MEC Siting as Urban Public Infrastructure*

Evidence from Busanand Sejong

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Structured Abstract

Purpose. This study redefines multi-access edge computing (MEC) as urban public infrastructure shared by smart-city services and interprets the difference between efficiency- and spatial-equity-based siting as the additional burden of universal provision.

Methods. Standardized MEC use cases are classified by latency sensitivity, data volume, and dependence on nearby computation. Proxy variables for five service categories are normalized on 500 m grids to form composite demand. Existing 5G base-station cells define candidate sites, and capacitated set-covering and maximal-covering models are compared under a 1,000 m service radius.

Results. The equity criterion requires 400 facilities in Busan and 264 in Sejong, compared with 210 and 126 under the efficiency criterion. Moving to equity raises demand coverage by 23.2 and 27.8 percentage points but cell coverage by 45.0 and 50.8 points. Under efficiency, only 13.4% and 13.2% of cells in the lowest demand quintile are served.

Contribution. Universal edge provision is less a question of aggregate facility count than of which areas are completed at each stage; candidate-site density and urban form determine both the shape and burden of service gaps.

Keywords: multi-access edge computing, facility location, capacitated covering, spatial equity, universal service, smart city

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1. Background, Research Gap, and Questions

Smart-city policy has shifted from asking whether technologies can be introduced to asking whether promised services can be delivered at adequate scale and quality (Choi & Song, 2023). Autonomous driving and cooperative intelligent transport require end-to-end latency of 3–100 ms, reliability up to 99.999%, and communication ranges of 50–1,000 m (3GPP, 2024). Intelligent video and environmental sensing continuously generate large data streams that benefit from processing near the point of origin (Motlagh et al., 2022). Centralized cloud architectures cannot eliminate distance-related delay or backhaul pressure through server performance alone (Khan et al., 2020).

MEC moves computing, storage, and intelligence toward the radio-access edge. Its distinctive value is therefore spatial: it requires physical sites near users and data sources (Liang et al., 2022). Base stations are representative co-location candidates because existing power, enclosures, rooftops, and network connections can reduce additional capital expenditure (Khan et al., 2020; Vitello et al., 2022). Once the candidate set is treated as a finite and georeferenced stock of urban assets, MEC deployment becomes a facility-location decision about how many sites to convert and where.

Connecting two research traditions

Edge-placement research establishes that siting is spatial and that workload capacity changes both server count and location, but it commonly reduces demand to traffic or aggregate workload and evaluates latency, load, and cost (Wang, S. et al., 2019; Lähderanta et al., 2021). Urban facility-location research distinguishes universal coverage from demand maximization, introduces capacity constraints, and shows that socially constructed demand changes siting outcomes (Toregas et al., 1971; Church & ReVelle, 1974; Pirkul & Schilling, 1991; Robinson et al., 2022). Computational edge infrastructure has rarely been placed at the intersection of these two traditions.

Question 1: How do efficiency and spatial-equity criteria change the required number and location of MEC facilities and the spatial form of service gaps?

Question 2: When planned-development areas are added to the demand surface while existing candidates and service radius are held constant, how do facility counts and selected sites change?

Analytical contribution

- Reformulate MEC placement as a radius-based capacitated covering problem.
- Construct demand from standardized smart-city service requirements rather than a single traffic measure.
- Define spatial equity as service to every reachable residential demand cell, not equality of redundant server coverage among users (He & Xie, 2022; Wu et al., 2025).

2. Study Areas, Demand, and Candidate Supply

Busan and Sejong contain Korea's first national pilot smart-city projects and are therefore plausible early locations for large-scale edge demand. The analysis covers each city's entire administrative territory using the most recent data available at the time of analysis. Demand and supply are represented on 500 m grid cells (Busan EDC Smart City Master Plan, 2018; Sejong Smart City Master Plan, 2018).

City	All cells	Candidate cells	Analysis cells	Beyond reach	Demand share beyond reach
Busan	3,135	1,567	2,942	193 (6.16%)	1.48%
Sejong	1,857	622	1,795	62 (3.34%)	0.89%

Table 1. Grid cells and existing-base-station candidate supply

Source: Original study, Table 3.

Composite potential demand

Eight standardized service groups are consolidated into five observable categories because public grid-level data cannot separately identify all services. Autonomous driving/C-ITS uses node traffic volume and interchange locations; intelligent CCTV/safety uses public CCTV locations and counts; population/activity combines de facto and resident populations, public-transport trips, and commercial density; environmental/IoT sensing uses air-quality stations and public Wi-Fi; smart manufacturing/industry uses industrial-complex boundaries. Planned-development area is included only in the future scenario. This consolidation is a data limitation rather than a claim that the merged services are theoretically identical.

$$s_{ik} = (1 / |V_k|)\ \Sigma_v \in V_k\ minmax(r_{iv}) \quad (1)$$

$$a_i = (1 / |K|)\ \Sigma_k \in K\ minmax(s_{ik}) \quad (2)$$

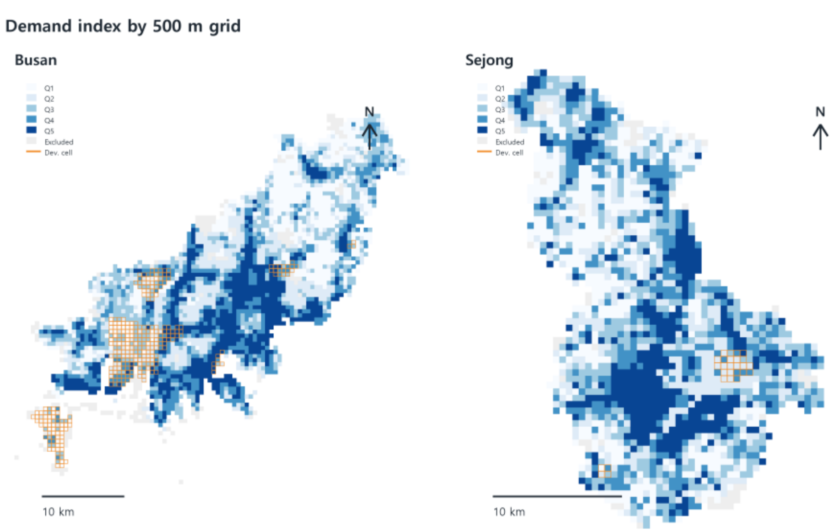

Figure 1. Composite potential demand by 500 m grid

Source: Original study, Figure 2.

3. Capacitated Covering Framework

The candidate set J is limited to 500 m cells containing at least one existing 5G base station, with at most one MEC facility per candidate cell. A demand cell is analytically reachable when at least one candidate lies within 1,000 m. Cells without any such candidate are separated before optimization because conversion of all existing base stations cannot serve them. The 1,000 m radius is the upper bound among minimum V2X communication-range requirements and is used as a deliberately permissive planning assumption (3GPP, 2021, 2024).

$$N_i(S) = \{ j \in J \,/\, d_{ij} \le S \}, \quad S = 1{,}000\ m \quad (3)$$

Facility capacity is set to 1.25 times mean load under the uncapacitated equity solution. This follows the location-allocation practice of imposing an upper workload limit, not an observed MEC server specification (Current & Storbeck, 1988; Pirkul & Schilling, 1991; Chauhan et al., 2019).

$$U = \kappa \cdot (\Sigma_i \in I' a_i \,/\, p_e q^0), \quad \kappa = 1.25 \quad (4)$$

Two criteria under a common constraint structure

Criterion	Objective	Binding interpretation	Facility count
Spatial equity	Minimize $\Sigma_j x_j$	Assign all demand in every reachable cell while respecting facility capacity	$p_e q$
Efficiency	Maximize $\Sigma_i \Sigma_j a_i y_{ij}$ for fixed p	Prioritize high-demand cells; a second stage maximizes served cells at the same optimal demand	$p_e ff$ at transition

Table 2. Equity and efficiency criteria

Source: Original study, Equations (5)–(16).

Indicators and solution sequence

$$C\_demand = assigned\ composite\ demand \,/\, total\ composite\ demand \times 100 \quad (17)$$

$$C\_cell = served\ analysis\ cells \,/\, all\ analysis\ cells \times 100 \quad (18)$$

$$G = p_e q - p_e ff, \quad G_{100} = G \,/\, A \times 100 \quad (19\text{–}20)$$

1. **Build.** construct a_i, candidate indicator b_j, and coverage set N_i.
2. **Calibrate.** solve the uncapacitated equity model and calculate U.
3. **Solve.** obtain $p_e q$ and repeat the efficiency model across p to form coverage curves.
4. **Interpret.** identify $p_e ff$ at the maximum marginal gain in cell coverage, then evaluate the development scenario.

4. Busan Results

Criterion	Facilities	Uncapacitated p^0	Demand coverage	Cell coverage	Unserved cells	Mean utilization
Equity	400	342	100.0%	100.0%	0	68.4%
Efficiency	210	—	76.8%	55.0%	1,323	100.0%

Table 3. Facility count and performance in Busan

Source: Original study, Table 4.

The efficiency transition occurs at 210 facilities. All installed facilities remain fully utilized through this point, and the marginal increase in cell coverage rises from 0.102 percentage points at p = 209 to 0.442 points at p = 210. Once residual capacity appears, facilities can absorb additional low-demand cells and spatial coverage expands more rapidly. The transition therefore marks the boundary between a demand-absorption phase and a spatial-completion phase.

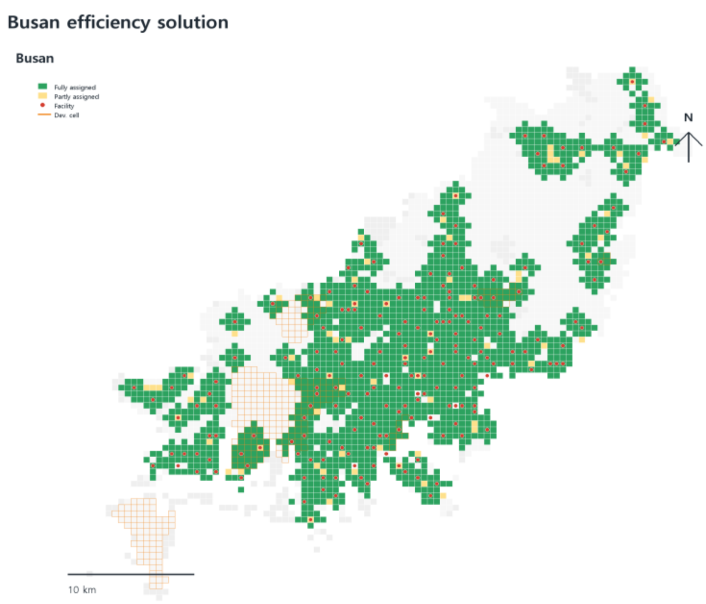

Figure 2. Busan efficiency solution (p = 210)

Source: Original study, Figure 7.

Spatial interpretation

Only 13.4% of cells in the lowest demand quintile are served, compared with 77.6–82.5% in the upper two quintiles. Served cells have 8.30 candidate sites within 1 km on average, whereas unserved cells have 4.42; 44.6% of the 1,323 unserved cells have three or fewer candidates. Coverage falls from 91.0% within 5 km of the demand-weighted center and 76.7% at 5–10 km to 39.5% at 10–15 km, then remains at 39.6% beyond 15 km. This forms a peripheral gap belt outside the continuous urban core.

The two optimal configurations are not nested. Only 65 of the 210 efficiency sites also appear in the equity solution. Moving to equity adds 335 sites but removes 145 efficiency sites, demonstrating that universal provision changes the location structure rather than merely adding the net gap of 190 facilities.

5. Sejong Results

Criterion	Facilities	Uncapacitated p^0	Demand coverage	Cell coverage	Unserved cells	Mean utilization
Equity	264	218	100.0%	100.0%	0	66.1%
Efficiency	126	—	72.2%	49.2%	911	100.0%

Table 4. Facility count and performance in Sejong

Source: Original study, Table 5.

The efficiency transition is identified at 126 facilities. Marginal cell coverage remains near 0.111 percentage points through p = 126, while mean utilization begins to fall below 100% after p = 128 and marginal cell coverage rises to 0.501 points at p = 129 and 0.724 points at p = 130. As in Busan, spatial expansion accelerates when capacity ceases to bind every facility.

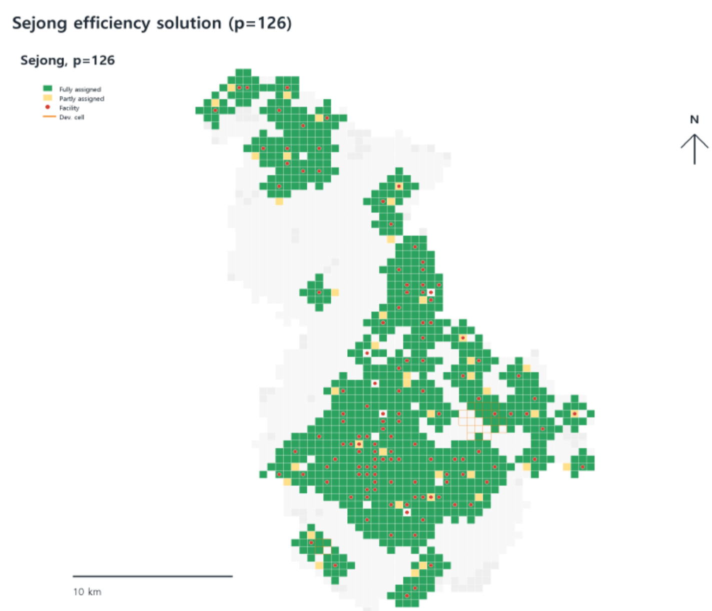

Figure 3. Sejong efficiency solution (p = 126)

Source: Original study, Figure 9.

Spatial interpretation

Coverage rises monotonically from 13.2% in the lowest demand quintile to 74.7% in the highest. Served cells have 5.80 candidates within 1 km on average, versus 3.00 for unserved cells; 68.8% of the 911 unserved cells have three or fewer candidates. Candidate scarcity is therefore more dominant than in Busan.

Coverage declines from 66.6% within 5 km to 57.1% at 5–10 km and 27.3% at 10–15 km, but rebounds to 55.1% beyond 15 km. All 214 cells in the outer band are north of the demand center, where Jochiwon forms a separate built-up area. Sejong's gap is thus an inter-center low-density corridor rather than a monotonic urban fringe. Only 59 efficiency sites overlap with the equity solution, an overlap rate of 46.8%.

6. Cross-City Comparison

City	p_eff	p_eq	Gap G	G per 100 km^2	Demand coverage at p_eff	Cell coverage at p_eff
Busan	210	400	190	26.33	76.8%	55.0%
Sejong	126	264	138	31.21	72.2%	49.2%

Table 5. Efficiency–equity gap by city

Source: Original study, Table 6.

Absolute gaps are larger in Busan, but area-standardized gaps reverse the ordering: 26.33 facilities per 100 km^2 in Busan versus 31.21 in Sejong. This finding runs against the expectation that the denser metropolitan city necessarily bears the larger equity burden. Under the study's fixed candidate-set assumption, the spatial density of inherited communications assets is more consequential than demand concentration alone.

Moving from efficiency to equity increases demand coverage by 23.2 percentage points in Busan and 27.8 in Sejong, but cell coverage by 45.0 and 50.8 points. Additional facilities are therefore used predominantly to fill spatial gaps rather than to capture large increments of demand. Capacity also adds 58 facilities in Busan and 46 in Sejong beyond the uncapacitated coverage requirement, equivalent to 14.5% and 17.4% of each equity solution.

Concentration and morphology of exclusion

City	Contiguous unserved areas	Largest area	Largest share	Top-three share	Urban form
Busan	84	708 cells	53.5%	79.6%	Peripheral belt beyond the core
Sejong	36	527 cells	57.8%	89.6%	Low-density corridor between two centers

Table 6. Spatial concentration of unserved cells

Source: Original study, Section 6.1.

The largest three contiguous areas contain most unserved cells in both cities. Equity planning should therefore target a small number of coherent territories rather than distribute facilities uniformly across the entire city. The similar lowest-quintile coverage rates—13.4% and 13.2%—also indicate that exclusion is a systematic property of the efficiency criterion, while urban structure determines its spatial form.

7. Planned-Development Scenario

The scenario holds candidate sites and the 1,000 m radius constant and adds confirmed planned-development districts to the demand surface. Busan includes ten projects totaling 46.1 km^2, of which 81% is concentrated in six Gangseo-gu projects; Sejong includes the 5-1 National Pilot Smart City district and a public-facility complex totaling approximately 3.1 km^2 (Busan Metropolitan City, 2024; Sejong National Pilot Smart City Implementation Plan, 2019).

City	Current p_{eq}	Future p_{eq}	Change	Facilities in development cells	Eligible development cells served	Beyond-reach development cells
Busan	400	391	−9	48 → 53	100.0%	32
Sejong	264	263	−1	2 → 3	100.0%	0

Table 7. Equity solution before and after planned development

Source: Original study, Table 8.

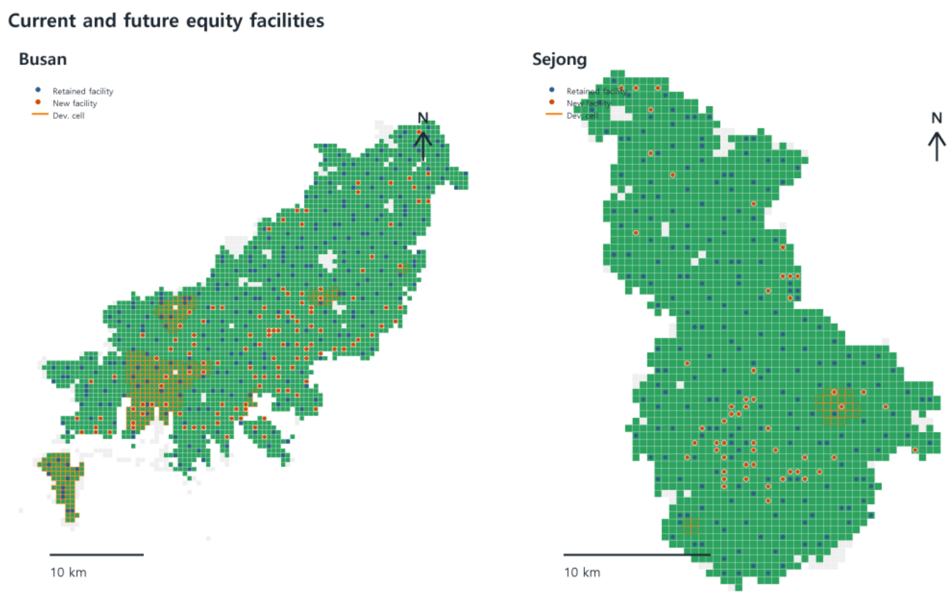

Figure 4. Retained and newly selected facilities in the future equity solution

Source: Original study, Figure 10.

Facility counts do not increase: Busan changes from 400 to 391 and Sejong from 264 to 263. The coverage constraint itself does not contain composite demand; development affects the solution through capacity. Because total demand and capacity increase together under the calibration rule, their aggregate ratio remains fixed, while spatial redistribution can reduce load concentration. This result is specific to the model and should not be generalized as evidence that development lowers infrastructure needs.

Locations change substantially despite stable totals. Busan selects 121 sites not used in the current solution and drops 130; Sejong selects 54 and drops 55. New and dropped Busan sites have nearly identical mean demand and distance profiles, so the turnover is interpreted as localized capacity reallocation rather than a one-way shift toward development districts. Targeted prior investment remains necessary for the 32 Busan development cells beyond existing-network reach.

8. Discussion, Planning Implications, and Conclusion

A differentiated three-layer strategy

Layer	Busan / Sejong	Planning meaning
1. Efficiency reference	210 / 126 facilities	High-demand urban and industrial axes that market-led deployment is more likely to reach
2. Equity gap	+190 / +138 facilities	Low-demand and low-density areas that can be served by reallocating or adding facilities within existing candidates
3. Beyond reach	193 / 62 cells	Areas requiring new base-station sites or alternative access before MEC conversion can serve them

Table 8. Planning layers derived from the model results

Source: Synthesis of original study, Section 6.3.

Demand and candidate scarcity reinforce one another because base stations reflect prior commercial demand. Reusing inherited assets therefore carries past supply bias into the new edge layer. The efficiency–equity gap can be read as a relative indicator of facilities for which market incentives may be weak, but it is not an expenditure estimate or a fixed public-sector obligation; installation cost, operator plans, and policy instruments are outside the model.

Staged implementation requires advance definition of the target service level. Only 31.0% of Busan efficiency sites and 46.8% of Sejong efficiency sites overlap with the equity solution, so building the efficiency optimum first can create relocation and sunk-cost risks. Service-specific priorities also require explicit policy choices: safety-critical transport may justify demand-focused priority in selected corridors, whereas environmental sensing and population-based services may require wider availability. Equal category weights in this study express the absence of defensible ordinal evidence, not proof of equal importance.

Conclusion

Treating MEC as an urban facility-location problem reveals that universal provision is fundamentally spatial. The equity criterion requires 400 facilities in Busan and 264 in Sejong, compared with 210 and 126 at the efficiency transition. The additional facilities produce much larger gains in cell coverage than in demand coverage and are located farther from demand centers. Busan's exclusion forms a peripheral belt, whereas Sejong's forms a corridor between distinct centers. Candidate-site density and urban morphology therefore determine where public intervention or coordinated provision may be necessary.

Limitations

- Centroid distance and a fixed radius do not directly model latency, backhaul conditions, network topology, or radio propagation (Lähderanta et al., 2021).
- All existing base stations are treated as technically convertible, without power, cooling, space, or ownership checks.
- Capacity is a multiple of mean proxy demand rather than measured server workload; the demand index is not observed MEC traffic.
- Equal weights and merged service categories reflect data limitations, and empirical analysis is limited to two cities.

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