CASE WRITING GUIDELINES

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Objective

Waterloo Cases in Design Engineering (WCDE) is a group in the Faculty of Engineering at the University of Waterloo which is dedicated to the production and implementation of Engineering Design Case studies throughout the curriculum. Case studies are a description of an engineering challenge. They provide real-world context for the discussion of engineering science and engineering design problems in class. They are inherently complex and multidisciplinary, and provide students with the opportunity to develop and hone engineering skills such as problem finding, problem solving, design, and the exercise of engineering judgement. Engineering cases can be developed in a number of ways, but a key focus of the WCDE effort is to develop case studies based on student work term experience. This is typically done through the conversion of submitted work term reports by WCDE staff.

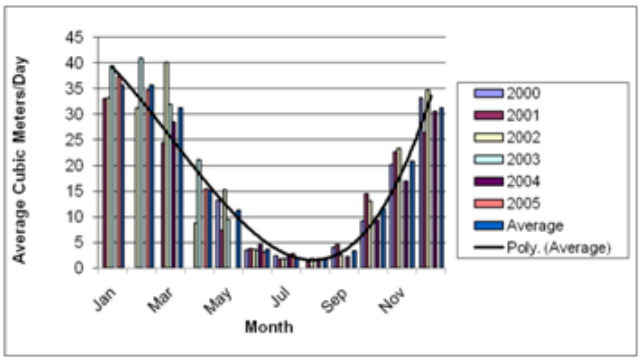
This document is intended to provide students with guidance on the writing of case studies based on their own experience. It may also be used to help with the writing of a work term report, or to decide whether to submit their work term report to WCDE for conversion to a case study.

Cases and Work Term Reports

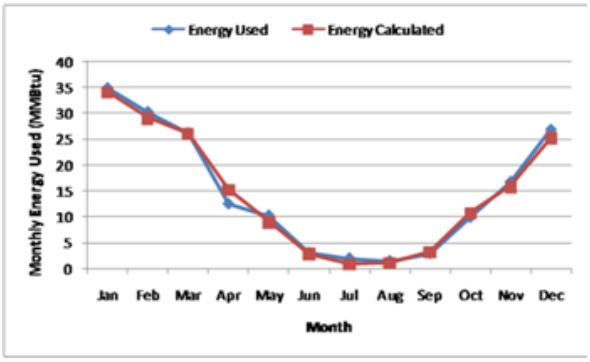
Cases and work term reports both document an engineering analysis and/or design. They both require a formal and clear writing style, logical content, and appropriate supporting material and references. They differ in their detailed structure. Consider the engineering challenge depicted in Figure 1, the retrofitting of a home heating system for a 150 year old stone house in Elora. This represents an actual engineering analysis performed by the author while renovating his house. The existing house, Figure 1(a), had no significant insulation when purchased in 1999, and was heated using a forced-air natural gas furnace. The plan was to completely gut the inside of the house, add new wall and ceiling insulation, and install a new hydronic in-floor heating system. A major question was the size of the new heating unit required to heat the water for the hydronic system, and to estimate the percentage heating savings. A one-dimensional, steady-state heat transfer analysis was developed in Excel to solve this problem. Real data, monthly natural gas heating bills over several years, Figure 1(b), was available to verify the heat transfer model. The results of this verification are presented in Figure 1(c). Once verified, calculations were made to determine the heat used on the coldest day of the year and energy consumed over a typical year.

This problem was used as a major engineering project for a first year Mechanical Engineering class. Students were walked through the analysis throughout the term, and asked to prepare a work term report to present this analysis and their results. Figure 2(a) gives the outline they were asked to use for this report. Figure 2(b) shows the outline for a case study based on the same analysis.

(a) Elora stone house (real context)



(b) Monthly natural gas usage (real data)



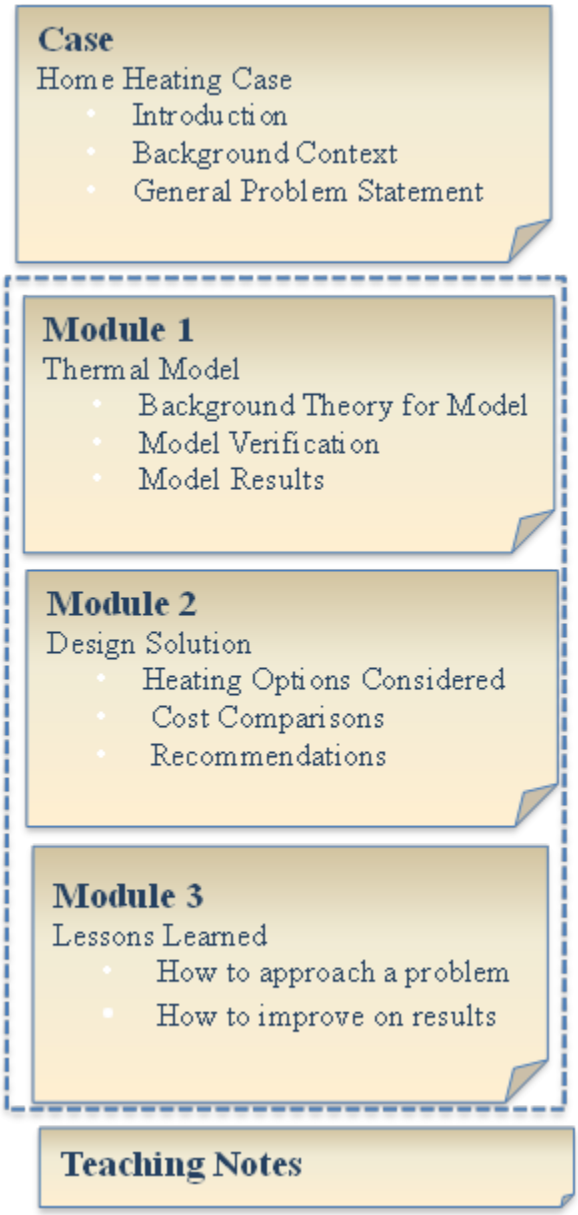
(c) Comparison of simulation and actual energy usage (verification)

Figure 1 − Outline of engineering challenge: Elora home heating retrofit

Both documents present the same material: a systematic presentation of an engineering approach to this particular challenge. The sequence is also the same: a presentation of the problem, background theory for the engineering model, verification of the model, results of the model for the renovated house, consideration and selection of a suitable heating system (application of the model), and a summary of the analysis in the form of conclusions and recommendations.

1. Introduction
2. Background (Context)
3. Thermal Model
   3.1. Background Theory and Assumptions
   3.2. Model Verification
   3.3. Model Results for Renovated House
4. Selection of Heating System
   4.1. Heating Systems Considered
   4.2. Cost Comparisons
   4.3. Selection of Best Option
5. Conclusions
6. Recommendations

(a) Outline for work term report



(b) Outline for case study

Figure 2 – Comparison of work term report and case study structure

The work term report is structured as one report with several sections: introduction, background, thermal model, selection of heating system, conclusions and recommendations. There is no one structure that is best. For example, the background context could have been included in the introduction, and the model results for the renovated house could have had its own section. A choice must also be made regarding the level of detail included, and this is related to the anticipated audience. In this case, students were asked to assume the

reader was an engineering student like them, but with no knowledge of the project or the underlying engineering science. If the reader was assumed to have more knowledge, then some sections could be more concise: the background if the reader was familiar with the project (unlikely) or the theory and assumptions if the reader was an expert in heat transfer in buildings. In any event, the report must be complete; it must include all equations and data required for someone to follow the analyses and verify the calculations. Often detailed calculations, such as a hand calculation to verify the excel simulation, would be included in an appendix. But the approach and key equations should be include in the main body of the report, as would a discussion of the major intermediate and final results. The conclusions and recommendations are a critical part of the report. They document the consequences of the analysis, and allow the author to document the next steps.

The case study follows a similar logical format. However, the first module, the case itself, provides the majority of information required to define the problem. This includes information normally provided in the introduction to a report, but also includes background contextual information. The targeted audience should be an engineering student. Critical general information and data should be provided in this first module. This includes the key dimensions of the house, current insulation levels, size of existing furnace, and data on the home heating bills for the Elora home heating retrofit case. This data allows students subsequently solving the case the necessary information to proceed. Putting this information up front also emphasizes the importance of gathering key data early on in the problem solving process.

Subsequent modules outline the approach, the solution, and the conclusions and recommendations. These are separated from the case and are typically not seen by students. This provides students the opportunity to decide how to approach the problem and to identify any further information that is required. For example, in the Elora home heating case, the approach that was used was to develop a simple one-dimensional heat transfer model to predict heat transfer on the coldest night of the year (to estimate the minimum boiler size) and the energy used in a typical year (to estimate cost savings). Students would either know how to use Fourier's law for one-dimensional heat transfer, or could learn it on their own from various sources, or in class. Sufficient information is provided in the case itself to develop and verify this model through comparison to the energy used in the existing house from the home heating bills. However, no information was provided in the case on the intended levels of insulation. This was provided later.

These subsequent modules are provided to the course instructor to see what was done and to be in a position to provide additional data where appropriate (such as new insulation levels, in this case). Note that many alternate solutions are typically possible, even in highly constrained problems. Different people will make different assumptions. And the instructor may intentionally deviate from what was done in the case, using the key data as the basis for a modified project or assignment. For example, in this situation, the instructor could first ask students to recommend appropriate levels of insulation to be added, based on a desired level of energy savings.

Case Development Process

Cases can be developed from existing work term reports, or directly. Much of the process is the same, and parallels a method for writing a work term report. This starts with the selection of a suitable work term report to convert, or a suitable topic. There must be a core of engineering analysis or design, and this effort must be clearly justified. In the Elora Home Heating case, the engineering analysis was used to help select boiler size and energy savings. In the original application, the analysis was also used to specify insulation levels and a layout for the radiant in-floor heating, although these were not featured in the resulting case study.

Once a topic has been selected, a case plan is developed. This serves the same purpose as an outline for a report, but has additional features. Key features of the case plan include: title, authors, opening paragraph, learning objectives, organization of the case, a list of key data and any hardware or multimedia requirements, and a time plan.

Also included as an appendix to each WCDE case plan is a model copyright agreement and final release form. Copyright is owned by the authors of the case but it is required that they provide the University of Waterloo a license to use the case for teaching purposes. The release form is signed after final review of the case by the company or institution for which the work was done, and ensures that they are comfortable with the material in the case, the way in which it is presented, and that any engineering analyses are correct. These forms are provided in the case plan at the start of the development process so that one can obtain provisional release for the case, and allows time for any required review by company lawyers. Provisional release means that the company is comfortable publishing the material outlined in the case plan, subject to final review at the end of case development. By sharing this information early in the development cycle, any sensitivities can be discussed and the effort to develop the case avoided if it is unlikely that it will be released in the end.

Others who will review the case plan include WCDE staff and potential instructors. WCDE looking at the overall quality of the potential case, key data, and its usefulness for instruction. Potential instructors for the case will be asked to review the case plan to provide input on structure and key data. This helps to obtain instructor buy-in and enhances the likelihood that a case will be implemented once released.

The title is important to the case as it is to a work term report. It must be both informative and concise. Typically it will include information about the context (“Elora Home”) and the content (“Home Heating Retrofit”). For the Elora case, there was no company involved. If there was, it is normal to include the company name in the title.

The authors would be those who performed the work. In cases where WCDE staff converts a work report, they are also listed as authors. Editors are not listed.

The opening paragraph is important to provide the overall context and a general description of the problem. It is usual to also include a key figure with the opening paragraph to help to convey the context. The opening paragraph should provide the reader with a clear overview of the project, and the overall objective.

The learning objectives for the case are the expected student outcomes from using the case in the context of an assignment or project in class. They are different but related to the objectives of doing the work in the first place. For example, the objective of the home heating project is to size the new boiler and to estimate energy savings. The learning objectives for the case could be to apply one-dimensional heat transfer to a real-world problem, make necessary simplifying assumptions for heat transfer analysis, and to learn to use Excel for simple engineering analyses and to effectively plot the results. Learning objectives are used by instructors to select suitable cases for use in a particular class.

The organization of the case provides an outline of the major elements and their sequence. The main topics are listed so that reviewers can comment on extraneous or missing information. The division of the case into separate modules is important to provide the maximum flexibility in implementation. The biggest decision is what to include in the case itself (the first module) and what to leave for subsequent modules. For the Elora home heating case, the case contains the key background information and with a general problem statement to design a new heating system. This allows the case to be used to select a boiler for (subsequently) specified new insulation levels, to specify the new insulation levels, or to select the layout of the new radiant in-floor heating system.

It is important to identify key data in the case plan, even if it is already included in the work term report from which the case will be developed. This allows reviewers to have a clear idea of what will be included. Company representatives must be aware of the material that will be released so that they can confirm their comfort level. Instructors must know that sufficient real data is included so that a successful implementation in class is possible. This is also an opportunity to request special hardware or multimedia exhibits to reinforce the learning opportunities. These may take time to collect.

The time plan is included so that everyone knows what is expected of them and can commit to spending the necessary time to review the material on a timely basis. This is particularly important if the student is about to graduate or the instructor wishes to use the case in an upcoming term.