VIETNAM NATIONAL UNIVERSITY, HANOI
VNU UNIVERSITY OF ENGINEERING AND TECHNOLOGY

SOCIALIST REPUBLIC OF VIETNAM
Independence – Freedom – Happiness

INFORMATION ON DOCTORAL THESIS

1. Full name : Tran Van Manh 2. Sex: Male

3. Date of birth: September 5, 1978 4. Place of birth: Quảng Ninh Province

5. Admission decision number: 778/QĐ-CTSV. Dated: August 21, 2017

6. Changes in academic process:

(List the forms of change and corresponding times)

- The decision on the change of Doctoral thesis title and academic supervisor for PhD candidate Tran Van Manh, No. 155/QĐ-ĐT dated March 17, 2020, issued by the Rector of the University of Engineering and Technology, Vietnam National University, Hanoi.
- The decision on the extension of study duration for K24 PhD candidates (first cohort), No. 561/QĐ-ĐT dated August 28, 2020, issued by the Rector of the University of Engineering and Technology, Vietnam National University, Hanoi. The extension duration is two years.
- The decision on returning the Doctoral candidate to their local authority/workplace, No. 1179/QĐ-ĐT dated November 29, 2022, issued by the Rector of the University of Engineering and Technology, Vietnam National University, Hanoi.
- The decision on the adjustment of the Dotoral thesis title for Ph.D candidate Tran Van Manh, No. 386/QĐ-ĐHCN dated February 27, 2025. The original title "Architecture of a Ridesharing Recommendation Service Based on Spatio-Temporal Data Mining" was changed to the new title "Developing Enhanced Methods for the Ridesharing Problem Based on Spatio-Temporal Data Mining" to better align with the thesis contents, without altering the research direction.

7. Official thesis title: Developing Enhanced Methods for the Ridesharing Problem Based on Spatio-Temporal Data Mining.

8. Major: Software Engineering 9. Code: 9480103

10. Supervisors: 1. Assoc. Prof. Dr. Truong Anh Hoang

2. Dr. Vu Thi Hong Nhan

11. Summary of the **new findings** of the thesis:

Purpose and scope of the Thesis:

The rapid growth of urban populations has posed serious challenges to transportation systems, including traffic congestion, environmental pollution, and inefficient use of resources. Although ride-sharing has emerged as a promising solution, existing approaches still exhibit many limitations, thereby revealing significant research gaps that need to be addressed. Firstly, most current ride-sharing models have not fully leveraged the potential of spatio-temporal trajectory data collected from GPS systems (Global Positioning System). As a result, valuable patterns of frequent long-distance movement which are crucial for ride-sharing planning, are often overlooked. Furthermore, group formation algorithms in ride-sharing often fail to integrate spatio-temporal constraints, leading to groupings that are impractical or inefficient in real-world operations. Moreover, traditional routing and scheduling methods struggle to balance cost optimization with service quality, especially under highly dynamic and diverse passenger demands.

To fill these research gaps, this thesis investigates static ride-sharing models, where shared trips are pre-scheduled and follow fixed routes. The main focus of this research include:

- Users with regular and recurring travel needs (e.g., commuting to work or school) along long-distance intra-urban or inter-urban routes.
- Spatio-temporal mobility data collected from GPS systems or ride-sharing platforms.
- Combinatorial optimization problems related to clustering and routing, particularly user clustering from spacio-temporal data, the Vehicle Routing Problem with Time Windows (VRPTW) and trajectory pattern mining.
- Models and algorithms supporting decision-making in ride-sharing systems, with a focus on evaluating efficiency, scalability and real-world applicability.

The thesis aims to achieve three main objectives:

- To develop a spatio-temporal pattern mining method that extracts long frequent routes from historical GPS mobility data to support ride-sharing service planning and design.
- To propose group formation algorithms based on these frequent routes, ensuring efficiency and compliance with spatiotemporal constraints to enhance feasibility and effectiveness;
- To design and implement routing and scheduling optimization techniques that maximize user participation, minimize transportation costs, and improve system scalability.

By achieving these objectives, the thesis aims to reduce dependence on private vehicles, promote the adoption of efficient ride-sharing models, and contribute to the development of sustainable, smart, and environmentally friendly urban transportation systems.

Research Methodology:

The thesis employs an interdisciplinary methodology that integrates spatio-temporal data mining, optimization algorithms, and mathematical modeling to accomplish the research objectives.

Spatio-temporal data mining techniques: Sequential pattern mining methods are applied to identify frequent long-distance routes and potential movement patterns through the MFSPM (Maximal Frequent Shared Path Mining) method.

Ride-sharing group formation algorithm: The aVC-growth algorithm is proposed to cluster passengers with similar routes while satisfying spatio-temporal constraints, resulting in the formation of more effective and practical ride-sharing groups.

Mathematical modeling and optimization: The Hybrid Routing and Scheduling (HRS) method is introduced as a mathematical framework for static ride-sharing services, grounded in the principles of the Vehicle Routing Problem with Time Windows (VRPTW). Empirical evaluations using both real and synthetic datasets are conducted to assess the performance of the proposed models and algorithms, and to benchmark them against existing methods.

All proposed methods are evaluated using both real-world and synthetic datasets and are compared against existing approaches to assess improvements in effectiveness and scalability.

Key Findings and Novel Contributions:

The thesis has yielded three key results:

1. **MFSPM Method for frequent route mining**: A novel method MFSPM is proposed for mining frequent long routes in spatiotemporal databases. It applies advanced database projection techniques and focuses on identifying Maximal Frequent Itemsets (MFI) instead of merely the Single Most Frequent Closed Itemsets (SMFCI*)*, thereby improving the speed and accuracy of route discovery.
2. **aVC-growth algorithm for group formation**: The *aVC-growth* algorithm is proposed to form ride-sharing groups based on frequent passenger routes. This algorithm enhances the VG-growth method surpasses VG-growth in clustering efficiency, reduces total travel distances, and increases real-world applicability.
3. **HRS Method for VRPTW optimization**: The HRS method addresses the classic VRPTW problem by optimizing transportation costs and minimizing the number of required vehicles. It assigns ride-sharing groups to appropriate vehicles and plans

trips based on vehicle capacity and route suitability, thereby improving operational efficiency.

Scientific and Practical Significance:

This thesis provides a comprehensive framework for the ride-sharing problem by integrating spatiotemporal data mining to discover frequent routes, group formation algorithms, and optimization techniques for routing and scheduling. The findings contribute to theoretical advancements in spatiotemporal mining and combinatorial optimization, while also offering practical value for the development of smart transportation systems, traffic congestion reduction, and sustainable shared mobility promotion.

12. Practical applicability, if any: The proposed methods have strong potential for application in pre-scheduled ride-sharing services in urban areas, industrial zones, or mobility corridors (e.g., home-to-work or home-to-school routes). The thesis contributes to reducing transportation system operational costs, improving vehicle usage efficiency, and reducing dependence on private vehicles. The models meet real-time computational requirements and can be integrated into existing technology platforms.

13. Further research directions, if any: The future research should focus on:

- Implementing the MineMLSP algorithm within the MFSPM framework to evaluate its effectiveness and real-world applicability.
- Enhancing the aVC-growth algorithm by incorporating real-world factors such as demand variation, traffic conditions, and machine learning techniques for real-time group assignment optimization.
- Extending the HRS method to accommodate varying pick-up and drop-off points and conducting experiments on larger and more diverse datasets to increase flexibility.
- Security and artificial intelligence applications: developing comprehensive security solutions and leveraging deep learning and reinforcement learning to predict user behavior and optimize routing.
- Exploring blockchain-based ride-sharing models: developing blockchain-driven solutions to enhance security, reduce transaction costs, and eliminate intermediaries. Integrating smart contracts to automate payments and decentralize the system.

14. Thesis-related publications:

STT	Tên công trình
1	Tran Van Manh, Thi Hong Nhan Vu, "*Design of architecture for carpooling based on flexible pickup and delivery locations*", (2020), Proceeding of the 16th International Conference on IIHMSP in Conjunction with the 13th International Conference on FITAT, November 5–7, 2020, Ho Chi Minh City, Vietnam, DOI: 10.1007/978-981-33-6757-9_26, pp 205-211 (**Scopus**).
2	Nhan T.H. Vu, Manh V.Tran, "*A Rideshare Model based on Movement Patterns*", (2021), The 13th international conference on future information & communication engineering (ICFICE 2020), 19th February, 2021 Online, Vol. 12, No. 1 ISSN 2765-3811, pp 3-7.
3	Manh V.Tran, Nhan T.H. Vu, "*A System for Rideshare Service*" (2020), The 13th international conference on future information & communication engineering (ICFICE 2020), 19th February, 2021 Online, Vol. 12, No. 1 ISSN 2765-3811, pp 8-12.
4	Van Manh Tran, Thi Hong Nhan Vu, "*Leveraging CPLEX to Solve the Vehicle Routing Problem with Time Windows*", (2021), 2021 13th International Conference on Knowledge and Systems Engineering (KSE-2021), Bangkok, Thailand, 10-12 November 2021, DOI: 10.1109/KSE53942.2021.9648591 (**Scopus**).
5	Van Manh Tran, Thi Hong Nhan Vu, "*A Routing Method for Ridesharing Service by Applying CPLEX*",(2022), 2022 13th Asian Control Conference (ASCC), Jeju, Korea, Republic of, 2022, DOI: 0.23919/ASCC56756.2022.9828064, 766-771 (**Scopus**).
6	Thi Hong Nhan Vu, Van Manh Tran, "*A Novel Scheduling Approach for Intelligent Ridesharing System*", (2022), 2022 The 13th Asian Control Conference (ASCC 2022), Jeju Island, Korea, May 4-7, 2022.
7	Van Manh Tran, Thi Hong Nhan Vu, "*A New Method for Forming Rideshare Groups*", (2023), 2023 15th International Conference on Knowledge and Systems Engineering (KSE-2023), Hanoi, Vietnam, October 18-20, 2023, DOI: 10.1109/KSE59128.2023.10299428 (**Scopus**)

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Note: ***"Information on Doctoral Thesis"*** *must be processed on Microsoft Word, font Unicode Times New Roman, letter size 13. " Summary of the new findings of the thesis" should be one-A4 page long.*