§ Line 12-14: What is lacking in the current method to solve the problem that led the Authors to propose the new method? Explain this in one sentence after line-14.

Re: Thanks for the reviewers’ comments. We have added this sentence after line-14 ‘Despite their effectiveness in smaller-scale problems, these approaches struggle with the complexity and scalability required for large-scale, multi-sector ATFM, leading to suboptimal performance in real-time scenarios.’

We believe current method is lacking suboptimal performance when it is applied to large-scale ATFM scenarios.

§ Line 15: Spell ‘NN-DCB’ in full for the first time in the text.

Re: Thanks for the rigorous comments. We have added the full name of ‘NN-DCB’ (neural network-based Demand and Capacity Balancing) in Line 15 when it the first time appears in the text.

§ Line 11: Place this sentence before the sentence in Line 15.

Re: We have revised the article and placed the sentence in before the sentence in Line 15. We appreciate the reviewers’ comments.

§ Abstract: Revise the structure of the paragraph. Define the problem statement and summarise what is lacking in the current approaches, before introducing the proposed solution.

Re: We have refined the Abstract, include revise the structure of the paragraph, define the problem statement and summarize the lacking in the current approaches, and supplement the full name of ‘NN-DCB’.

§ Line 45: Provide references for ‘CPLEX and Gurobi’

Re: We have added the references for ‘CPLEX and Gurobi’. Moreover, we revised the sentence to make the article easily to read. Thanks for reviewers’ comments.

§ Line 46: Provide reference for the claim.

Re: We have added the reference[8,9,10,11] in Line 48 for the claim.

§ Line 58-66: Author reported what other researchers explored and investigated. What were the findings? Mention where this is discussed in the manuscript, after line-66.

Re: We have summarized the current investigation of other researchers explored. Main fundings are ‘they still face challenges such as low efficiency, poor scalability, and insufficient real-time processing capabilities when dealing with large-scale, dynamically changing, uncertainty airspace capacity.’ Therefore, we are further proposing our main research contents ‘a novel neural network-based demand and capacity balancing method (NN-DCB) aims to provide a more efficient, flexible, and scalable solution by utilizing neural branching and neural diving techniques.’ (see in Line 68-74)

§ Figure 1: Why is Figure 1 placed in Chapter 0? It is not referred anywhere in the chapter.

Re: We have placed Figure 1 to Chapter 1.

§ Figure 1 & 2: Always place the figures after being referred in the text, in the same sub-section. Check for all occurrences in the manuscript.

Re: We have moved and placed Figure1 &2 in section 1.2 after them being referred in the text. We checked all occurrences in the manuscript and make sure the revised paper not to cause ambiguity. We appreciate the rigorous comments.

§ Table 1: Provides a good synthesis of the related studies.

Re: Thanks for the comments. We have added a summarize sentence at the bottom of Table 1. The statement conclude the contents of Table 1 and highlight the innovation of our work.

§ Section 2.3.2: Narrate a sentence before the figure by referring to Figure 3 in the sentence. Place line-220 from “This image….” until end of line-223.

Re: we have added the sentence to referring the Figure 3 ‘This image, provided by Variflight, illustrates the distribution of flights across Chinese national airspace. The dense clustering of aircraft highlights high-traffic areas, predominantly in the eastern and southern regions of China, while the western regions see significantly fewer flights.’（see in Line 228-232）

We have placed it in the right place.

§ Table 3: Should be ‘Origin Airport’ instead of “Original Airport”. Revise and check for the same usage throughout the manuscript.

Re: We have revised the terminology in Table 3. We warily checked the whole paper to make sure every term in its right form.

§ Figure 6: Improve the font size for the legend. It is too tiny.

Re: we have revised the legend for Figure 6.

§ Figure 9: Instead of using “This work” to refer to the Computing time, replace it with ‘NN-DCB’. Authors can explain that NN-DCB refers to the method proposed in this work.

Re: we have revised the Figure 9. Replace ‘This work’ with‘NN-DCB’. Moreover, we added a sentence to explain NN-DCB refers to the method proposed in this work.

§ Conclusion: It is noted that the proposed model only focuses on Multi-airport ground delay. Is there any future research plan to enhance the model to include airborne delay?

Re: We appreciate the reviewers’ instruction for our future work. we have revised the conclusion, to enhance the model, we plan to consider sector opening schemes，fairness，and more uncertainty factors in our future study. Airborne delay could be an interesting point to improve our model in further research. We hope such potential research orientation may inspire the readers.

Revise and check the manuscript for minor grammatical errors.

Re: We warily check the article again. The grammatical errors in the manuscript have been fixed, we would like to deeply thank the anonymous reviewers for the comments, we resubmit this revised manuscript in the hope that the editors and reviewers could satisfy with our endeavor.

Comments and Suggestions for Authors

The paper proposes a novel neural network framework, NN-DCB, to address large-scale ATFM problems within China's national airspace. It highlights the limitations of traditional MIP solvers for ATFM. It introduces a customized neural network to efficiently solve problems by leveraging techniques such as neural diving and branching. The paper reports that the proposed solution significantly improves computational efficiency, finding optimal solutions for 15,927 flight trajectories in just 15 minutes.

Strengths:

1. The paper introduces a deep learning-based solution to address the computational challenges of solving MIP problems in ATFM, a novel and potentially impactful application.

2. The NN-DCB model effectively reduces computation time while maintaining high-quality results for large-scale ATFM problems, showcasing a practical solution for real-world scenarios.

Drawbacks:

1. The introduction of neural diving and branching components is interesting, but their motivation is unclear. The paper could benefit from a more explicit explanation of why these components were selected over others and how they specifically contribute to improving MIP performance.

2. The paper reports that the NN-DCB model achieves a shorter solution time than traditional and RL-based methods. However, it does not comprehensively analyze model performance metrics like accuracy, fairness, robustness, or sensitivity to various input parameters.

3. The paper presents promising computational results in a simulation environment. However, there is no discussion of the feasibility of integrating the NN-DCB model into existing ATFM systems for real-time decision-making.

Recommendations:

1. Include a dedicated section or subsection discussing the reasons for selecting neural diving and branching approaches compared to existing deep learning techniques for MIP optimization. Provide insight into why these were expected to be successful in the ATFM context.

Re: Thanks for the reviewers’ comments. We have added a paragraph to provide insight into neural diving and branching techniques for MIP optimization which is superior to handle the ATFM problem compared to the existing deep learning techniques. We emphasis that neural diving and branching methods focus on efficiently exploring and narrowing the solution space. Their direct integration with MIP solvers enhances solution quality and reduces computation time, making them highly effective for real-time optimization. ATFM problem typically involves large-scale with both discrete and continuous variables, neural diving and branching offer superior efficiency for handling extensive datasets. We hope such explanation could better illustrate our motivation for this study. (See in Line 239-253)

2. Provide additional analysis on the model's performance metrics beyond computation time, such as model robustness under different air traffic conditions, the fairness of delay allocations among flights, and the solution's sensitivity to different operational constraints.

Re: Thanks for this valuable suggestion. We have enhanced our model's performance analysis with additional metrics:

Model Robustness:

Our neural network incorporates dropout layers (rate 0.3) and early stopping (after 20 epochs without improvement) to ensure stability.

The model was validated using a large-scale dataset of 15,927 flight trajectories across 287 sectors, demonstrating robust performance under varying traffic conditions.

As shown in Figure 6, the training process exhibits stable convergence characteristics across different phases.

Delay Allocation Fairness:

As illustrated in Figure 7, we analyzed delay distributions across all flights. The results show an average delay of 23 minutes, with maximum and minimum delays of 18,365 seconds and 17 seconds respectively.

By setting the postponement probability to 0.15, only 15% of flights experience delays, ensuring system fairness while effectively balancing demand and capacity.

Figure 8 demonstrates that optimized demand curves are evenly distributed below capacity limits, indicating balanced delay allocation.

Sensitivity Analysis:

Our model includes several key parameters that can be tuned based on operational requirements:

Time window (T): Set to 360 minutes maximum delay

Time step (τ): 15-minute intervals for capacity updates, aligning with CAAC requirements

Postponement probability: 0.15 for delay allocation

Computation time: 15 minutes on standard hardware, demonstrating practical applicability

3. Address the potential challenges of implementing this model in a real-time ATFM setting, such as latency, system integration requirements, and adaptability to changing flight conditions. Discussing how to overcome these challenges would improve the paper's practical applicability.

我认为这是审稿人是想要对潜在的问题提出某些可行方向上的指引，因此我在总结中提出了云计算或边缘计算可以用来提高可扩展性和性能，、预测分析和机器学习技术来促进对航班时刻表的主动调整 检查Line 401-403

4. Incorporate methods to handle uncertainty, such as stochastic modelling or scenario analysis. Discuss how the NN-DCB model could be extended to account for these uncertainties or propose a plan for future work to address this limitation.

Re: Thank you for this important suggestion. While our current implementation focuses on deterministic optimization, we propose several extensions to handle uncertainties in future work:

Stochastic Capacity Modeling:

The current optimize\_gpu() method could be enhanced to incorporate:

Probabilistic sector capacity variations based on weather conditions

Monte Carlo simulation for multiple scenario generation

Dynamic capacity updates using a sliding time window approach

Neural Network Extensions:

Our neural network architecture (implemented in NeuralNetwork class) could be modified to:

Output probability distributions instead of deterministic values

Implement ensemble methods for more robust predictions

Add uncertainty-aware loss functions

Scenario Analysis:

The model could be extended to handle:

Weather-related uncertainties through multiple scenario evaluations

Flight plan variations using probabilistic trajectory modeling

Dynamic rerouting options under uncertain conditions

5. Either conduct experiments on a range of computational hardware to demonstrate scalability or include a discussion on how the proposed method would perform on more powerful, typical industry-standard systems.

请检查 Line 377-382。

6. Provide a fairness analysis of the model's solutions, discussing whether certain flights or sectors are disproportionately affected by delays. This would enhance the model's applicability in scenarios where equity among stakeholders is crucial.

本文没考虑公平性，我按照本文存在的局限性进行了说明，请检查Line399-406

7. It would be beneficial to provide a more detailed description of the neural network architectures used for diving and branching. For instance, specify the number of layers, activation functions, and whether techniques like dropout or batch normalization were used to improve generalization. A technical analysis of how the weights were initialized and how hyperparameters were optimized (e.g., using grid search or random search) would help understand these components' efficacy.

对网络结构、超参数都进行了简单的描述，但是不清楚你具体的网络结构，所以请检查是否符合要求或者进行微调 Line 221-228

8. The paper mentions using Binary Cross-Entropy for Neural Diving. It would be helpful to elaborate on how this loss function was selected over others and whether any alternative formulations (e.g., Huber loss for mixed-integer problems) were considered. Additionally, detailing the optimization algorithm used, such as SGD or Adam, and any adjustments made during training (e.g., learning rate schedules or early stopping) would enhance the technical rigour of the manuscript.

Re: Thanks for the comments. We have elaborated on the reason of choosing Binary Cross-Entropy for Neural Diving, a related explanation has given in Line 229-238. We state that ‘alternatives such as Huber loss were considered, they are more appropriate for regression tasks and mixed-variable problems, which would introduce unnecessary complexity in this binary context.’ This is main reason of choosing Binary Cross-Entropy. Besides, we have supplemented the training details, we are detailing the optimization algorithm used (Adam). A paragraph has added in Line 234-238. We hope such revision could enhance the technical rigorous and make article easily to understand.