Revision Report

Computing, Springer (Submission ID: 5ae64eee-b5a0-40bc-90cb-7c5d7f483485)

EV-GREEN: Electric Vehicle Routing with GreenZone Prioritization and Vehicle-to-Grid Incentive Integration

This document is a revision report corresponding to the manuscript titled "*EV-GREEN: Electric Vehicle Routing with GreenZone Prioritization and Vehicle-to-Grid Incentive Integration*" (**Submission ID: 5ae64eee-b5a0-40bc-90cb-7c5d7f483485**), submitted to **Computing, Springer**. As suggested by the Editor, we addressed all the issues raised by the reviewers, details of which are given in this report. We serially addressed the comments of the reviewers by providing each comment, followed by our respective responses. We greatly appreciate and thank the reviewers and the Editorial team, for their valuable comments/suggestions that have enabled us to improve our paper significantly.

The BLUE coloured texts in the revised manuscript represent the added or modified parts of the paper.

Associate Editor

Comment: This manuscript requires rigorous revision and will be re-evaluated by the same or by alternative reviewers. The authors are requested to provide their source-code implementation via GitHub or a similar platform to enable cross-validation of the correctness of the implementation and the validity of the reported results. Please note that failure to supply executable source code may affect the editorial decision on the manuscript, regardless of the stage of the review process. AI-generated writings are strictly prohibited and must not be used in any part of the manuscript.

Response: We thank the Associate Editor for emphasizing reproducibility and transparency. The complete source-code implementation corresponding to the proposed EV-GREEN framework has been made publicly available via GitHub at `https://github.com/kripa-sindhu-007/ev-routing`. The repository contains the simulation scripts, baseline implementations, configuration files, and documentation required to reproduce the experimental results reported in the manuscript.

Regarding the use of AI-generated content, we confirm that the manuscript represents original scholarly work authored by the contributors, and no AI-generated text has been used in any part of the manuscript. All revisions were carried out manually in accordance with the journal's ethical guidelines.

Comments and Responses

Reviewer #1

1. **Comment:** First, authors should make several proofreading to improve the quality of the work.
   Response: We thank the reviewer for this observation. The entire manuscript has been thoroughly proofread and revised to improve clarity, grammar, and technical readability. Several sentences were restructured for better flow, figures and tables were re-captioned for consistency, and notation was standardized across sections. We believe that these revisions have significantly improved the overall presentation quality of the paper.

2. **Comment:** Second, what about the computation complexity of the proposed real-time EV routing model (hybrid approach which is based on an Integer Linear Programming (ILP) formulation with heuristic methods—specifically Dijkstra's algorithm and Ant Colony Optimization (ACO)).

   Response: We thank the reviewer for this insightful comment. In the revised manuscript, we have clarified the computational roles of both components of the hybrid model. The ILP formulation is a Mixed-Integer Linear Program and therefore exhibits exponential worst-case complexity; accordingly, it is used only for small-scale offline benchmarking and is not part of the real-time routing workflow. The real-time computations rely solely on the heuristic pipeline. As now detailed in the "Complexity Analysis" subsection (Section 5.5, Page 15), the shortest-path initialization using Dijkstra's algorithm runs in near-linear time, while the ACO refinement scales as $O(kmt)$ with user-controlled parameters for ants, iterations, and search depth. This explicit distinction has been added to ensure clarity on how the proposed model remains computationally feasible for real-time EV routing in dynamic urban networks.

3. **Comment:** Third, the state of the Charge (SoC) and the state of the health (SoH) are very challenging parameters for EVs especially for the frequency, ampere and voltage stability. Authors should clarify how the proposed model can support and manage these parameters (SoC, SoH).
   Response: We thank the reviewer for highlighting the importance of SoC and SoH in EV operation. The revised manuscript (Section 4.3, Page 11) now clarifies the handling of these parameters within the proposed eco-routing framework. The model explicitly incorporates the state of charge (SoC) through minimum and maximum battery limits, feasible discharge conditions, and energy-balance constraints at charging and V2G stations. These constraints ensure that all routing and V2G decisions remain within safe operating ranges and therefore implicitly respect voltage, current, and frequency limits at the energy-management layer.

   Regarding the state of health (SoH), we note that SoH evolves on a much slower time scale than SoC and is typically treated as a fixed battery-capacity parameter during individual trips (Section 4.3, Page 11). In practice, SoH affects the effective usable capacity of the battery; this influence is already captured in our model through the parameters $E_{\min}$, $E_{\max}$, and discharge-capacity bounds C_k. As SoH does not fluctuate at real-time routing frequencies, it is incorporated as a static battery parameter without affecting the computational or decision-making process of the routing algorithm. We have added a brief discussion in the manuscript to clarify this point.

4. **Comment:** Forth, the following references should be add to this paper:

   [1] D. Said, S. Cherkaoui and L. Khoukhi, "Scheduling protocol with load managementfor EV charging," 2014 IEEE Global Communications Conference, Austin, TX, USA, 2014, pp. 362-367, doi: 10.1109/GLOCOM.2014.7036835.

   [2] A. A. Ahmed, A. A. Alkheir, D. Said and H. T. Mouftah, "Cooperative spectrum sensing for cognitive radio vehicular ad hoc networks: An overview and open research issues," 2016 IEEE Canadian Conference on Electrical and Computer Engineering (CCECE), Vancouver, BC, Canada, 2016, pp. 1-4, doi: 10.1109/CCECE.2016.7726681.

   [3] D. Abd Eldjalil Chekired, S. Dhaou, L. Khoukhi and H. T. Mouftah, "Dynamic pricing model for EV charging-discharging service based on cloud computing scheduling," 2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC), Valencia, Spain, 2017, pp. 1010-1015,
   doi: 10.1109/IWCMC.2017.7986424.

   [4] D. Said, "A Decentralized Electricity Trading Framework (DETF) for Connected EVs: A Blockchain and Machine Learning for Profit Margin Optimization," in IEEE Transactions on Industrial Informatics, vol. 17, no. 10, pp. 6594-6602, Oct. 2021, doi: 10.1109/TII.2020.3045011.

   [5] D. Said and M. Elloumi, "A New False Data Injection Detection Protocol based Machine Learning for P2P Energy Transaction between CEVs," 2022 IEEE International Conference on Electrical Sciences and

Technologies in Maghreb (CISTEM), Tunis, Tunisia, 2022, pp. 1-5, doi: 10.1109/CISTEM55808.2022.10044067.

Response: We thank the reviewer for the suggested references [1, 2, 3, 4, 5]. These works have now been briefly discussed in the Related Work section (Section 2, Page 6) to acknowledge complementary research on EV charging coordination, energy trading, and vehicular communication. The discussion has been intentionally kept concise, as these studies address infrastructure-level scheduling, pricing, and communication aspects that are tangential to the routing-centric focus of the proposed EV-GREEN framework.

Reviewer #2

In this paper the authors propose a hybrid approach for real-time EV routing by combining a Mixed-Integer Linear Program with heuristics such as Ant Colony Optimization. The model incorporate GreenZone compliance, Vehicle-2-Grid and Grid interactions. Basically, the topic is interesting and worth investigating. However, the paper in its current form has some major shortcomings, which I would address in the following:

1. **Comment:** Basically, the topic is clearly motivated but lacks in references. For instance, on page 3 the authors argue that most existing models treat energy consumption minimzation as standalone objective or that prior research focused mainly on static conditions - but there is no evidence. Such statements should underline the contribution of the own work and need to be justified in more details.

   Response: We thank the reviewer for this valuable comment. In the revised manuscript, we have added specific references that support the statements (Section 1, Page 3) regarding (i) existing eco-routing models focusing primarily on energy minimization as a single objective, and (ii) prior work relying on static or time-invariant conditions. Additional citations have been incorporated into both the Introduction and Related Work sections to justify these claims and to better situate the contribution of our work within the existing literature. We believe these additions strengthen the motivation and contextual grounding of our study.

2. **Comment:** The authors do not exactly describe which V2G policies they consider. I strongly recommend to clarify the terms and assumptions. A short Google Scholar research reveals the following paper https://doi.org/10.1016/j.apenergy.2025.126361 explaining different V2G approaches.

   Response: We thank the reviewer for this important observation. In the revised manuscript (Section 3, Page 8), we have explicitly clarified the V2G policy assumptions adopted in our model, including the incentive mechanism, temporal characteristics, and operational constraints. In particular, we now state that the proposed framework considers tariff-based V2G incentives, where EVs receive compensation proportional to the amount of energy discharged during periods of high grid demand.

   We further acknowledge that the V2G literature encompasses a broader range of policies and market mechanisms (Section 3, Page 8), as discussed in recent survey and taxonomy works, including the paper suggested by the reviewer [6]. Our clarification helps position the proposed routing model within this broader context while clearly defining the scope of V2G policies considered in this study.

3. **Comment:** The problem formulation of the optimization problem is clealry a Mixed-Integer Linear Program with discrete and continuous optimization variables - so why are the authors talking about ILP? Additionally, they also mentioned MILP in one of the section... Please clarify that and use the exact mathematical terms.

   Response: We thank the reviewer for pointing out this inconsistency. The optimization problem formulated in this work is indeed a Mixed-Integer Linear Program (MILP), as it includes both binary routing variables and continuous energy-related variables. The earlier use of the term "ILP" was imprecise. In the revised manuscript, we have corrected this throughout the paper and now consistently use the term "MILP" to refer to the exact optimization formulation. We have also clarified this distinction explicitly to avoid any ambiguity.

4. **Comment:** The related work section is interesting to read but results from literature are missing. There is only a overview of methods which are used in the state-of-the-art but the reader would be also interested in the results. Please also identify differences to your own work. The related work section should be revised carefully.

Additionally, please do not begin a sentence with a reference. Name the authors in the beginning. The citation style between Section 2 and 7 is totally different!

Response: We thank the reviewer for this constructive feedback. In the revised manuscript, we have carefully revised the Related Work section (Section 2, Page 5) to include representative quantitative results reported in prior studies (e.g., energy or emission reductions and trade-offs). We have also explicitly highlighted the differences between existing approaches and our proposed framework to better position the contribution of this work (Section 5.6, Page 15). Furthermore, we have revised the writing style to avoid starting sentences with citations by explicitly naming authors, and we have unified the citation style across Sections 2 (Page 5) and 7 (Page 19) to ensure consistency throughout the manuscript.

5. **Comment:** The organization of the work could be improved. I do not understand why the authors introduce ILP in Sec. 3 and afterwards explore the analysis of the proposed solution. I suggest to reorganize some sections for a better readability.

   Response: We thank the reviewer for the comment on the manuscript organization.

   The Mixed Integer Linear Programming (MILP) formulation is first introduced (Section 4, Page 8) to formally define the global optimization problem, including routing decisions, energy consumption, V2G incentives, and GreenZone constraints. Due to the computational intractability of solving the MILP in large-scale and real-time settings, a scalable hybrid heuristic solution is then proposed (Section 5, Page 12).

   The subsequent analysis section (Section 6, Page 16) is designed to theoretically justify both the exact formulation and the heuristic strategy. In particular, it establishes the existence of optimal eco-routes under energy and GreenZone constraints, analyzes feasibility under dynamically changing GreenZones, and characterizes optimal V2G discharge behavior. These analytical results rely on the structure of the heuristic and therefore naturally follow its presentation.

   To improve readability and avoid confusion, we have added explicit clarifications at the beginning of the analysis section (Section 6, Page 16) explaining its role as a theoretical validation of the previously introduced formulation and heuristic, rather than as an independent modeling component. This preserves the logical flow while enhancing clarity.

   Let us know if we need to change the structure or flow of the paper further.

6. **Comment:** Why do you only consider energy amounts and no power variables? I miss a clear problem formulation taking charging and discharing rates into account. (see also Sec. 4.2). What about efficiencies etc.?

   Response: We thank the reviewer for the comment. The model is formulated at the route-planning level and therefore uses an energy-based abstraction. Charging and discharging rates are implicitly captured via station-level energy bounds, and conversion efficiencies are included through fixed efficiency factors. We have added a dedicated clarification subsection (Section 4.3, Page 11) to explicitly explain these modeling assumptions and scope.

7. **Comment:** Do you have certain requirements for parameters such as alpha, beta, gamma? Should the sum of these parameters be one?

   Response: The parameters α, β, and γ are independent weighting coefficients and are not required to sum to one. They are not convex-combination weights but scaling factors that control the relative importance of heterogeneous objectives (energy consumption, V2G incentives, and GreenZone compliance), which are already normalized or expressed in compatible cost units. Imposing a summation constraint would unnecessarily restrict modeling flexibility. We clarified this explicitly in the revised manuscript (Section 4.2, Page 10) and note that fixed parameter values are used across all experiments, with qualitative robustness observed under moderate parameter variations.

8. **Comment:** In Sec. 4.4 the authors discussed MILP as in the sections before it was a ILP - this is confusing for the readers and terms should be used in the right way.

Response: We thank the reviewer for pointing out this inconsistency. This concern refers to the same terminology issue addressed through a global revision of the manuscript. In the revised version, the optimization problem is consistently referred to as a Mixed-Integer Linear Program (MILP) in Sec. 4.4 as well as in all preceding sections. Any wording that previously suggested a distinction between ILP and MILP across sections has been corrected to ensure terminological consistency throughout the paper.

9. **Comment:** In Sec. 5 I miss a comparison to the related work - which methods are already used in literature? What are the benefits and drawbacks?
   Response: We thank the reviewer for this valuable suggestion. To improve the contextualization of the proposed model, we have added a dedicated subsection entitled *"Positioning with Respect to Existing Approaches"* (Section 5.6, Page 15). This subsection explicitly compares the proposed formulation with major classes of eco-routing methods reported in the literature, including shortest-path-based approaches, stochastic and multi-objective frameworks, and EV-specific energy-aware routing models. We summarize the key benefits and limitations of these approaches and clarify how the proposed hybrid MILP–ACO framework differs by jointly incorporating V2G incentives and GreenZone compliance. This addition complements the Related Work section and strengthens the methodological positioning of the proposed solution.

10. **Comment:** Why is there an additional problem formulation and nomenclature table in Sec. 5? (see also Chapter 3)
    Response: Thank you for pointing this out. Section 3 presents the global problem formulation and complete nomenclature of the proposed eco-routing framework. Section 5 does not introduce a new formulation; rather, it derives an algorithm-specific representation required for the MILP component of the hybrid solution. To improve clarity and avoid redundancy, we have revised Section 5 to explicitly reference the formulation and nomenclature in Section 3, and we removed/reduced the repeated nomenclature table, retaining only auxiliary variables specific to the MILP implementation.

11. **Comment:** The experimental setup is unclear and should be discussed in more details. For instance, how are the speed limits assigned to different segments? Makes it sense in this way?
    Response: We thank the reviewer for pointing out the need for additional clarification of the experimental setup. In the revised manuscript (Section 7.1, Page 19), we have explicitly described how speed limits are assigned to road segments in the synthetic urban network and justified the rationale behind this design choice. Speed limits are sampled from a discrete set of realistic urban speed categories using a non-uniform probability distribution to reflect the heterogeneous nature of real city road networks (e.g., local streets, arterials, and major roads). This clarification has been added to the Simulation Environment subsection to improve transparency and reproducibility.

12. **Comment:** In Sec. 7.1.1 I do not understand why charging stations have also a capacity? Is there another battery storage installed? If so, I totally missed the explaination for that.
    Response: We thank the reviewer for this observation. In the revised manuscript, we clarify that the capacity associated with a charging station does not necessarily imply a dedicated physical battery installed at the station. Instead, it represents the maximum amount of energy that can be absorbed from or injected into the grid through that station within the considered time window, accounting for grid-side constraints, transformer limits, and contractual V2G aggregation limits. This abstraction is commonly used in V2G modeling to capture grid interaction constraints without explicitly modeling low-level power infrastructure. The clarification has been added to Section 7.1.1 (Page 20).

13. **Comment:** Why are parameters such as acceleration or rolling resistance important (see also Table 2)? None of these parameters play a role in the problem formulation and it is totally confusing!
    Response: We thank the reviewer for highlighting this potential source of confusion. The parameters listed in Table 2 (e.g., acceleration limits, rolling resistance coefficients) are not decision variables in the optimization problem and therefore do not appear explicitly in the mathematical formulation. Instead, they are used

in a preprocessing stage to compute segment-level energy consumption values, which are then provided as inputs to the routing optimization. The proposed MILP–ACO framework operates on these aggregated energy costs rather than raw vehicle dynamics. To avoid ambiguity, we have clarified this distinction in Section 7.1 (Section 7.1.1, Page 20) and explicitly stated the role of these parameters.

14. **Comment:** The results are interesting but the discussion is too short. How do you achieve the comparisons in Fig. 2? How do you implement the other approaches etc.
Response: We thank the reviewer for this valuable comment. In the revised manuscript, we expand the discussion to explicitly explain how the comparative results in Fig. 2 were obtained and how the baseline approaches were implemented (Section 7.2, Page 21). Specifically, all methods were evaluated under identical network conditions, vehicle profiles, and demand scenarios, differing only in their routing and optimization logic. The state-of-the-art methods were implemented following their original formulations, excluding V2G incentives and GreenZone constraints, which are not considered in those works. A detailed description of the comparison protocol and baseline implementation has been added to Section 7.2 (Page 21) to improve clarity and reproducibility.

References

[1] D. Said, S. Cherkaoui, and L. Khoukhi, "Scheduling protocol with load management for ev charging," in *Proc. IEEE GLOBECOM*, 2014, pp. 362–367.

[2] D. A. E. Chekired, S. Dhaou, L. Khoukhi, and H. T. Mouftah, "Dynamic pricing model for ev charging-discharging service based on cloud computing scheduling," in *Proc. IWCMC*, 2017, pp. 1010–1015.

[3] D. Said, "A decentralized electricity trading framework (detf) for connected evs: A blockchain and machine learning for profit margin optimization," *IEEE Transactions on Industrial Informatics*, vol. 17, no. 10, pp. 6594–6602, 2021.

[4] A. A. Ahmed, A. A. Alkheir, D. Said, and H. T. Mouftah, "Cooperative spectrum sensing for cognitive radio vehicular ad hoc networks: An overview and open research issues," in *Proc. IEEE CCECE*, 2016, pp. 1–4.

[5] D. Said and M. Elloumi, "A new false data injection detection protocol based machine learning for p2p energy transaction between cevs," in *Proc. IEEE CISTEM*, 2022, pp. 1–5.

[6] A. Fahmin, M. A. Cheema, M. Eunus Ali, A. Nadjaran Toosi, H. Lu, H. Li, D. Taniar, H. A. Rakha, and B. Shen, "Eco-friendly route planning algorithms: Taxonomies, literature review and future directions," *ACM Computing Surveys*, vol. 57, no. 1, pp. 1–42, 2024.