**ANSWER TO REVIEWER COMMENTS**

**TRD\_2016\_462\_R1**

The authors would first of all like to thank the reviewers for the positive and constructive feedback on our original manuscript. We believe that your comments have enabled us to more clearly state our scope, results and conclusions and we hope we have reflected this to your satisfaction in our revised manuscript. The tables below address the specific comments. Correspondingly, some changes to the text of the original submission have been made and such changes are marked with red color.

**REVIEWER #1**

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| **#** | **Comment** | **Answer** |
| **1** | #1. The title does not seem to cover the contents of the paper very well, or at least it can be improved. The model does calculate only emissions, but also costs, travel time and travel time reliability. Please consider updating the title. | Thank you for the advice. The title has been changed to “A method of emission and traveler behavior analysis under multimodal traffic condition” |
| **2** | #2. In connection with comment #1, the aims as described in the abstract are not consistent with the title, nor with the aims stated in the Introduction (Section 1).  The abstract reads “In this paper, a study focusing on travel time reliability of ferry service during peak travel periods is performed. Furthermore, as a key result an emission loss model under multimodal conditions is developed”.  The Introduction states: “Therefore, in this paper, ferry travel time and corresponding reliability are studied, and travel costs influenced by gas prices are also examined.” and “The contributions in this study contain, (1) travel time and travel time reliability formulation in ferry service; (2) route choice model of traveler behavior in multimodal condition based on the empirical distribution of travel time and travel time reliability studied; (3) formulation of emission loss in joint condition of freeway and ferry service, and relative analysis in peak time.”  Of course, it is generally, after reading the whole text, clear what has been done, but these confusing messages early on in the text should be avoided. Please consider carefully what the essential aims of the paper are, and update the text in various places accordingly. | Thank you for pointing out this issue.  The abstract has been updated to reflect the work in analysis of travel time reliability and travel cost. |
| **3** | #3. In various places in the text and in eq. 27, carbon dioxide is abbreviated as CO2. Please place the “2” in subscript. | Thank you for pointing out this issue. The format of CO2 in equation (27) and context have been updated to CO2. |
| **4** | #4. The model is described in non-SI units, e.g. mile and gallon. Usually, scientific work is presented in SI units. Please consider updating this, or at least make sure to add a note how to convert the units to SI units. | Thank you for pointing out this issue. A note has been added in table 3 to clarify the conversion between SI units and non-SI units as follows:  “In this paper, non-SI units such as mile and gallon are used. For conversion, note that 1 mile=1,609 meters, and 1 gallon=3.785 litres.” |
| **5** | #5. Table 1 and Figure 2 (a) and (b): please provide a reference for this data. | Thank you for pointing out this issue.  Table 1 is obtained from WSDOT (2014):  WSDOT, 2014. WSDOT’s Handbook for Corridor Capacity Evaluation. 1st edition, Washington State.  The cited literature has been added to reference part.  The data in Figure 2(a) and (b) are obtained from Washington State Ferries, which is also marked in the paper. |
| **6** | #6. The ferry traffic clearly is periodic. I recommend adding a reference in the last paragraph of Section 2, to other work where this periodic nature of ferry traffic has been found. E.g.:  Ståhlberg K, Goerlandt F, Ehlers S, Kujala P. 2013. Impact scenario models for probabilistic risk-based design for ship-ship collision. Marine Structures 33:238-264.  Zhang WB, Zou YJ, Tang JJ, Ash J, Wang YH. 2016. Short-term prediction of vehicle queue at ferry terminal based on machine learning. Journal of Marine Science, in press. | Thank you for indicating this issue.  The advised paper has been added in the references section, and language was also added in the last paragraph of Section 2,  “An obvious periodic trend in the ferry traffic can clearly be observed, and the existence of such a trend has been shown in some previous studies (Stahlberg et al, 2013; Zhang et al, 2016a).” |
| **7** | #7. Eq. 2. Please make sure all terms are explained. I don’t exactly understand what Average speed\_Peak 5-min means. | According to the handbook of (WSDOT, 2014),  Average travel time is the ratio of the route length to the average speed along the route. The average speed along the commute corridor is calculated for every 5-minute interval of the day (12 intervals for each hour, multiplied by 24 hours each day equals 288 intervals) on each commute corridor, using the speed data collected from up to 261 weekdays i.e., all available weekdays of a calendar year.  The content above is the explanation for equation (1).  Accordingly, average peak travel time is the longest travel time within the morning and evening peak periods. The corresponding 5-minute intervals become the peak 5-minute intervals as defined in equation (2). |
| **8** | #8. Eq. 4. The lognormal distribution is of course well-known, but please for completeness add the meaning of mu and sigma. | Thank you for pointing out this issue.  A sentence has been added under equation (4) for clarification of parameter meaning,  “here is the mean and is the standard deviation of the log-normal distribution” |
| **9** | #9. Eq. 12. and 22. There seems to be some symbols lacking. These equations are not clear to me. Please update. | Thank you for indicating the issues.  For equation 12, the explanation of symbols has been updated as follows:  “The price of gasoline per gallon changes frequently, which can be known from Figure 7 in section 4. Fuel efficiency is calculated for various vehicle models every year. For example, for a 2000 model year vehicle, fuel efficiency is 20.3 miles per gallon from the U.S. Energy Information Administration (WSDOT, 2014). Fuel efficiency can further be obtained from statistics provided by the Department of Transportation of U.S.”  For equation (22), the explanation of symbols has been added as follows:  “here *LL* means log-likelihood, and *N* is the number of travelers, is the probability of the choices of traveler *n*.” |
| **10** | #10. Table 4. Please delete row 4. It seems superfluous. | The 3rd parameter of row 1 and row 4 is different for different probability distributions. One is ‘Mean’, the other is ‘P’. Therefore, row 4 should be reserved. |
| **11** | #11. Section 4.3. You argue that there may be reasons for the deviation between the model and the observations, and state “special considerations” can be relevant for a person. Can you please provide some examples of this? | In a logit model, it is supposed that all travelers are rational, and will make the choice following the selected factors strictly, such as travel time, travel time reliability, and travel cost, etc. However, in practice, some travelers may consider other reasons based on personal considerations (e.g., convenience due to proximity to a shop, or the scenery on the road etc.). These personal considerations will definitely cause deviation between the model and the observations. |
| **12** | #12. P.17, top paragraph. There seems to be a verb missing in the sentence “Fig. 4 shows that average utilities …” I believe the word “fluctuate” should be added to the sentence. | Thanks for pointing out this issue. The word “fluctuate” as missed, and has been added in that sentence. |
| **13** | #13. Figure 4. What unit does the utility have? Please add this unit to the figure. | Utility has no unit. It is simply a metric used to indicate the expense of choice, and it can be compared with other choices. The symbol ‘(-)’ is added for utility to show the unit clearly. |
| **14** | #14. Figure 5. Is the left figure “from” and right figure “to”? Please clarify. | Thank you for pointing out this issue. Sub captions have been added in Figure 5 to indicate the figures meaning. |
| **15** | #15. Section 4.5.1 and 4.5.2. and 4.5.3. The analyses done are meaningful and good to show, but I don’t fully understand what exactly is being calculated. I believe a more elaborate description of the process of calculation (e.g. a flowchart or more text) would be very helpful. I think it’s enough to elaborate in only one section (e.g. 4.5.1) as the process in the two other Sections are very similar. | Thank you for pointing out this issue.  The comparison calculation is performed by following the proposed method and data in the other part of section 4. Some conditions are changed in the assumptions, like those involving travel time, travel time reliability, and travel cost on freeways. Then, the corresponding change of traveler behavior and emission loss are observed.  The three sub sections have been merged into one section, 4.5. |
| **16** | #16. In the paper, only the travel time reliability of the ferry traffic is accounted for in the model, whereas highway travel time unreliability is not considered. Why is this, given that e.g. accidents may cause large travel time fluctuations as well? It is OK for me to leave this as is for the current paper, but it should be mentioned as an uncertainty (see comment #17) and listed as a point of future research. | Thank you for this question.  Travel time reliability is an important metric for travelers to indicate the degree of unreliableness in travel time which is incurred by scheduled or unscheduled delay. As a general metric, travel time reliability works for both highway and ferry trips. For highway trips, there are several studies that have been done to estimate travel time reliability. Therefore, this paper only focuses on how to formulate travel time reliability for ferry trips in section 3.2. However, in the logit model of section 3.4, influences from both ferry trips and highway trips are taken into considered equally. |
| **17** | #17. My main (and most important) comment concerns the discussion. First, I’d recommend making this a separate section, i.e. not 4.6 but 5. Second, it is a very short discussion, which would benefit greatly from adding several discussion points. I will number these #17a, #17b and #17c, and suggest you make a subsection 5.1, 5.2 and 5.3 for these. | Thank you for pointing out this important issue. The authors have added discussion content for #17a, #17b, and #17c below. |
| **17a** | #17a. First, I believe it would be a great benefit of the model to make the strength-of-evidence of the different parts of the model construction more explicit. In recent work on reliability of critical systems (Zio 2016), it has been argued that appropriate consideration of uncertainties (or, conversely, the strength of evidence) is essential. I refer to a method presented by Goerlandt and Reniers (2016) where a qualitative uncertainty assessment is shown (the method is presented in a risk analysis context but is more widely applicable). Please use this to list (in a Table) the different parts of the model (route choice model, emission model, etc) and evaluate (subjectively) the quality of the evidence. Also include other factors not included in the current model, which may cause deviations with reality. Then rate each of these using the scheme by Goerlandt and Reniers (2016). The hightest uncertainties with highest possible impact on the model outcome should be considered “future research” and reported as such.  References:  Goerlandt F, Reniers G. 2016. On the assessment of uncertainty in risk diagrams. Safety Science 84:67-77.  Zio E. 2016. Challenges in the vulnerability and risk analysis of critical infrastructures. Reliability Engineering and System Safety 152:137-150. | Thank you for the advice.  A new paragraph and Table 8 have been added in section 5.  “In the proposed model, three factors including travel time, travel time reliability, and travel cost are taken into consideration. Additional factors, such as weather, safety, comfort, scenery viewed during travel etc. were ignored as all of these factors contain much uncertainty with regards to how to measure/quantify them. Some studies, however, such as Goerlandt and Reniers (2016), and Zio (2016), have proposed methods of qualitative uncertainty assessment. Analysis results are listed in Table 8 based upon Goerlandt’s method (Goerlandt and Reniers, 2016). In the table, characteristics are identified as ‘Strong’ when they are classified with a low number of errors, have high accuracy of recording, have a high reliability among data sources, have a large volume of relevant data available, are such that existing experimental tests agree well with model output, or are such that expected results from models lead to good predictions etc.(Goerlandt and Reniers, 2016). If aforementioned criteria are not met, the characteristics are identified as ‘Weak’.”  The suggested literature has been added into the reference part as well. |
| **17b** | #17b. Second, one of the assumptions (which should be evaluated in terms of the strength of evidence) is the assumption that Tf from Eq. 3 (sailing time) is constant. Elsewhere in the paper, it is acknowledged that this may also differ due to e.g. environmental conditions or mechanical problems with the ferries. I believe it would be good to discuss this assumption a bit in more detail, as it is a quite central assumption (like the omission from highway travel time unreliability from the model, see comment #16). I suggest you discuss it and highlight it as a point for future research. In maritime traffic engineering, AIS data has been used to study traffic patterns, see e.g. Ståhlberg et al. (2013) and Xiao et al. (2015). Studying AIS data of ferries may be a good approach to study and model the travel time fluctuation of ferries.  References:  Xiao F, Ligteringen H, van Gulijk C, Ale B. Comparison study on AIS data of ship traffic behavior. Ocean Engineering 95:84-93.  Ståhlberg K, Goerlandt F, Ehlers S, Kujala P. 2013. Impact scenario models for probabilistic risk-based design for ship-ship collision. Marine Structures 33:238-264. | Thank you for pointing out this issue.  Some paragraphs and Table 9 have been added in section 5 to discuss the on-time performance situation of some ferry routes.  “It is important to note that, in this paper, that some assumptions surrounding issues such as the time of a ferry trip, weather, etc., were made in order to avoid more uncertainty; in many cases, these factors were assumed to be constant (e.g., constant ferry trip time). This does not reflect the true, real-life situation every time as such factors will always be variable to some degree. For example, in practice, the ferry trip time is always subject to change based on weather, marine traffic, and other random factors. Specifically, bad weather may have a significant influence on ferry trip time.  Table 9 shows on-time performance for a selection of ferry routes in Washington State in May 2016. The by collected from Washington State Ferries. For some ferry routes, such as Seattle/Bremerton and Seattle/Bainbridge Island, that were studied in the case study section of this paper, the on-time performance is around 95% or more, which is quite good and indicates a high degree of reliability. However, for some ferry routes, like Anacortes/San Juans or Fauntleroy/Vashon, the on-time performances are around 88%, meaning more than 10% of all sailings encounter delay. In future studies, the fluctuation of ferry route on-time performance will be considered to refine accuracy of the proposed model.” |
| **17c** | #17c. Third, the model currently includes travel time, travel time reliability and cost in the utility model, and emissions in the output (to minimize). I recommend to discuss the possibility to also include also safety considerations of highway vs ferry traffic as possible factors. I can imagine a planning system where the authorities aim to reduce number of accidents (and related costs) by switching from road to ferry traffic (assuming ferry traffic is safer). Maybe safety considerations can also be a decisive factor for people to make a route choice (or it can be considered a policy variable e.g. through setting ferry ticket prices, to change people’s behavior to make more use of ferries, to reduce number of road fatalities [assuming ferry traffic is safer]).  I recommend following literature to include in this discussion, addressing risk models for highway and ferry (maritime) traffic (literature review papers suffice here, as a general overview of the possible future research to link your model with risk models, but you may of course add additional work if you consider these relevant), and a study on risk of Washington State ferries, which I believe is highly relevant as it considers the same area.  References:  Lord D, Mannering F. 2010. The statistical analysis of crash-frequency data: a review and assessment of methodological alternatives. Transportation Research Part A: Policy and Practice 44(5):291-305.  Goerlandt F, Montewka J. 2015. Maritime transportation risk analysis: review and analysis in light of some foundational issues. Reliability Engineering and System Safety 138:115-134.  van Dorp JR, Merrick JRW, Harrald JR, Mazzuchi TA, Grabowski M. 2001. A risk management procedure for the Washington State ferries. Risk Analysis 21(1):127-142. | Thank you for pointing out this issue. Traffic risk is another important factor for consideration in traveler behavior studies. A paragraph has been added in section 5 as follows:  “Some other factors such as weather and safety, which also have strong influence on either empirical validation or theoretical viability, are related to risk associated with travel, an issue that arises regardless of travel mode (i.e., for either freeway or ferry trips). Traffic risk is identified as another important factor and it has been studied in many previous works (Lord and Mannering, 2010; Goerlandt and Montewka, 2015; van et al., 2001). In future studies based upon the results herein, more data related traffic risk will be collected, and related research will be conducted to further improve the proposed model.”  The suggested literature also has been cited. |

**REVIEWER #2**

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| **#** | **Comment** | **Answer** |
| **1** | Th literature review is weak. A thorough literature review on emission analysis under multimodal traffic condition would help the paper. Please cite the following and add more past literature.  a.       Zhao, L., Xu, X., Gao, H. O., Wang, J., & Xie, Y. (2016). A bi-level model for GHG emission charge based on a continuous distribution of travelers’ value of time (VOT). *Transportation Research Part D: Transport and Environment*, *47*, 371-382.  b.       Mishra, S., and Welch, T. A Joint Travel Demand and Environmental Model To Incorporate Emission Pricing For Large Transportation Networks. Transportation Research Record, Journal of Transportation Research Board, 2032, pp. 29-42.  c.       Nagurney, A., Ramanujam, P., & Dhanda, K. K. (1998). A multimodal traffic network equilibrium model with emission pollution permits: compliance vs noncompliance. *Transportation Research Part D: Transport and Environment*,*3*(5), 349-374.  d.       Sharma, S., and Mishra, S. ITS Enabled Optimal Emission Pricing Models for Reducing Carbon Footprints in a Bi-Modal Network. Journal of Intelligent Transportation Systems, Taylor and Francis, 17 (1), pp. 54-64.  e.       Gkritza, K., & Karlaftis, M. G. (2013). Intelligent transportation systems applications for the environment and energy conservation (Part 1). *Journal of Intelligent Transportation Systems*, *17*(1), 1-2.  5. | Thank you for pointing out this issue.  A new paragraph has been added in introduction section, and the suggested literature has been added as follows.  “Issues surrounding emissions from transportation have attracted the attention of some scholars in recent years. Several studies were conducted to that focused on providing guidance in policy-making for traffic management through intelligent traffic systems (Gkritza and Karlaftis, 2013), traveler behavior research, and flexible methods for of travel pricing (Sharma and Mishra, 2013). In particular, Transportation system optimization in multimodal conditions is an effective way to reduce emissions due to the obvious differences in emission patterns for different traffic modes. Therefore, how to optimize the share of different traffic modes, in an effort to reduce emissions, through policy has being become a research hotspot. As such, many scholars have presented methods to decrease emissions in multimodal traffic systems (Nagurney et al., 1998). For example, Zhao et al (2016) developed a bi-level model for greenhouse gas emissions based on a continuous distribution of travelers’ value of time; Mishra and Welch (2012) studied vehicle emission pricing strategies for large transportation networks. At present, however, these studies focusing on multimodal traffic have not devoted much attention to ferry services.” |
| **2** | 2.       Can the model be used for forecasting purposes? Since reliability is typically unknown, but travel time is somewhat known. How reliability can be forecasted? | The model can be used for the purpose of emission forecasting if the distribution of travel time, travel time reliability, and travel cost are known.  Usually travel time reliability cannot be forecasted. However, the distribution of traffic volume exhibits an obvious periodic trend, peak time and non-peak time patterns, and this feature has been verified by many studies. As travel time is definitely related to traffic state, travel time reliability may also show a periodic trend to a certain extent. Thus, for the normal traffic state, the travel time reliability can be forecasted. At the same time, travel time reliability is also affected simultaneously by some random factors such as the occurrence of accidents, weather etc., therefore it is difficult to accurately estimate the variation of reliability in abnormal conditions. This issue will be studied in future research. |
| **3** | 3.       Table 7, is it travel volume or traffic volume? | Thank you for pointing out this issue.  It should be ‘traffic volume’, and this issue has been corrected. |
| **4** | 4.       Is the proposed model can be somehow validated? How to measure accuracy? | The proposed model can be validated through comparison between the modelled result and survey data. In section 4.3, a comparison of traveler behavior between the modeled results and observed results is performed. The more survey data that is collected, the more accurate the validation is.  From the comparison results, the proposed model shows around a 90% correct ratio in this case. Reasons causing deviation of model outputs are analyzed in section 4.3.  The model accuracy is also affected by other factors that are not taken into consideration in this model. In section 5, some discussion is made to cover the influence of other factors. |
| **5** | How the analysis will be further complicated when other facilities in addition to Freeway will be included? | In this paper, only two traffic modes, freeway and ferry trip are compared. However, the discrete route choice model in section 3.4 is a general method that is not limited for usage on freeway and ferry trips. In regard to applying the proposed model, the distributions of travel time, travel time reliability and travel cost for the traffic mode should be known, and corresponding data should be collected. Then, all information mentioned above are conditions under which the proposed model can be used, and thus the model can be extended to more traffic modes in the future if desirable. |