

G06 Space, Digital Transformation and AI for Regional Implications

For Ordinary Sessions (O-)

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Title: Structural Digital Dependence in Urban Systems: A Probability-Based Measurement Approach

Abstract (200 – 400 words)

Large-scale digital infrastructure disruptions have revealed the depth of contemporary urban dependence on centralized digital layers. When core data facilities malfunction, cascading interruptions across administrative platforms, mobility management systems, financial transactions, and public services make visible the systemic dependencies underlying urban operations. These events raise a fundamental question: to what extent have regional urban systems become structurally dependent on digital infrastructures? This study conceptualizes urban systems as regionally defined functional configurations composed of interrelated social, economic, and infrastructural subsystems. Digital infrastructures operate as coordination and control layers that mediate transactions, governance processes, mobility flows, and service provision. Digital dependence is defined as the structural dependence of core regional services on digital infrastructures.

The empirical analysis draws on multi-source regional operational data collected between 2016 and 2025, including ICT network failure logs, administrative system interruptions, mobility management disruptions, energy supply incidents, and platform-service outages. These datasets enable identification of simultaneous digital-system interruptions and service-level malfunction events across sectors within regions. Methodologically, the study adapts probabilistic dependency metrics developed in engineering research on complex technical infrastructures to regional systems analysis. Regional service sectors are modeled as system nodes, and operational time-series records are converted into binary state matrices representing normal operation and disruption events. Functional dependence is computed using conditional co-occurrence probabilities between digital-system interruptions and service disruptions, normalized by marginal occurrence rates to distinguish structural dependence from stochastic coincidence. This produces a digital structural dependence measure derived from probabilistic dependency metrics, calculated at the regional level.

The results show that sector-specific configurations of structural dependence are observed across regional systems. Transport control and administrative information platforms exhibit particularly strong functional dependence on digital infrastructures, while energy management systems show intermediate levels and certain localized services remain comparatively less dependent. Asymmetric dependence

structures are observed: service sectors rely heavily on digital infrastructures, whereas digital infrastructures do not rely to the same extent on individual service domains. Notably, the intensity and configuration of digital dependence vary across regions, indicating territorially differentiated patterns of structural reliance. These findings demonstrate that regional urban systems have become structurally digital-dependent. As digital transformation advances, operational reliance becomes increasingly centralized within digital coordination layers, intensifying cross-sector vulnerability to digital disruption. By introducing a probability-based dependency measurement framework into regional analysis, this study provides a structural foundation for assessing digital resilience across regions and for identifying territorially differentiated concentrations of digital vulnerability.

Keywords (Max. 5): Urban Systems, Digital Transformation, Digital Dependence, Infrastructure Interdependency, Digital Resilience