

DIGITAL ACTIVITY ENGAGEMENT AND LOCATION STOP DURATIONS IN JABODETABEK: A MICRO STOP-EPIISODE PERSPECTIVE

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Abstract. The pervasive adoption of mobile smartphone applications has eroded traditional space-time constraints, leading to activity fragmentation across physical urban environments. This study examines how digital activity engagement as secondary virtual task participation during stationary physical stays and investigates its spatial relationship with physical stay duration across non-transit location stops in the Jakarta Metropolitan Area. A secondary dataset comprising 15,350 non-transit stop episodes collected from 341 residents was analyzed using multivariable Ordinary Least Squares regression models. Heteroscedasticity was addressed through White's HC3 robust standard error corrections, while primary physical activity land-use contexts were controlled. The empirical results reveal that active digital engagement during location stops holds a statistically significant positive association with physical dwell duration across all functional domains. The presence of digital mandatory, maintenance, and leisure activities was associated with an increase in stop duration relative to baseline physical visits. These findings provide evidence consistent with micro-level location complementarity and dwell-time amplification, highlighting the role of virtual connectivity in extending stationary urban stays.

Keyword: Activity Fragmentation; Digital Multitasking; Dwell Time; Location Complementarity

[Judul: AKTIVITAS DIGITAL DAN DURASI PEMBERHENTIAN LOKASI DI JABODETABEK: PERSPEKTIF EPISODE PERSINGGAHAN MIKRO]. Adopsi aplikasi telepon pintar seluler yang meluas telah mengikis batasan ruang-waktu tradisional, memicu fragmentasi aktivitas di lingkungan fisik perkotaan. Penelitian ini menguji bagaimana keterlibatan aktivitas digital sebagai partisipasi tugas virtual sekunder selama menetap fisik di lokasi pemberhentian dan menguji hubungan spasialnya dengan durasi menetap fisik pada pemberhentian lokasi non-transit di Wilayah Metropolitan Jakarta. Dataset sekunder yang mencakup 15.350 episode pemberhentian non-transit dari 341 penduduk dianalisis menggunakan model regresi Kuadrat Terkecil Biasa multivariabel. Heteroskedastisitas ditangani melalui koreksi kesalahan standar kuat HC3 White, sementara konteks penggunaan lahan aktivitas fisik utama dikontrol. Hasil empiris menunjukkan bahwa keterlibatan digital aktif selama pemberhentian lokasi memiliki hubungan positif yang signifikan secara statistik dengan durasi menetap fisik di seluruh domain fungsional. Kehadiran aktivitas digital wajib, pemeliharaan, dan hiburan berhubungan dengan peningkatan durasi singgah relatif terhadap kunjungan fisik standar. Temuan ini memberikan bukti yang konsisten dengan komplementaritas lokasi skala mikro dan amplifikasi durasi singgah, menegaskan peran konektivitas virtual dalam memperpanjang durasi menetap di ruang perkotaan.

Kata Kunci: Fragmentasi Aktivitas; Multitasking Digital; Durasi Singgah; Komplementaritas Lokasi.

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1. INTRODUCTION

The rapid penetration of mobile smartphone technologies and wireless internet networks in developing megacities has transformed traditional space-time structures that historically governed human activities (Shen et al., 2020; Sun et al., 2021). In the Jakarta Metropolitan Area (Jabodetabek), continuous digital connectivity allows urban residents to perform virtual tasks while present at physical locations throughout the day (Jamal et al., 2025; Safira & Chikaraishi, 2022). Under classical activity-based time-geography frameworks, daily activities were bound to rigid schedules and fixed physical locations (Jara-Díaz & Rosales-Salas, 2017; Xue et al., 2025). In contemporary digitally connected environments, activity fragmentation occurs as continuous activity blocks are disaggregated into smaller, discrete sub-episodes that can be conducted across flexible times and varied spatial contexts (Fielbaum & Alonso-Mora, 2024).

In parallel with activity fragmentation, mobile platform usage enables in-situ digital multitasking, in this study where defined as secondary virtual tasks participation are conducted during stationary physical stays at location stops (Tang et al., 2020; Varghese et al., 2022; Wang & Mokhtarian, 2024). While the impact of ICT on aggregate daily travel budgets has been widely evaluated, transport geography literature presents ongoing debates regarding how concurrent digital platform engagement influences physical stay duration at destination stops (Julsrud & Denstadli, 2017; Robbennolt et al., 2025). On one hand, virtual accessibility may compress physical dwell times by enabling efficient transaction fulfillment and remote coordination (Le et al., 2022; Shukla & Raval, 2021). On the other hand, ICT-mediated multitasking relaxes subjective time constraints during location visits, potentially extending physical stay durations through dwell-time amplification and location complementarity (Jamal et al., 2025; Kong et al., 2020).

A major gap in prior empirical research is that ICT-travel relationships are predominantly examined at aggregate full-day scales or focused exclusively on

travel time perception during transit segments (Ženka et al., 2025). Micro-level evaluations examining how active digital engagement during stationary stops interacts with location stay duration across different land-use environments remain limited, particularly in developing country megacities (Jamal et al., 2025). Short-term activity choices at specific stop locations represent fundamental building blocks of daily routines, yet single-level daily models obscure these localized dwell-time adjustments (Harding et al., 2025; Ozbilen et al., 2021). Addressing this gap requires an empirical framework that disaggregates physical trajectories into discrete stop episodes while controlling for primary physical land-use contexts.

Positioning this research within Urban Development is particularly critical for rapidly expanding megacities such as Jabodetabek, where rapid suburbanization, polycentric development, and transit-oriented development (TOD) initiatives interact with a hyper-digitized app ecosystem (Widita et al., 2025). As digital platforms dissolve traditional functional boundaries between residential, commercial, and employment spaces, physical urban destinations are increasingly functioning as "hybrid urban spaces" (Li et al., 2018). Understanding the micro-scale dwell-time adjustments driven by digital multitasking provides key evidence for urban planning, including the design of flexible public spaces, management of curbside congestion, allocation of parking facilities, and enhancing the urban vitality of polycentric activity nodes (Gong et al., 2024).

To address this limitation, this study examines the association between active digital activity engagement during non-transit location stops and physical stay duration in Jabodetabek at the micro stop-episode level. Digital engagement is disaggregated into three binary functional

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indicators, including e-mandatory, e-maintenance, and e-leisure activities. A secondary dataset comprising 15,350 non-transit stop episodes extracted from multi-week GPS travel diaries of 341 residents is analyzed using multivariable Ordinary Least Squares regression models with White's HC3 robust standard error corrections. By controlling for primary physical land-use purposes, including workplace, maintenance, and discretionary sites relative to home anchor baselines, this investigation provides empirical evidence regarding whether in-situ digital platform usage corresponds with micro-level location dwell-time compression or complementarity in a developing megacity setting.

2. METHODS OR EXPERIMENT

The micro-level empirical analysis was conducted using a secondary multi-week travel diary dataset collected in the Jakarta Metropolitan Area (Jabodetabek), Indonesia. Individual activity trajectories were recorded continuously between January and February 2020 using the X-ING smartphone tracking application. Continuous trajectory logs gathered from 341 unique respondents were filtered to extract discrete non-transit physical stop episodes.

Travel segments, transit transfer stops, and data gap intervals representing GPS signal losses were excluded from the analysis, resulting in a micro dataset comprising 15,350 valid location stop episodes. Each recorded stop episode captured precise start and end timestamps, spatial coordinates, primary physical activity purposes, and accompanying digital platform engagements.

Physical location contexts were classified into four primary land-use categories to establish baseline stay duration expectations. Primary physical activities recorded in the diary were grouped into home anchor points, mandatory stops (workplaces and educational institutions), maintenance locations (retail stores, markets, medical centers, and personal services), and discretionary sites (recreational venues, dining spots, and social gatherings). Digital activity participation during each physical episode was operationalized using three binary indicator variables (1 if present, 0

otherwise), capturing e-mandatory engagement (remote work and online learning), e-maintenance tasks (e-commerce, online food ordering, and mobile banking), and e-leisure pursuits (video streaming, online gaming, and social networking).

Digital activity participation during each physical episode was operationalized using three distinct binary indicator variables (E_1, E_2, E_3), capturing e-mandatory engagement (remote work and online learning), e-maintenance tasks (e-commerce, online food ordering, and mobile banking), and e-leisure pursuits (video streaming, online gaming, and social networking). It is important to clarify why three binary indicator variables were specified rather than two. Because an individual can engage in multiple digital activity domains simultaneously during a single physical stop episode (e.g., streaming music while conducting mobile banking), these digital indicators were specified as non-mutually exclusive binary variables under a multi-label flagging structure. Thus, E_1, E_2 , and E_3 each take a value of 1 if the corresponding digital activity occurred during the stop episode and 0 otherwise. Unlike dummy coding of a single categorical variable with $K - 1$ categories, this three-binary specification allows independent and combined evaluation of each digital domain, where the baseline condition ($E_1 = 0, E_2 = 0, E_3 = 0$) represents physical stops conducted with zero digital activity participation.

To account for the multi-layered nature of digitally augmented routines, multi-label flagging was preserved during episode construction. Because multiple digital activity domains could be reported simultaneously within a single physical stop, binary indicators were specified as non-mutually exclusive variables. Furthermore, structural positioning of dependent and explanatory metrics was specified under observational modeling logic rather than strict experimental design. Recorded start and end timestamps corresponded to the physical stop episode, indicating whether digital activities were reported within that physical timeframe rather than measuring isolated app-usage durations. Consequently, estimated parameters were formulated to identify structured behavioral associations reflecting dwell-time amplification rather than direct causal mechanisms.

The relationship between active digital platform engagement and physical stay duration across non-transit location stops was evaluated using a multivariable Ordinary Least Squares regression model. The micro stop-episode model is mathematically formulated as shown in Equation below:

$$S_{ij} = \alpha_0 + \alpha_1 E_{1,ij} + \alpha_2 E_{2,ij} + \alpha_3 E_{3,ij} + \sum_{k=1}^{K-1} \delta_k D_{k,ij} + u_{ij}$$

where S_{ij} represents the physical stop duration in minutes for episode j conducted by individual i . Binary explanatory variables $E_{1,ij}$, $E_{2,ij}$, and $E_{3,ij}$ denote the presence of e-mandatory, e-maintenance, and e-leisure activities during the episode, respectively. Categorical dummy variables $D_{k,ij}$ represent primary physical activity land-use purposes, including mandatory, maintenance, and discretionary stops, with home anchor points serving as the baseline reference category (α_0). Parameters α_0 , α_k , and δ_k denote the model intercept, digital engagement coefficients, and physical location controls, while u_{ij} represents the random error term.

Econometric diagnostics and residual properties were evaluated to confirm parameter stability and inference validity. Non-constant error variance was identified across location stop durations, reflecting high behavioral variation in stay lengths. Estimation was executed using White's HC3 robust standard error corrections, adjusting covariance matrices to yield unbiased hypothesis tests. Residual independence was confirmed by a Durbin-Watson statistic of 1.718, indicating the absence of residual autocorrelation across discrete episode observations. Multicollinearity among predictors was ruled out, as the model condition number was evaluated at 5.66. Although residual normality was rejected by the Jarque-Bera test due to right-skewness in stop durations, asymptotic parameter efficiency and statistical consistency were preserved under the Central Limit Theorem given the large sample size of 15,350 stop episodes.

3. RESULT AND DISCUSSION

Digital platform participation rates displayed substantial co-occurrence across non-transit physical location stops. Across the total sample of 15,350 non-transit stop episodes, concurrent digital activities were recorded in 10,442 segments (68.03%), whereas 4,908 segments (31.97%) were conducted purely through physical presence. Mandatory work and study stops recorded digital participation in 3,961 segments (69.95%), physical maintenance locations exhibited digital platform usage in 1,255 segments (68.39%), discretionary recreational stops were accompanied by digital activities in 1,126 segments (67.34%), and home anchor points recorded digital engagement in 4,100 segments (66.34%). A summary of cross-tabulation distributions across physical activity domains is presented in Table 1.

Unadjusted stop duration differences between digitally accompanied episodes and purely physical visits were evaluated using non-parametric comparison tests. For non-transit location stops, digitally accompanied episodes ($N = 10,442$) recorded a mean duration of 117.51 minutes (median = 11.90 minutes), whereas purely physical stops ($N = 4,908$) averaged 303.37 minutes (median = 93.25 minutes). Statistical significance was confirmed by both testing methods (Mann-Whitney $U = 62,507,937.0, p < 0.0001$; Welch's $t = -27.47, p < 0.0001$), yielding a medium effect size (Cohen's $d = -0.4323$). These unadjusted metrics reflect time condensation in raw comparisons, where digital platform usage is frequently recorded during shorter, high-frequency activity blocks throughout the day. Controlling for primary land-use contexts is therefore essential to isolate true dwell-time associations.

The multivariable Ordinary Least Squares regression model was estimated to evaluate how active digital platform engagement relates to physical stay duration at non-transit stops under controlled land-use conditions. Overall model fit was confirmed with an R^2 of 0.1059, an Adjusted R^2 of 0.1056, and a statistically significant F -statistic of 282.70 ($p < 0.0001$). Model performance and parameter estimation outputs corrected with White's HC3 robust standard errors are detailed in Table 2.

Table 1. Cross-Tabulation Analysis of Physical Activity Domains and Digital Engagement

Physical Domain	With Digital Activity	Without Digital Activity	Total Count	Episode Share With Digital (%)
Home Anchor Points	4,100	2,080	6,180	66.34
Mandatory Locations	3,961	1,702	5,663	69.95
Maintenance Locations	1,255	580	1,835	68.39
Discretionary Locations	1,126	546	1,672	67.34
Total Non-Transit Stops	10,442	4,908	15,350	68.03

Table 2. Micro Stop-Episode Level OLS Regression Output

Variable Label	Coefficient (b)	HC3 Robust Std. Error	t-statistic	p-value	Empirical Conclusion
Intercept (α_0)	450.8998	9.5466	47.23	< 0.0001	Home Baseline (~7.5 hrs)
Discretionary Location (D_1)	-368.7183	11.7701	-31.33	< 0.0001	Shorter than Home Baseline
Maintenance Location (D_2)	-402.0246	11.1052	-36.20	< 0.0001	Shorter than Home Baseline
Mandatory Location (D_3)	-264.4991	11.1775	-23.66	< 0.0001	Shorter than Home Baseline
Has E-Mandatory (E_1)	106.8029	17.7184	6.03	< 0.0001	Positive Dwell-Time Association
Has E-Maintenance (E_2)	215.7115	21.1797	10.18	< 0.0001	Positive Dwell-Time Association
Has E-Leisure (E_3)	212.0374	23.4166	9.05	< 0.0001	Positive Dwell-Time Association

The relationship between stop characteristics and length of stay operates interactively with digital activity engagement. Primary land-use functions set the structural boundaries of physical dwell time where mandatory anchor sites inherently command longer stay durations due to institutional obligations, while maintenance stops are inherently brief and transactional (Stinson & Mohammadian, 2025; Wang & Nurul Habib, 2025). However, when active digital engagement is introduced within these locations, dwell times are substantially amplified across all land-use types.

Positive and statistically significant associations were identified across all binary digital activity indicators after controlling for primary physical activity land-use contexts ($p < 0.0001$). Holding physical location types constant, the presence of e-mandatory activity was associated with an additional 106.80 minutes of physical stop duration ($b = +106.8029$). E-maintenance activity presence

was associated with an additional 215.71 minutes of stay duration ($b = +215.7115$), while e-leisure activity presence was associated with an additional 212.04 minutes ($b = +212.0374$). This reveals a dual association: longer baseline physical stays (such as at home or work) offer larger "opportunity windows" for individuals to engage in digital multitasking, while active digital engagement simultaneously relaxes subjective time pressure, making individuals willing to stay longer at non-residential stops (Lizana et al., 2022).

These substantial positive parameters reflect strong co-occurrence between virtual multitasking and prolonged physical stays, particularly at high-baseline anchor locations like home and major workplace hubs. Rather than implying a direct causal extension of stay duration, these magnitudes indicate that long-duration stays inherently provide larger time windows for digital platform engagement. Reconciling these controlled

regression outputs with the unadjusted bivariate comparisons, where digital episodes appeared shorter, driven by high-frequency, short-duration digital check-ins during short daily stops. Once land-use baselines are held constant, active digital engagement systematically co-occurs with extended dwell times.

The empirical findings from this model provide evidence consistent with micro-level location complementarity and dwell-time amplification. Active digital engagement during stationary physical stops enhances individual capacity to perform secondary tasks, conduct remote communications, or access virtual entertainment (Julsrud & Denstadli, 2017). This ICT-mediated multitasking relaxes subjective time constraints, making physical stays at destination stops more productive or enjoyable and leading to longer stay durations (Franco & Birenboim, 2024). Comparing these micro results with macro daily models illustrates how virtual-physical activity relationships vary by analytical scale, as digital leisure can simultaneously support aggregate daily travel substitution while extending dwell times during specific out-of-home visits.

Reconciling unadjusted non-parametric comparisons with controlled multivariable regression outputs highlights the necessity of controlling for primary physical land-use contexts. Unadjusted comparisons reflect the high frequency of brief digital check-ins during short daily stops, whereas multivariable regression isolates the specific association of active digital engagement within comparable land-use categories. Because digital platform usage and location stay durations were observed simultaneously in secondary travel diaries, these positive regression parameters represent structured behavioral associations rather than direct causal effects (Safira & Chikaraishi, 2022). Extended stay durations provide greater windows of opportunity for digital interaction, while virtual connectivity simultaneously encourages individuals to remain longer at visited locations.

From an urban and regional planning also spatial policy perspective, these empirical results offer vital

insights for metropolitan strategy in Jabodetabek. Traditional urban planning assumptions that treat destination visits as single-purpose, time-restricted stops are challenged by digitally augmented activity routines. However, the finding that digital multitasking significantly extends dwell times even at maintenance locations by over 200 minutes, demonstrates that physical locations in megacities are rapidly evolving into multipurpose "hybrid spaces". Municipal authorities should promote flexible third places, community co-working nodes, and digitally equipped public spaces that accommodate both physical presence and virtual multitasking. Furthermore, because extended dwell times increase localized parking demand and curbside pressure around commercial nodes, transport planners must implement dynamic curbside management and enhance active transport access surrounding primary activity centers (Rizki et al., 2024).

4. CONCLUSION

This study examined the associations between active digital activity engagement during non-transit location stops and physical stay duration in the Jakarta Metropolitan Area using a micro stop-episode analytical perspective. The empirical findings demonstrate that active digital platform participation during location stops is systematically associated with extended physical stay duration across all functional domains. Specifically, the presence of digital mandatory, maintenance, and leisure activities was associated with statistically significant increases in physical stop duration relative to baseline visits after controlling for primary land-use contexts. These results contribute to transport geography and activity-based time-geography literature by providing empirical evidence of micro-level location complementarity and dwell-time amplification, demonstrating how virtual connectivity relaxes subjective time constraints during stationary location visits in a developing megacity. From an urban development standpoint, the findings highlight the transformation of physical urban destinations into hybrid spaces, calling for flexible public space planning, dynamic curbside management, and polycentric land-use strategies in Jabodetabek.

Nevertheless, several methodological limitations should be considered, including the cross-sectional observational structure of secondary travel diary logs, which records digital platform usage and physical stay duration simultaneously, thus preventing strict causal inferences. Future research should integrate high-resolution spatial GIS variables, implement longitudinal panel tracking across multi-year horizons, and utilize structural equation modeling to capture micro-scale built environment interactions and long-term activity adaptation.

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