



School of Social Sciences

Master in Business Administration

Master Thesis

Market Readiness Analysis for City Digital Twins:

A Strategic Marketing Approach

Exploring market acceptance and commercialization dynamics in Smart Cities with a focus on Cooperative, Connected and Automated Mobility (CCAM) applications.

Georgios Kolionis

Supervisor: Persefoni Polychronidou

Patras, Greece, September 2026

© Hellenic Open University, 2026

The content of this thesis along with its results is owned by the Hellenic Open University and his author, where each of them has the sole and exclusive right to use, reproduce, and publish it (totally or partially) for educational or research purposes, with the obligation to make reference to the thesis's title, the author's name and to the Hellenic Open University where the thesis was written.



Market Readiness Analysis for City Digital Twins: A Strategic Marketing Approach

Exploring market acceptance and commercialization dynamics in Smart Cities with a focus on Cooperative, Connected and Automated Mobility (CCAM) applications.

Georgios Kolionis

Supervising Committee

Supervisor:

Persefoni Polychronidou

Hellenic Open University

International Hellenic University

Co-Supervisor:

Antonios Reztis

Hellenic Open University

Agricultural University of Athens

Patras, Greece, June 2026

Abstract

This dissertation examines the market readiness of City Digital Twins (CDTs) in smart-city environments, with a focus on Cooperative, Connected and Automated Mobility (CCAM) applications. The technical promise of these systems is not really in question; the harder problem is whether they can become accepted, trusted and commercially sustainable offerings rather than perpetual demonstrators. We use the Horizon Europe FRODDO project as the main case context because it brings the relevant pieces together in one place (Digital Twin architecture, CCAM safety, Operational Design Domain continuity, physical and digital infrastructure, predictive analytics, data governance, pilots and exploitation planning) which makes it well suited to studying the distance between a working demonstrator and a market-ready solution.

The analysis takes a strategic marketing perspective, drawing on technology readiness, innovation diffusion, technology acceptance, value co-creation and Business-to-Government innovation, and it weighs adoption drivers and barriers ranging from usefulness and trust to interoperability, data security, legal compliance, procurement logic, organisational capacity and clarity of the value proposition. Methodologically it follows a qualitative, literature-based case synthesis drawing on academic literature, policy sources and FRODDO project material. The central argument is that technical validation, while necessary, is not sufficient: a City Digital Twin becomes market-ready only once it is useful, trusted, legally safe, institutionally compatible and clearly positioned for the actors expected to adopt it.

Keywords

City Digital Twins, Cooperative, Connected and Automated Mobility, Market Readiness Analysis

Περίληψη

Η παρούσα διπλωματική εργασία εξετάζει την ετοιμότητα αγοράς των Ψηφιακών Διδύμων Πόλης σε περιβάλλοντα έξυπνων πόλεων, με έμφαση στις εφαρμογές Συνεργατικής, Συνδεδεμένης και Αυτοματοποιημένης Κινητικότητας. Το ερώτημα δεν είναι αν τα συστήματα αυτά είναι τεχνικά υποσχόμενα. Το πιο δύσκολο ζήτημα είναι αν μπορούν να εξελιχθούν σε αποδεκτές, αξιόπιστες και βιώσιμες λύσεις αγοράς.

Το έργο Horizon Europe FRODDO χρησιμοποιείται ως βασικό πλαίσιο μελέτης περίπτωσης. Συνδυάζει αρχιτεκτονική Ψηφιακού Διδύμου, ασφάλεια CCAM, συνέχεια του Επιχειρησιακού Πεδίου Σχεδιασμού, φυσικές και ψηφιακές υποδομές, προγνωστική ανάλυση, διακυβέρνηση δεδομένων, πιλοτικές εφαρμογές και σχεδιασμό αξιοποίησης. Έτσι, προσφέρει ένα χρήσιμο πεδίο για τη μελέτη του κενού ανάμεσα σε έναν λειτουργικό επιδεικτικό μηχανισμό και σε μια λύση έτοιμη για την αγορά.

Η εργασία υιοθετεί μια στρατηγική προσέγγιση μάρκετινγκ, αντλώντας από την τεχνολογική ετοιμότητα, τη διάχυση της καινοτομίας, την αποδοχή της τεχνολογίας, τη συν-δημιουργία αξίας και την καινοτομία Business-to-Government. Εξετάζει παράγοντες και εμπόδια υιοθέτησης, όπως η χρησιμότητα, η εμπιστοσύνη, η διαλειτουργικότητα, η ασφάλεια δεδομένων, η νομική συμμόρφωση, η λογική των δημόσιων προμηθειών, η οργανωσιακή ικανότητα και η σαφήνεια της πρότασης αξίας.

Η έρευνα ακολουθεί μια ποιοτική σύνθεση βιβλιογραφίας και μελέτης περίπτωσης, αξιοποιώντας ακαδημαϊκή βιβλιογραφία, πηγές πολιτικής και υλικό του έργου FRODDO. Υποστηρίζει ότι η τεχνική επικύρωση είναι αναγκαία, αλλά δεν αρκεί. Ένα Ψηφιακό Δίδυμο Πόλης γίνεται έτοιμο για την αγορά μόνο όταν είναι χρήσιμο, αξιόπιστο, νομικά ασφαλές, θεσμικά συμβατό και καθαρά τοποθετημένο για τους φορείς που αναμένεται να το υιοθετήσουν.

Λέξεις – Κλειδιά

Ψηφιακά Δίδυμα Πόλεων, Συνεργατική, Διασυνδεδεμένη και Αυτοματοποιημένη Κινητικότητα, Ανάλυση Ετοιμότητας για την Αγορά

Bibliography

- Bal, A. S., Käpylä, J., Li, H., & Helander, N. (2023). Collaborative value co-creation from a stakeholder perspective: A literature review. *Journal of Creating Value*, 9(2). <https://doi.org/10.1177/23949643231151831>
- Batty, M. (2018). Digital twins. *Environment and Planning B: Urban Analytics and City Science*, 45(5), 817–820. <https://doi.org/10.1177/2399808318796416>
- Braun, V., & Clarke, V. (2021). *Thematic analysis: A practical guide*. SAGE Publications.
- Call, D. R., & Herber, D. R. (2022). Applicability of the diffusion of innovation theory to accelerate model-based systems engineering adoption. *Systems Engineering*, 25(6), 574–583. <https://doi.org/10.1002/sys.21638>
- Calzati, S. (2023). No longer hype, not yet mainstream? Recalibrating CDTs' expectations and reality: A case study perspective. *Frontiers in Big Data*, 6, Article 1236397. <https://doi.org/10.3389/fdata.2023.1236397>
- Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in Europe. *Journal of Urban Technology*, 18(2), 65–82. <https://doi.org/10.1080/10630732.2011.601117>
- Carrasco-Farré, C., Snihur, Y., Berrone, P., & Ricart, J. E. (2022). The stakeholder value proposition of digital platforms in an urban ecosystem. *Research Policy*, 51(4), Article 104488. <https://doi.org/10.1016/j.respol.2022.104488>
- CCAM Association. (2023). *Strategic Research and Innovation Agenda: Connected, Cooperative and Automated Mobility - Updated version 2023*. European Partnership on Connected, Cooperative and Automated Mobility. <https://www.ccam.eu/wp-content/uploads/2023/11/CCAM-SRIA-Update-2023.pdf>
- Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approaches* (6th ed.). SAGE Publications.
- Cureton, P., & Hartley, E. (2023). City Information Models (CIMs) as precursors for Urban Digital Twins (UDTs): A case study of Lancaster. *Frontiers in Built Environment*, 9, Article 1048510. <https://doi.org/10.3389/fbuil.2023.1048510>

- Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly* 1 September 1989; 13 (3): 319–340. <https://doi.org/10.2307/249008>
- Digital Twin Consortium. (2023). Platform Stack Architectural Framework: An introductory guide. Digital Twin Consortium. <https://www.digitaltwinconsortium.org/platform-stack-architectural-framework-an-introductory-guide-form/>
- European Commission. (n.d.). Cooperative, connected and automated mobility (CCAM). Directorate-General for Mobility and Transport. Retrieved May 19, 2026, from
- European Commission. (2021, November 18). DUET Local Digital Twin named Best Enabling Technology at World Smart City Awards. Directorate-General for Communications Networks, Content and Technology. <https://digital-strategy.ec.europa.eu/en/news/duet-local-digital-twin-named-best-enabling-technology-world-smart-city-awards>
- European Commission. (2025a). Creating a common European mobility data space. Directorate-General for Mobility and Transport. https://transport.ec.europa.eu/transport-themes/smart-mobility/creating-common-european-mobility-data-space_en
- European Commission, Interoperable Europe Portal. (2025). EU Local Digital Twin Toolbox. Interoperable Europe Portal. <https://interoperable-europe.ec.europa.eu/collection/ldttoolbox>
- European Commission, CORDIS PORTAL. (2026). Federated cybeR-physical infrastructure for ODD cOntinuity: FRODDO project fact sheet. European Commission. <https://cordis.europa.eu/project/id/101147819>
- European Parliament & Council of the European Union. (2023). Regulation (EU) 2023/2854 of the European Parliament and of the Council of 13 December 2023 on harmonised rules on fair access to and use of data and amending Regulation (EU) 2017/2394 and Directive (EU) 2020/1828 (Data Act). Official Journal of the European Union. <https://eur-lex.europa.eu/eli/reg/2023/2854/oj/eng>

- European Parliament & Council of the European Union. (2024). Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending several Union legal acts (Artificial Intelligence Act). Official Journal of the European Union. <https://eur-lex.europa.eu/eli/reg/2024/1689/oj/eng>
- FRODDO Consortium. (2024a). Grant Agreement: Project 101147819 - FRODDO - HORIZON-CL5-2023-D6-01. European Climate, Infrastructure and Environment Executive Agency.
- FRODDO Consortium. (2024b). D1.1 – Project Manual (Final v1.0). Horizon Europe FRODDO Project, Grant Agreement No. 101147819.
- FRODDO Consortium. (2024c). D6.2 – Ethical & Legal Framework (initial version) (Final v1.0). Horizon Europe FRODDO Project, Grant Agreement No. 101147819.
- FRODDO Consortium. (2025a). D4.1 – FRODDO DT for transport management – first version (Final v1.0). Horizon Europe FRODDO Project, Grant Agreement No. 101147819.
- FRODDO Consortium. (2025b). D1.3 – Data Management Plan (DMP) updated version (Final v1.0). Horizon Europe FRODDO Project, Grant Agreement No. 101147819.
- FRODDO Consortium. (2025c). D2.1 – Co-creation outcomes and User requirements (Final v1.0). Horizon Europe FRODDO Project, Grant Agreement No. 101147819.
- FRODDO Consortium. (2025d). D3.1 – Dynamic ODD Extension Framework with Predictive Analytics (Final v1.0). Horizon Europe FRODDO Project, Grant Agreement No. 101147819.
- FRODDO Consortium. (2025e). D4.6 – Decision Support Dashboards – first version (Final v1.0). Horizon Europe FRODDO Project, Grant Agreement No. 101147819.
- FRODDO Consortium. (2025f). D5.1 – FRODDO Pilot Testing Framework (Final v1.0). Horizon Europe FRODDO Project, Grant Agreement No. 101147819.
- FRODDO Consortium. (2025g). D7.3 – FRODDO Interim Exploitation Report (Final v1.0). Horizon Europe FRODDO Project, Grant Agreement No. 101147819.

- Gupta, A., Panagiotopoulos, P., & Bowen, F. (2023). Developing capabilities in smart city ecosystems: A multi-level approach. *Organization Studies*, 44(10), 1703–1724. <https://doi.org/10.1177/01708406231164114>
- Hickerson, K., & Lee, Y.-C. (2022). A psychometric evaluation of a Technology Acceptance Model for autonomous vehicle. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 66(1), 1819–1823. <https://doi.org/10.1177/1071181322661400>
- International Organization for Standardization. (2023). Road vehicles - Test scenarios for automated driving systems - Specification for operational design domain (ISO 34503:2023). International Organization for Standardization
- King, W., & Halawi, L. (2024). A quantitative analysis of autonomous vehicle cybersecurity as a component of trust. *SAE International Journal of Connected and Automated Vehicles*, 7(1), 15–26. <https://doi.org/10.4271/12-07-01-0002>
- Kitchin, R. (2014). The real-time city? Big data and smart urbanism. *GeoJournal*, 79(1), 1–14. <https://doi.org/10.1007/s10708-013-9516-8>
- Kraus, S., Breier, M., Lim, W. M., Dabić, M., Kumar, S., Kanbach, D., Mukherjee, D., Corvello, V., Piñeiro-Chousa, J., Liguori, E., Palacios-Marqués, D., Schiavone, F., Ferraris, A., Fernandes, C., & Ferreira, J. J. (2022). Literature reviews as independent studies: Guidelines for academic practice. *Review of Managerial Science*, 16, 2577–2595. <https://doi.org/10.1007/s11846-022-00588-8>
- Mankins, J. C. (1995). Technology readiness levels: A white paper. Advanced Concepts Office, Office of Space Access and Technology, NASA.
- Martínez-Plumed, F., Caballero, F., Castellano-Falcón, D., Fernández-Llorca, D., Gómez, E., Hupont-Torres, I., Merino, L., Monserrat, C., Hernández-Orallo, J., AI Watch: Revisiting Technology Readiness Levels for relevant Artificial Intelligence technologies, EUR 31066 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-52328-4, doi:10.2760/495140, JRC129399, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC129399/JRC129399_01.pdf

- Mazzetto, S. (2024). A review of Urban Digital Twins integration, challenges, and future directions in smart city development. *Sustainability*, 16(19), Article 8337. <https://doi.org/10.3390/su16198337>
- Meijer, A., & Bolívar, M. P. R. (2016). Governing the smart city: A review of the literature on smart urban governance. *International Review of Administrative Sciences*, 82(2), 392–408. <https://doi.org/10.1177/0020852314564308>
- Monteiro, B., Hlacs, A., & Boéchat, P. (2024). Public procurement for public sector innovation: Facilitating innovators' access to innovation procurement (OECD Working Papers on Public Governance No. 80). OECD Publishing. <https://doi.org/10.1787/9aad76b7-en>
- Nussipova, G. (2022). Framing changes of the value proposition of emerging technologies in a B2B context. *Journal of Business-to-Business Marketing*, 29(2), 99–118. <https://doi.org/10.1080/1051712X.2022.2051833>
- OECD. (2024). Enabling digital innovation in government: The OECD GovTech Policy Framework. OECD Digital Government Studies. OECD Publishing. <https://doi.org/10.1787/a51eb9b2-en>
- Overbye-Thompson, H., & Hamilton, K. A. (2025). A diffusion of innovations measurement scale for reinvention, relative advantage, compatibility, complexity, trialability and observability. *PLOS ONE*, 20(10), e0334616. <https://doi.org/10.1371/journal.pone.0334616>
- Paul, J., Lim, W. M., O'Cass, A., Hao, A. W., & Bresciani, S. (2021). Scientific procedures and rationales for systematic literature reviews (SPAR-4-SLR). *International Journal of Consumer Studies*, 45(4), O1–O16. <https://doi.org/10.1111/ijcs.12695>
- Parasuraman, A. (2000). Technology Readiness Index (TRI): A multiple-item scale to measure readiness to embrace new technologies. *Journal of Service Research*, 2(4), 307–320. <https://doi.org/10.1177/109467050024001>
- Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press
- Salazar, G., & Russi-Vigoya, M. N. (2021). Technology readiness level as the foundation of human readiness level. *Ergonomics in Design*, 29(4), 25–29. <https://doi.org/10.1177/10648046211020527>

- Semeraro, C., Lezoche, M., Panetto, H., & Dassisti, M. (2021). Digital twin paradigm: A systematic literature review. *Computers in Industry*, 130, Article 103469. <https://doi.org/10.1016/j.compind.2021.103469>
- Tornatzky, L. G., & Fleischer, M. (1990). *The processes of technological innovation*. Lexington Books
- Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, 27(3), 425–478. <https://doi.org/10.2307/30036540>.
- Yan, S., Lee, J.-Y., & Josephson, B. W. (2024). The effect of customer asset strategies on acquisition performance in business-to-government markets. *Journal of the Academy of Marketing Science*, 52(3), 789–814. <https://doi.org/10.1007/s11747-023-00955-1>
- Yeon, H., Eom, T., Jang, K., & Yeo, J. (2023). DTUMOS, digital twin for large-scale urban mobility operating system. *Scientific Reports*, 13, Article 5154. <https://doi.org/10.1038/s41598-023-32326-9>