MSc/PGDip in Data Analytics (January 2022 Entry)

Modelling, Simulation and Optimisation (H9MSO)

Project CA

DEADLINE: 18th August 2022 23:59
WEIGHT: 60% of overall marks

Project Outline

A small village in the commuter belt of a large town shares the local school with a neighbouring village. The local school is about 1km East of the village on the Old School Road which connects the two villages in East-West Direction. Years ago, the kids from both villages could easily walk or cycle to the school.

With the expansion of the commuter belt, the rush hour traffic in the village became unbearable and a small bypass was constructed that diverted the national road around the village. The national road now crosses the Old School Road about 700m from the village. Crossing the national road is dangerous, so the parents now bring their children with the car to the school. Every morning during a 15-minute peak time shortly before the 9am start of school 50 cars make the trip from the village to the local school and later back again. Crossing the national road is not easy, and when too many cars come at once, there is quite a build-up of a queue on the crossing. The parents learned this the hard way and spread their schedule, some leaving home as early as 8:30.

The morning rush hour on the national road is from 7:30am to 9:15am. The South bound traffic flow during this period has increased over the years from 200 veh/h to 300 veh/h, but this didn't affect the cross traffic of parents bringing their children to school too much. The average travel time to the school increased only marginally and is still just under 2 minutes. And the maximum travel time increased from 3 to 4 minutes. The North bound traffic flow during the morning appears static at 120 veh/h. The evening rush hour goes in the opposite direction, but we ignore this, as there is no interference with school traffic in the evening hours.

North of the village a new estate is planned. Once Phase 1 is finished, the traffic flow in the morning rush hour is expected to increase to 400 veh/h. Once Phase 2 of the new estate is finished, the rush hour traffic is expected to increase to 600 veh/h. The building company has provided lots of glossy material, but local residents are sceptical. Parents are concerned about the impact on the local school traffic. You are being tasked with investigating if there is a *statistically significant* change in the length of the queues of the cars waiting to cross the national road, and hence in the waiting time at the crossing and the overall traveling time.

Part 1 Baseline Simulation

Create a simulation model of the crossing under the following assumptions:

1. Cars on the national road are travelling at constant speed of 100km/h.
2. On the national road the inter-arrival time of cars in both directions follows an exponential distribution.
3. Cars on the Old School Road are limited to 50km/h.
4. The inter-arrival time of cars on the Old School Road follows an exponential distribution.
5. Every morning 50 cars make the drive to the school.
6. The simulation runs for 30 minutes

Validate the simulation model by running it with a traffic flow of 200 veh/h and 300 veh/h on the National Road and check the average and maximum travel times for the 1km distance from the village to the school. The average travel time should stay just under 2 minutes and the maximum travel time just under 4 minutes.

Part 2 Simulation Study

Create a framework for running multiple simulations of 30 minutes each, combine their results and enable suitable statistical tests.

1. Compare the effects of the higher anticipated traffic flow on the national road of 400 veh/h and 600 veh/h to the effect of the current traffic flow of 300 veh/h on different variables.
2. Is there a statistically significant effect ($p<0.01$) on the queue length and the waiting time at the crossing of the Old School Road and the national road.
3. Your task is to investigate if there is a statistically significant effect of a speed limit of 60km/h or 80km/h on the national road. Formulate your hypothesis and run the necessary simulations to support or reject your hypothesis and draw your conclusions.

This project is based on the simulation for a rural crossing between a national road in North-South direction and a local road in East-West direction, as indicated in Figure 1.

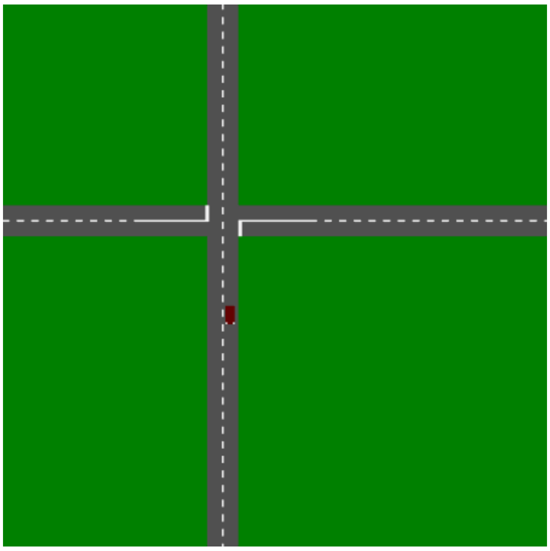

Fig. 1: Model of the Cross Road as developed in class

General Remarks

- For this simulation study you will have to make some assumptions about the vehicle's parameters (vehicle size, average and maximum acceleration and deceleration) and the driver's behaviour. You have free choice about these assumptions, but the assumptions you made need to be clearly documented in the final report.
- The number of vehicles driving to school in the morning is fixed (50) as is the time period for each simulation run (30 mins). To obtain statistically meaningful results, you have to run multiple simulations. You argue for the number of simulations you have chosen.
- Provide suitable graphs for the simulation results (i.e. s/t Graphs, Count Graphs, queue length, wait time, travel times) and statistical summaries (i.e. histograms, box-plots).
- All graphs included in the report must have their origin in one of the jupyter notebooks provided. Provide the file name and cell number as part of the figure caption.
- **Use your student ID as initial seed value for all your simulations**. Consequently, everyone will have different albeit somehow similar results and graphs.
- The teaching material used for this course is updated every semester. Code versions from different semesters may be incompatible. Do not use code from previous semesters.
- As citation for class material use: C. Horn. Modelling, Simulation, and Optimisation. Lecture Notes. National College of Ireland. July 2022

Deliverables

The project has two deliverables:

1. A final report in .pdf format describing your simulation study should have maximal 6 pages in IEEE conference format and follow the outline structure given below
2. A .zip file that contains the code as (one or more) Jupyter Notebook files and any additional data, configuration files or documentation that may be required to run the code.

The final report will be uploaded through the Turn-it-in link provided on Moodle.
For evaluation criteria please check the Rubrics given at the end of this project outline.
You may use components from the Simulation Study presented in class. When re-using code or design elements, refer to the version uploaded on Moodle.

Academic Integrity

- By submitting you work on Moodle you declare that this is your own work.
- Any material created by others must be properly referenced. Verbatim text copies should be included in quotes.
- Figures not created by yourself should include an acknowledgement detailing the name(s) of the creator(s) and proper references.
- Code and figures copied from class material or other sources should be clearly marked as such and properly referenced. In particular it should not be (directly or implicitly) claimed as your own. Instead a comment should be included in the source code indicating where you obtained it from. If your modification form just a small part of the code, highlight explicitly what is yours.
- Students are strongly advised to familiarise themselves with the Guide to Academic Integrity. All submissions will be electronically screened for evidence of academic misconduct, e.g. plagiarism, collusion and misrepresentation. Any submission showing evidence of such misconduct will be referred to the college's processes.

The Structure of the Final Report

Title

Abstract with Keywords

1. Introduction
   In this section you introduce the problem you intend to investigate and articulate the research question you intend to answer.
2. Literature Review
   To the extend you have referred to the literature for model parameters or in the evaluation section give a summary of your sources and the parameter values you have extracted. When you refer to data provided in class use as reference the material provided on Moodle.
3. Methodology
   Describe the sequence and possibly intermediate stages of your development and give references to the relevant section of code in the Jupyter Notebook file. Give details of the Model Validation you performed and the criteria you applied for the simulation runs, in particular the number of simulation runs, the parameters used, and the statistical evaluation of the simulation results.
4. Results and Interpretation
   Report the results of your simulation study and give an interpretation of the same as detailed in the requirements section above. The statistical significance of the results should be discussed.
5. Reflections and Future Work
   Discuss how your research could be improved and suggest problems for future research. Check if your results are consistent with data published in the literature and/or common sense. Should there be major deviations, discuss possible reasons for the same.
6. References

Rubrics

Grade Criterion	Solid H1 > 80%	H1 > 70%	H2.1 > 60%	H2.2 > 50%	PASS > 40%	FAIL < 40%
Methodology (20%)	All elements of project requirements have been thoroughly addressed. The logic of the simulation study is well presented.	All elements of the project requirements have been thoroughly addressed. Arguments have been given for the type and number of simulation runs.	Some minor requirements missing from project. No arguments have been given for the type and number of simulation runs.	Multiple omissions from the project. The proposed number of simulation runs is insufficient for statistical evaluation.	Major parts of the project are missing. The project may contain parts that are not relevant. The proposed simulation runs are insufficient for the project.	The solution bears no resemblance to the project requirements at all.
Simulation (20%)	An excellent, thorough simulation was carried out. Effort exceeds the requirements.	An excellent, fully complete simulation was carried out. The results go beyond the minimal requirement.	A very good and largely complete simulation of the required models was carried out.	A good and largely complete simulation of one model or an inadequate simulation of multiple models was carried out.	An inadequate simulation of one model was carried out. Some logical errors exist.	Little or no simulation carried out.
Code (20%)	The notebook executes without problems. Code is elegant and fully commented. The notebook is well presented. The implementation significantly exceeds the requirements	The notebook executes without problems. Code is fully commented. There is no excess code used. The notebook is well presented.	The notebook executes without problems. Code is partially commented. There is a minimal amount of excess code used.	The notebook works and allows the output to be reproduced. The notebook is poorly commented or contains a lot of excess code.	The output of the notebook file can't be reproduced. The notebook file contains minor errors, is not commented or contains a lot of unrelated code.	The notebook file doesn't contain output or contains errors that prevent it from being executed.
Evaluation & Results (30%)	Models are fully evaluated. Results are thoroughly discussed. Statistics is applied flawlessly. There is significant reflection on the challenges faced in this project and possible resolution to remaining problems	Models are fully evaluated. Results are presented and thoroughly discussed. Statistics is applied appropriately. There is significant reflection on the challenges faced in this project.	Models are evaluated based on a sufficient number of simulation runs. Results are presented and thoroughly discussed. There is very good reflection on the challenges faced in this project.	Models and results are presented and appropriately discussed. There is good reflection on the challenges faced in this project in particular related to the insufficient number of simulation runs, if this was the case.	Cursory evaluation of one model. Cursory discussion of the results. There is some reflection on the challenges faced in this project. There is no reflection on the insufficient number of simulation runs.	Little to no evaluation of model. Little to no discussion of results. There is no reflection on the challenges faced in this project
Quality of Writing (10%)	Very well written, with no language errors. All figures are well conceived and readable. The IEEE template is strictly adhered to. Report does not exceed the length limits. References are appropriately and correctly used.	Well written, with only minor language errors. All figures are well conceived and readable. The IEEE template is adhered to. Report does not exceed the length limits. References are appropriately and correctly used.	Main document has a few language and/or style errors. Figures are well presented. IEEE template and length limit are adhered to. References are complete, and correctly used.	Main document has a few language and/or style errors. Some figures are may be hard to read. IEEE template and length limit are largely adhered to. References are complete, and correctly used.	Main report is readable with some language and/or style errors. Figures may be hard to read or presented in a suboptimal manner. IEEE template may have been broken. References are mostly complete and correctly used.	Littered with typos, and/or poor use of English. IEEE template not used. Figures may be hard to read. References (if any) are incomplete or incorrect.