



Záverečná karta projektu

Názov projektu

Evidenčné číslo projektu

APVV-19-0441

Pridelovanie obmedzených zdrojov do verejných obslužných systémov s konfliktnými kritériami kvality

Zodpovedný riešiteľ **prof. RNDr. Jaroslav Janáček, CSc.**

Príjemca **Žilinská univerzita v Žiline - Fakulta riadenia a informatiky**

Názov pracoviska, na ktorom bol projekt riešený

Žilinská univerzita v Žiline, Fakulta riadenia a informatiky

Názov a štát zahraničného pracoviska, ktoré spolupracovalo pri riešení

Dr. Rui Carvalho, Department of Engineering, University of Durham, GB

Dr. Gianluca Fulli, Energy Security, Distribution and Markets Unit, Joint Research Centre, Ispra, Italy

Dr. Santiago Mazuelas Franco, Basque center for applied mathematics, Bilbao, Spain

Prof. Tomer Toledo, university Technion, Haifa, Izrael

Doc. Ing. Dušan Teichmann, PhD. VŠB-Technická univerzita Ostrava, ČR

Doc. Ing. Denisa Mocková, Ph.D. ČVUT Praha, Fakulta dopravní, ústav logistiky a manažmentu dopravy, ČR

Udelené patenty/podané patentové prihlášky, vynálezy alebo úžitkové vzory, ktoré sú výsledkami projektu

ne

Najvýznamnejšie publikácie (knihy, články, prednášky, správy a pod.) zhrňujúce výsledky projektu – uveďte aj publikácie prijaté do tlače

Vedecké práce v zahraničných karentovaných časopisoch (ADC)

1. Jánošíková Ľudmila, Jankovič Peter, Kvet Marek, Zajacová Frederika: Coverage versus response time objectives in ambulance location. In: International Journal of Health Geographics. ISSN 1476-072X. Roč.20 (2021), s. 1-16. Spôsob prístupu:

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2. Straka Milan, Carvalho Rui, van der Poel Gijs, Buzna Ľuboš: Analysis of energy consumption at slow charging infrastructure for electric vehicles. In: IEEE Access [electronic]: practical innovations, open solutions. ISSN 2169-3536 (online). Roč. 9 (2021), s. 53885-53901 [online]. Zaradené v: Current Content Connect; SCOPUS; Web of Science Core Collection

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3. Buzna Ľuboš, De Falco Pasquale, Ferruzzi Gabriella, Khormali Shahab, Proto Daniela, Refa Nazir, Straka Milan, van der Poel Gijs: An ensemble methodology for hierarchical probabilistic electric vehicle load forecasting at regular charging stations. In: Applied Energy

[print, electronic]. ISSN 0306-2619. č. 283 (2021), s. [1-18] [print, online]. Zaradené v: Current Content Connect; SCOPUS; Web of Science Core Collection.
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7. Jansen Luca Lena, Thomaßen Georg, Antonopoulos Georgios, Buzna Ľuboš: An efficient framework to estimate the state of charge profiles of hydro units for large-scale zonal and nodal pricing models. In: Energies [electronic]. ISSN 1996-1073 (online). Roč. 15, č. 12 (2022), s. [1-23] [online]. Zaradené v: Current Content Connect; SCOPUS; Web of Science Core Collection
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8. Jánošíková Ľudmila, Jankovič Peter, Kvet Marek, Ivanov Gaston, Holod Jakub, Berta Imrich: Reorganization of an emergency medical system in a mixed urban-rural area. In: International Journal of Environmental Research and Public Health 2022 [print, electronic]. ISSN 1661-7827. Roč. 19, č. 19, s. [1-17] [online, print]. Zaradené v: Current Content Connect, SCOPUS, Web of Science Core Collection. <https://www.mdpi.com/1660-4601/19/19/12369>

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9. Finkelberg Ilya, Petrov Tibor, Gal-Tzur Ayelet, Zarkhin Nina, Počta Peter, Kováčiková Tatiana, Buzna Ľuboš, Dado Milan, Toledo Tomer: The effects of vehicle-to-infrastructure communication reliability on performance of signalized intersection traffic control. In: IEEE Transactions on Intelligent Transportation Systems [print, electronic]. ISSN 1558-0016 (online). Roč. 23, č. 9 (2022), s. 15450-15461 [print, online]. Zaradené v: SCOPUS, Web of Science Core Collection, Current Content Connect.
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11. Borčinová Zuzana: Kernel search for the capacitated vehicle routing problem. In: Applied sciences [electronic]. ISSN 2076-3417 (online). Roč. 12, č. 22 (2022), s. [1-11] [online]. Zaradené v: Current Content Connect, SCOPUS, Web of Science Core Collection
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12. Kvet Marek, Janáček Jaroslav: Directed search for non-dominated emergency medical system designs. In: Applied sciences [electronic]. ISSN 2076-3417 (online). Roč. 13, č. 8 (2023), s. [1-12] [online]. Zaradené v: SCOPUS; Current Content Connect; Web of Science Core Collection
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14. Leitner Bohuš, Ballay Michal, Kvet Marek, Kvet Michal: Optimization of fire brigade deployment by means of mathematical programming. In: Processes [electronic]. ISSN 2227-9717 (online). Roč. 11, č. 4 (2023), s. [1-21] [online]. Zariadené v: Current Content Connect, SCOPUS, Web of Science Core Collection, Science Citation Index Expanded. <https://www.mdpi.com/2227-9717/11/4/1262>

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19. Gábrišová Lýdia: Decision-making in strategic management of the public service system. In: Public security and public order [electronic, print] = Visuomenės saugumas ir viešoji tvarka: scientific articles: Mokslinių straipsnių rinkinys. ISSN 2029-1701. č. 25 (2021), s. 128-135 [online, print]. <https://repository.mruni.eu/handle/007/17073>

20. Janáček Jaroslav, Kvet Marek: Efficient incrementing heuristics for generalized p-location problems. In: Central European Journal of Operations Research. Heidelberg: Springer International Publishing AG. [print, online]. ISSN 1435-246X. Roč. 29, č. 3 (2021), s. 989-1000 [print, online].

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25. Malichová Eva, Straka Milan, Buzna Ľuboš, Scandolari Damiano, Scrocca Mario, Comerio Marco: Study of travellers' preferences towards travel offer categories and incentives in the journey planning context. In: PLoS One [electronic]. ISSN 1932-6203 (online). Roč. 18, č. 4 (2023), s. 1-25 [online]. Zaradené v: Science Citation Index Expanded; Web of Science Core Collection; SCOPUS.

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31. Janáček Jaroslav, Kvet Marek: Adaptive Path-Relinking Method for Public Service System Design. In: 38th International Conference on Mathematical Methods in Economics. Brno: Mendel University in Brno, 2020. ISBN 978-80-7509-734-7. S. 229-235. (online).

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32. Janáček Jaroslav, Kvet Marek: Contour approach to p-location problem solving. In: Transport problems 2020 [print]: XII International Scientific Conference and IX International Symposium of Young Researchers. 1. vyd. Katowice: Silesian University of Technology Press, 2020. ISBN 978-83-959742-0-5. s. 285-290 [print].

33. Kvet Marek, Janáček Jaroslav: All-to-one strategy with diversity management for min-sum p-location problem. In: Transport problems 2020 [print]: XII International Scientific Conference and IX International Symposium of Young Researchers. 1. vyd. Katowice: Silesian University of Technology Press, 2020. ISBN 978-83-959742-0-5. s. 354-359 [print].

34. Janáček Jaroslav, Kvet Marek: Shrinking fence search strategy for p-location problems. In: 20th IEEE international symposium on Computational intelligence and informatics: proceedings. Danvers: Institute of Electrical and Electronics Engineers. ISBN 978-1-7281-8339-8 (online). s. 55-59 [USB-key]. Zaradené v: SCOPUS.

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38. Jansen Luca Lena, Purvins Arturs, Buzna Ľuboš, Antonopoulos Georgios A., Zani Alessandro: Modeling methodology to assess the impact of demand elasticity on the Italian electricity system in a European context. In: International conference on European electricity market, roč. 17 [print, electronic]. ISSN 2165-4077. 1. vyd. New Jersey: Institute of Electrical and Electronics Engineers, 2020. ISBN 978-1-7281-6920-0. s. [1-6]. Zaradené v: SCOPUS <https://ieeexplore.ieee.org/document/9221900>
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61. Czimmermann Peter: Detection of edges in transport networks which are critical for public service systems. In: RelStat-2022 - selected papers from the 22nd international multidisciplinary conference on Reliability and Statistics in transportation and communication in Transportation and Communication: artificial intelligence in transportation,. 1. vyd. Cham:

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Uplatnenie výsledkov projektu

Aj keď ide o projekt základného výskumu, ktorého ciele boli splnené, výsledky tohto projektu majú aj praktický význam. Prostredníctvom výskumu vlastností úloh návrhu verejného obslužného systému s konfliktnými kritériami boli navrhnuté, implementované a overené rôzne hybridné metaheuristiky na získanie dobrej aproximácie Paretovho frontu návrhov verejných obslužných systémov v akceptovateľnom výpočtovom čase. Samotný návrh verejného obslužného systému s konfliktnými kritériami je úloha, ktorú nie je možné exaktne riešiť, ak nie je definovaný vzájomný vzťah medzi kritériami. Riešenie projektu ponúka prekonanie uvedených prekážok tým, že berie do úvahy súčasne všetky individuálne kritéria kvality a ako výsledok spracovania návrhu systému ponúka zriaďovateľovi systému množinu nedominovaných riešení. To umožní zriaďovateľovi transparentnú diskusiu s verejnosťou a výber akceptovateľného kompromisného variantu. V priebehu riešenia projektu bol získaný celý rad čiastkových výsledkov, ktoré môžu byť aplikované pri riešení úloh mimo rámec tohto projektu. Tu spomeniem spôsob merania kvality aproximácie Paretovho frontu, ďalej schému postupného zjemňovania aproximácie Paretovho frontu, ktorá sa stala základom úspešných hybridných metaheuristik a celý rad rôznych prístupov na navrhovanie reálnych obslužných systémov. Sformulovali sme aj nový model časovej dostupnosti pre stochasticky heterogénny región a navrhli metódu jeho riešenia. Navyše sme množinu skúmaných verejných obslužných systémov rozšírili o ďalšie typy, a to o systémy súvisiace s elektrifikáciou systému verejnej dopravy.

Súhrn výsledkov riešenia projektu a naplnenia cieľov projektu v slovenskom jazyku (max. 20 riadkov)

Cieľom projektu bolo prostredníctvom výskumu vlastností úloh návrhu verejného obslužného systému s konfliktnými kritériami navrhnuť, implementovať a overiť hybridnú metaheuristicu na získanie dobrej aproximácie Paretovho frontu návrhov verejných obslužných systémov.

Tento cieľ bol dosiahnutý radom výskumných činností, ktoré v prvej fáze zahŕňali výskum vlastností modelov rôznych verejných obslužných systémov a výskum optimalizačných metód s jedným hlavným kritériom kvality riešenia. V prvom prípade boli modelované verejné obslužné systémy, kde hlavnými rozhodnutiami boli rozhodnutia o umiestnení alebo neumiestnení obslužného strediska ako je ambulancia záchranej služby alebo nabíjacia stanica pre elektromobily až po systémy, kde hlavným rozhodnutím je poradie obsluhy užívateľov systému [1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 14, 15, 16, 17, 18, 19, 24, 29, 37, 48, 52, 56, 61, 65, 69, 73, 84, 85, 91]. V druhom prípade bola pozornosť venovaná heuristikám na riešenie rôznych typov lokačných úloh [20, 21, 22, 28, 32, 33, 34, 35, 39, 40, 41, 46, 47, 49, 50, 77, 80, 81, 82, 83, 86].

Na základe výsledkov primárneho výskumu bolo navrhnutá schéma postupného zjemňovania, ktorá sa stala základom heuristik a metaheuristik na navrhovanie dobrej aproximácie Paretovho frontu nedominovaných návrhov verejného obslužného systému [12, 23, 26, 30, 42, 44, 45, 51, 53, 54, 57, 58, 59, 60, 62, 63, 64, 67, 68, 74, 75, 87]. Aby sa umožnilo efektívne vykonávanie evolučnej metaheuristiky na riešenie lokačných úloh, bol

vykonaný výskum metód na určenie rovnomerne distribuovaného súboru riešení ako východiskovej populácie [13, 78, 89, 90]. V záverečnej fáze projektu boli skúmané metódy adaptívneho nastavovania parametrov metaheuristik [31, 66, 72].

Súhrn výsledkov riešenia projektu a naplnenia cieľov projektu v anglickom jazyku (max. 20 riadkov)

The goal of the project was to propose, implement and verify a hybrid metaheuristic to obtain a good approximation of the Pareto front of public service system designs by researching the characteristics of public service system design problems with conflicting criteria.

This goal was achieved through a series of research activities, which in the first phase included research on the properties of models of various public service systems and research on optimization methods with one main criterion of solution quality.

In the first case, such public service systems were modeled, where the main decisions were decisions on locating or non-locating a service center such as an ambulance or a charging station for electric cars, up to systems where the main decision was the order of service of system users [1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 14, 15, 16, 17, 18, 19, 24, 29, 37, 48, 52, 56, 61, 65, 69, 73, 84, 85, 91]. In the second case, attention was paid to heuristics for solving different types of location problems [20, 21, 22, 28, 32, 33, 34, 35, 39, 40, 41, 46, 47, 49, 50, 77, 80, 81, 82, 83, 86]. Based on the results of primary research, a gradual refinement scheme was proposed, which became the basis of heuristics and metaheuristics for designing a good approximation of the Pareto front of non-dominated solutions of the public service system design problem [12, 23, 26, 30, 42, 44, 45, 51, 53, 54, 57, 58, 59, 60, 62, 63, 64, 67, 68, 74, 75, 87].

To enable efficient performance of evolutionary metaheuristics for solving location-type problems, research has been carried out on methods for determining a uniformly distributed set of solutions as a starting population [13, 78, 89, 90]. In the final phase of the project, methods of adaptive setting of metaheuristic parameters were investigated [31, 66, 72].