP 1,173,218 (3.9%); substituting the demand-adjusted billable hours constant (H_b = 5.85h) for the flat 9-hour assumption then reduces the remainder by a further PhP 21,003,526 (70.1%); and finally multiplying by the collection efficiency coefficient (η = 0.80) accounts for the remaining PhP 7,801,310 (26.0%). The three reductions sum exactly to the total variance, and the cumulative percentage reaches 100.0% at Step 3, confirming that the three quantified filters fully account for the PhP 31,205,239 capacity-constrained result reported in Table 2, with no residual unexplained.

The key practical implication of this decomposition is that the modeled reduction relative to the static baseline is driven primarily by the occupancy assumption embedded in H_b, not by the geometric exclusion of illegal inventory. Using $D_y = 260.715$, chargeable operating days, recalibrating H_b upward or downward by one-hour changes projected annual revenue by approximately PhP 5.33 million, which is about 4.55 times the PhP 1.17 million impact of the Supply Filter, with D_γ=260.715. This makes empirical measurement of actual average daily occupancy, through a structured pilot survey, the single highest-priority data collection task before the model can be used as a formal budget reference.

Table 3. Sequential Filter Decomposition Summary

Step	Filter Applied	Revenue After Filter	Reduction (₱)	% of Total Reduction	Cumulative % Reduced
0	*Static Baseline (no filters)*	₱61,183,293	—	—	0.0%
1	Supply Filter — $E_i = \min(O_i, C_i)$ Caps 10 illegally parked cars (481 → 471)	₱60,010,075	₱1,173,218	3.9%	3.9%
2	Demand Filter — H_static (9h) → Hb (5.85h) Replaces flat 9-hour day with 65% occupancy-adjusted billable hours	₱39,006,549	₱21,003,526	70.1%	74.0%
3	Efficiency Filter — multiply by η = 0.80. Discounts 20% for user evasion, enforcement gaps, exemptions (Litman, 2016)	₱31,205,239	₱7,801,310	26%	100.0%
	TOTAL REDUCTION		**₱29,978,054**	**100.0%**	

8.3 Scenario Testing for Policy and Investment Decisions

Because the Demand Filter (H_b) and Efficiency Filter (η) jointly account for 96.1% of the modeled reduction, they represent the most influential levers of fiscal performance. The Supply Filter (E_i), fixed by geometric field measurement, introduces minimal uncertainty by comparison. This sensitivity analysis therefore isolates how variations in behavioral demand and enforcement efficiency shape annual revenue outcomes.

Table 4 illustrates how modest shifts in occupancy and collection efficiency can swing projected revenues by over 70% between pessimistic and optimistic bounds. The Base scenario, aligned with this paper, anchors the model to empirically constrained conditions, while the Low and High cases bracket the plausible range of administrative performance. This framing not only quantifies uncertainty but also highlights the fiscal payoff of stronger enforcement and demand management.

Table 4. Scenario-Based Revenue Sensitivity Matrix for Ordinance Planning

Scenario (Operational)	Description	Hb (hrs)	η	Annual Revenue (₱)	vs. Base (₱)	vs. Base (%)
LOW	Pessimistic — 50% occupancy, 70% collection efficiency (4.50h = 50% of 9h; η represents weak enforcement)	4.50	0.70	21,003,526	10,201,713	-32.7
BASE	Kamid et al. (2026); this paper — 65% occupancy, 80% efficiency	5.85	0.80	31,205,239	—	—
HIGH	Optimistic — 80% occupancy, 90% collection efficiency (7.20h = 80% of 9h; η assumes strong enforcement)	7.20	0.90	43,207,254	+12,002,015	+38.5

8.4 Identification of High-Yield Corridors

Aggregating segment-level results by street name and ranking corridors by projected annual revenue under the capacity-constrained model isolates the priority corridors for initial enforcement deployment. Table 5 presents the top five revenue-generating streets.

Table 5. Top Five Revenue-Generating Street Corridors Under the Capacity-Constrained Parking Management Model

Rank	Street	Segments	Effective Car Spaces	Effective MC Spaces	Annual Revenue (New Model, PhP)	Annual Revenue (Static, PhP)
1	J. Hernandez	11	129	23	8,571,527	16,483,706
2	General Luna	8	89	5	5,582,169	11,790,836
3	Elias Angeles	7	52	17	3,690,942	7,097,966
4	Arana St.	6	36	7	2,409,789	4,634,209
5	Penafrancia St.	3	36	0	2,196,263	4,223,583
	TOTAL				**22,450,690**	**44,230,300**

Below are the map locations of the top five highest revenue-generating corridors identified in Table 5.



Figure 2. J. Hernandez Avenue



Figure 3. General Luna



Figure 4. Elias Angeles

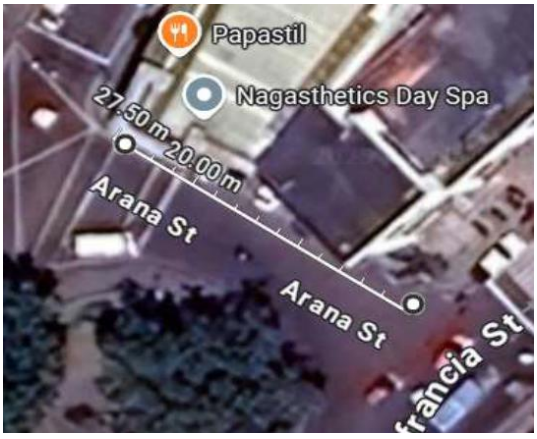


Figure 5. Arana Street



Figure 6. Penafrancia Street

Consistent with field expectations, J. Hernandez Avenue emerges as the single highest-yield corridor, projected to generate approximately PhP 8.57 million annually, nearly 27 percent of total projected citywide revenue, driven by its eleven segments, the largest effective car inventory (129 spaces) of any corridor, and a meaningful motorcycle presence (23 spaces). General Luna and Elias Angeles follow as the second- and third-ranked corridors, respectively, together contributing a further PhP 9.27 million in projected annual yield. These three corridors alone account for approximately 57.2 percent of total citywide projected revenue despite

comprising only 26 of the 57 surveyed segments, indicating a strongly concentrated revenue base.

This concentration carries a direct operational implication for the NCTPMO: limited initial enforcement personnel and infrastructure (parking meters, signage, field staff) should be deployed first to J. Hernandez, General Luna, and Elias Angeles, where the capacity-constrained model indicates the highest defensible revenue yield per unit of enforcement effort. Corridors at the lower end of the ranking, such as Plaza Quezon, Dinaga St., and Plaza Rizal, the latter recording zero observed vehicles in the survey window, represent comparatively low-priority segments for Phase 1 deployment, though they should be retained in the inventory for future monitoring as usage patterns evolve.

8.5 Interpretation Relative to the Conceptual Framework

The segment-level results validate the three-layer Supply-Demand-Efficiency structure proposed in the Conceptual Framework. The Supply Filter alone accounts for the removal of ten vehicles from the manageable inventory, while the combined Demand and Efficiency Filters (the 65 percent effective billable-hours assumption and 80 percent collection efficiency) are jointly responsible for most of the reduction from the static baseline to the final annualized figure. This decomposition gives the NCTPMO and municipal auditors a transparent audit trail: any variance between the projected PhP 31.2 million and actual field collections in future periods can be diagnosed against a specific filter, physical capacity, turnover assumptions, or collection efficiency, rather than treated as an undifferentiated forecasting failure.

Collectively, these findings support the Significance of the Study's framing of the model as an auditable planning framework, as the corridor rankings provide a defensible basis for ring-fenced infrastructure reinvestment prioritization, while the magnitude of the static-versus-constrained variance provides the NCTPMO with a quantified justification for adopting capacity-constrained budgeting over the original CTMP baseline.

The practical value of the proposed framework lies in its ability to support transparent municipal budgeting using data that are readily obtainable through routine field surveys. By explicitly separating legal parking capacity, operational utilization, and collection efficiency, the framework provides a clear basis for developing literature-informed planning-level revenue scenarios that require local calibration as implementation data become available.

9. CONCLUSIONS AND RECOMMENDATIONS

This study developed a deterministic, capacity-constrained planning framework to address the principal limitations of the static observational methodology used in the draft Comprehensive Traffic Management Plan for estimating on-street parking revenue. The findings confirm that the original baseline methodology substantially overstates achievable revenue: across the 57 surveyed segments, the static model projects approximately PhP 61.18 million in annual revenue, while the capacity-constrained model, after sequentially applying legal-capacity, turnover, and collection-efficiency filters, projects approximately PhP 31.21 million, a variance of nearly PhP 29.98 million, or roughly 49 percent. Had the LGU budgeted against the unadjusted baseline, the model indicates substantial exposure to a revenue shortfall. The magnitude of any actual shortfall, however, can be established only after pilot implementation.

The decomposition quantifies three sources of difference from the static baseline: legal-capacity constraints, occupancy-adjusted billable hours, and collection efficiency. Post-pricing

behavioral displacement was not modeled and is therefore not part of the ₱29.98 million variance.

At the corridor level, the analysis identified J. Hernandez Avenue, General Luna, and Elias Angeles as the three highest-yield streets in the CBD, jointly responsible for approximately 56 percent of total projected citywide revenue despite comprising less than half of the surveyed segments. This concentration demonstrates that parking revenue potential in Naga City's CBD is not evenly distributed across the street network but is instead heavily weighted toward a small number of high-traffic commercial corridors, providing a clear, data-driven basis for sequencing enforcement rollout rather than deploying limited municipal resources uniformly.

In summary, these findings support the central thesis of the study: that a transparent, three-layer deterministic model, grounded in legal geometric standards, effective billable-hours assumption, and planning-level efficiency discounting, offers local government units a practical, auditable, and immediately implementable alternative to both unconstrained static baselines and the data-intensive dynamic models that remain out of reach for developing urban centers such as Naga City.

10. RECOMMENDATIONS

For the Naga City Traffic and Parking Management Office (NCTPMO). The capacity-constrained estimate may be used as a pre-pilot planning scenario and performance benchmark rather than as the official revenue or budgeting reference. Formal adoption should occur only after a pilot has provided local occupancy, payment-compliance, enforcement-coverage, operating-calendar, and collection data for model calibration. The NCTPMO should initially pilot the deployment of enforcement personnel, signage, and metering infrastructure on J. Hernandez, General Luna, and Elias Angeles Streets, where the model indicates the highest projected yield, before extending coverage to lower-ranked corridors. During the pilot, actual daily and monthly collections by corridor should be compared with the modeled $\boldsymbol{R_{daily}}$ and $\boldsymbol{R_{annual}}$ values. Differences should be assessed against occupancy, payment compliance, enforcement coverage, post-pricing behavioral response, and the number of chargeable operating days before being attributed to collection leakage.

For Urban Planning Policy and Spatial Resource Allocation. Consistent with the Ring-Fenced Infrastructure Reinvestment justification articulated in the Significance of the Study, the city should formally earmark a defined share of realized parking revenue, calculated against the conservative capacity-constrained baseline rather than optimistic static projections, to finance the Class 2 bike lanes and pedestrian facilities identified as priorities in the CTMP. Using the lower, defensible figure as the legislative basis for ring-fencing reduces the risk that infrastructure financing commitments outpace actual collections.

For Local Economic Development and Retail Logistics. Given that high-yield corridors are also the city's primary commercial streets, the NCTPMO should coordinate with local business associations along J. Hernandez, General Luna, and Elias Angeles prior to enforcement rollout to manage the transition from free, long-duration occupation to paid, turnover-oriented parking. Clear communication that the policy is designed to increase customer access and curb-space availability, rather than simply to generate municipal revenue, will help secure local business buy-in and reduce political resistance during initial implementation.

For Municipal Budgeting and Legislative Approval. When presenting this framework to the Sangguniang Panlungsod for ordinance consideration, the LGU should present both the static and capacity-constrained figures side by side, explicitly framing the latter as a pre-pilot planning scenario requiring local calibration rather than as an official budget projection. This comparison illustrates the effects of the model's capacity, utilization, and collection-efficiency assumptions, but formal revenue commitments should be based on locally calibrated pilot results.

For Phasing and Future Pricing Strategy. Because the model assumes a uniform fee across all 57 segments, the LGU should treat the results of this study as a Phase 1 Baseline Inventory Management Plan only. Once baseline collection data is available from initial enforcement, the city should evaluate a transition toward zonal or dynamic pricing, charging a premium in chronically congested, high-demand corridors such as J. Hernandez to encourage turnover, while maintaining lower rates in peripheral segments to avoid artificial vacancy.

11. FURTHER STUDIES

While the deterministic capacity-constrained framework developed in this study offers a practical and readily implementable improvement over the existing static baseline, its design intentionally trades dynamic precision for data-lean feasibility. Several avenues for future research would extend and refine the framework as the NCTPMO's institutional capacity and data infrastructure mature:

Longitudinal and Multi-Period Validation. This study relies on a single cross-sectional field survey, which carries an inherent risk of anomaly bias. Future research should replicate the survey across multiple time periods, different days of the week, seasons, and before/after major city events, to test the stability of the observed vehicle mix and occupancy assumptions, and to develop segment-specific rather than citywide turnover multipliers.

Empirical Calibration of the Efficiency Coefficient. The operational efficiency coefficient ($\eta = 0.80$) and the effective billable hours constant ($\boldsymbol{H_b} = 5.85$) were adopted from literature-supported general assumptions rather than Naga City-specific enforcement data. Once a pilot enforcement phase generates actual collection records, future studies should statistically recalibrate these coefficients using observed local collection-to-capacity ratios, improving the model's predictive accuracy for subsequent budget cycles.

Post-Pricing Behavioral Displacement Modeling. This framework explicitly excludes post-pricing behavioral response and therefore produces a baseline-demand revenue ceiling rather than a realized post-pricing forecast. A valuable extension would be a before-and-after study measuring actual driver adaptation, mode shift, diversion to off-street facilities, or trip suppression, once paid parking is implemented, allowing the static maximum-yield ceiling developed here to be paired with a realized-demand estimate for more precise medium-term budgeting.

Direct Measurement of Space Allocation by Vehicle Type. Because the current dataset records only aggregate vehicle counts per segment, this study approximated the proportional length allocation between cars and motorcycles ($\boldsymbol{P_i}$) from the observed vehicle mix. Future

data collection efforts should directly survey or mark actual curb-space allocation by vehicle type, enabling a more precise Supply Filter calculation independent of observed demand patterns.

Zonal and Dynamic Pricing Analysis. Building on the Phase 1 uniform-fee structure established here, subsequent research should model the revenue and congestion-relief impact of differentiated zonal pricing, varying tariffs by corridor demand intensity as suggested by recent literature on dynamic parking allocation, to evaluate whether a tiered rate structure would more efficiently clear high-demand corridors such as J. Hernandez while sustaining utilization in peripheral segments.

Integration with Smart Parking Infrastructure. As the NCTPMO's technical capacity grows, future studies should examine the feasibility and return on investment of transitioning from manual field counts to sensor-based or camera-based occupancy monitoring, enabling the shift from this study's deterministic, snapshot-based model toward a continuously updated, data-driven framework as demonstrated in recent smart-parking research.

Expansion of Scope Beyond the CBD Core. This study confined its analysis to the 57 segments within the Naga City CBD identified in the current CTMP survey. Future research should extend the same capacity-constrained methodology to peripheral commercial districts and barangay-level commercial strips, both to capture citywide revenue potential and to assess whether managed CBD pricing produces spillover parking demand in adjacent unmanaged areas.

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