The Final Report is the archival record of the design project and its results. The report emphasizes *your original contributions to the design solution;* it should not, in other words, merely repeat known solutions and vendor information. The intended readers of the report include your sponsors, peers, and any industrial representative familiar with the design problem and its possible solutions. Those readers expect an accurate and complete account of the design process and an appraisal of its results. Consequently, you must show that you have subjected the results to stringent tests and that the prototype is a true solution to the problem. The report must compare in quality with professional engineering reports in conciseness, accessibility, completeness of information, and conformance to format standards and rules of language usage.

*Title Page:* The title page of each report gives the title, TA names, and date of the report, the name of the

Course (EE464 Senior Design Project), name of the department (Electrical and Computer Engineering Department), and the name of the university. The Template of the Final Report on Blackboard gives instructions for the layout of the title page.

*Table of Contents:* Unlike earlier project reports, the final report requires a table of contents, which appears immediately after the title page. This table lists the section headings and subheadings as well as the page number of each. The Template of the Final Report on Blackboard gives you the format requirements for the table of contents.

*List of tables and list of figures:*

After the table of contents are two separate lists, one for tables and one for figures. Each list gives the number, title, and page number of each table or figure.

You must provide a one-page, single spaced, section-by-section

*Executive Summary:*

You must provide a one-page, single-spaced, section-by-section summary of the contents of this report

*[The title page contains the title of the report, the names of the authors, the names of the sponsors and TAs, the names of the department and university, and the date the report is submitted. Note that this page is considered to be the first page of the front matter (that is, page i; see Item 6 of the General Specifications for Final Reports; however, the number does not appear on the page.* ***Everything on this and the following pages between brackets and/or set in italics represents instructions or examples and is to be replaced with information unique to your report.****]*

**[Place Title of Report Here]**

*[Type the title of the report in 24-point Times New Roman Bold type at the optical center of the page, that is, centered on the page about one-third the length of the page from the top. Use upper and lower case letters.* ***Do not use italics.*** *The title should be informative, casting light on both the project and the design object.]*

**Submitted To**

**[Name of TA]**

**[Name of Sponsor (if applicable)]**

**[Sponsor’s Affiliation (if applicable)]**

*[This and the following information should be set in 14-point Times New Roman Bold.]*

**Prepared By**

**[Name of Author]**

**[Name of Author]**

**EE464 Senior Design Project**

**Electrical and Computer Engineering Department**

**University of Texas at Austin**

**[Semester Year]**

**CONTENTS** *[Set in all caps.]*

*[Skip a line (press the Enter key twice) after typing a centered heading.]*

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**FIGURES............................................................................................................................. vi**

**EXECUTIVE SUMMARY............................................................................................... vii**

*[Skip a line space here.]*

**1.0  . INTRODUCTION** *[This is a first-level heading. Use bold, all capital letters.]***.......... 1**

**2.0  . DESIGN PROBLEM STATEMENT....................................................................... 2**

**3.0  . DESIGN PROBLEM SOLUTION............................................................................ 2**

**3.1... [SECOND-LEVEL HEADING]** *[Bold, all caps.]***............................................ 3**

**3.2... [SECOND-LEVEL HEADING]....................................................................... 3**

**3.2.1 [Third-Level Heading]** *[Bold, initial caps.]***............................................... 4**

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**APPENDIX B – [TITLE OF SECOND APPENDIX]*.................................................* B-1**

*[Etc.]*

*[The table of contents receives the page number ii. If the table extends to a second page (page iii), place the heading “CONTENTS (Continued)” at the top of the second page. Note that you use both decimal numbers and indentation in this table to distinguish the different levels of headings.*

***Note:*** *The first-level headings shown above are those required for the final report. You can, however, add your own second- and third-level headings to describe your particular project.]*

**TABLES** *[Set in all caps.]*

*[Skip a line (press the Enter key twice) after typing the centered heading.]*

1... *[Title of first table]............................................................................................................* 7

2... *[Title of second table]................................................................................................ [etc.]*

*[Etc.]*

*[The list of tables follows the table of contents and is also page numbered with a lowercase Roman numeral. Note that the list of tables and the following list of figures are two separate pages.]*

**FIGURES** *[Set in all caps.]*

*[Skip a line (press the Enter key twice) after typing the centered heading.]*

1... *[Title of first figure]...........................................................................................................* 6

2... *[Title of second figure]............................................................................................... [etc.]*

*[Etc.]*

*[The list of figures follows the table of contents and is also page numbered with a lowercase Roman numeral. Note that the list of figures and list of tables are two separate pages.]*

**EXECUTIVE SUMMARY**

*[Skip a line (press the Enter key twice) after typing the centered heading.]*

*[Start your Executive Summary on a new page immediately after your table of contents (or list of figures or tables). The Executive Summary is part of the front matter of the report, and it should therefore have a lowercase Roman numeral page number. Set the heading in 12-point bold, all caps.*

*Note that the Executive Summary is the only section in the report that is typed in single space.* ***The length of the summary is limited to one page.***

*The purpose of the Executive Summary is to give your readers a quick overview of the contents of the final report. As such, it identifies the major ideas in the general order they appear in the report, so that the readers can go directly to a full discussion of these ideas if they desire.*

*Write the Executive Summary under the assumption that it may be the only part of the report some readers look at. Emphasize the important aspects of the problem, your design approach, and the specifics of your solution.*

*A good idea is to write your Executive Summary after you have completed the rest of your report, but do not sacrifice its quality. All too often, students write the Executive Summary at the last minute and give it insufficient attention.]*

ok so the plan is to write this at the end of the report.

Topics:

- What is the CMDVRPTW/carpool problem? why is it hard?

-

**1.0  INTRODUCTION**

*[With line spacing set at 1-1/2, press Enter to skip a line after centered headings only.]*

[

*[The Introduction prepares the reader for the information that is to follow. You may want to write, or at least revise, your introduction after you have written the rest of the report.*

*The Introduction begins by giving the purpose of the report (what the final report is to accomplish), identifying its topic (your design project), and defining your design product solution (what it is that you designed). The important point is this:  Get to the point immediately. You can then provide background information, including identification of the team members and general information about the sponsor. In addition, you should describe how your design project has contributed to engineering knowledge and practice. Finally, the Introduction provides the reader with a brief overview of the organization of the report.*

*The Introduction starts a new page after the Executive Summary. It does not need to be long to be effective. A length from a half page to a single full page will generally suffice.*

*The Introduction begins your first page of the body of the report. Although this page represents page 1 of the numbering system, do not place a page number on this page; only on page 2 and succeeding pages do the page numbers appear in the body text. Note that the first-level heading is centered on the page, set in all capital letters, and designated by a decimal section number (1.0). Skip a line space after the centered heading. The Introduction and all following text take 1-1/2 line spacing.]*

**2.0  DESIGN PROBLEM STATEMENT**

*[With line spacing set at 1-1/2, press Enter twice to skip a line after centered headings.]*

*[This section gives a complete description of your project, including its goals, motivation,* *and requirements. This description should include an explicit statement of the design problem, problem specifications, the design parameters, and all constraints on problem solutions. Provide a general statement of your design approach to the problem and explain early decisions that influenced your approach. Keep the focus on the design path you followed; that is, do not go into details of the alternative designs you considered.*

*Note that this section is again designated by a first-level heading centered on the page. Skip a line (press the Enter key twice) to separate the heading from the previous text. Do not start a first-level section on a new page unless it is necessary. You may use subheadings to help organize information within the section, as follows.]*

**3.0  DESIGN PROBLEM SOLUTION**

*[With line spacing set at 1-1/2, press Enter twice to skip a line before and after centered headings.]*

*[Whereas in the previous section you described the design problem, in this section you describe the design solution. Describe your product (artifact, program, system, etc.) by explaining its underlying theory and its operating principles. Describe the design decisions leading up to your solution and how you implemented them. A brief discussion of alternative designs is appropriate in this section. Emphasize how your solution meets the various problem specifications, parameters, and constraints. Be as explicit in describing areas where your solution fails to meet specs as you are in describing areas where it does.*

*Again, this section may require subsections as previously described. Use figures and tables to support your explanation where necessary.*

*Note****:*** *A technically knowledgeable person should have enough information to understand and judge your solution and its implementation. An economic analysis should be included as part of the project solution. An economic analysis addresses, for instance, cost/benefit analysis.]*

**3.1  Optimizer Framework**

Our design for the optimizers involved a modular approach. We would first create a framework with the sorts of utilities all of the optimizers need. The following are a few of the more important utilities.

A common scoring function was needed to allow us to evaluate the results of the optimizations, as well as compare the different optimizers. Each optimizer returns a solution, which includes a set of rideshares and a set of unmatched riders. We used two criteria for scoring a given solution. The first is the number of users matched, and the second is the sum of the total route lengths over all drivers, taking into account deviations due to carrying riders. Figure 1 details the equation the scoring function uses. The integer part of the equation corresponds to the primary criteria, and the fraction corresponds to the secondary criteria for scoring.



**Figure 1.  Score Equation**

meet the terms

Optimizers would also need to be able to check for compatibility between a Rideshare and an unmatched rider. In order to assert that a rider is compatible with a rideshare, we must , and In order to implement the optimizers,

**Figure 2.  Score Comparison: Bipartite Matching vs. Genetic**

*[Use subheadings as necessary to improve accessibility to the contents of your report. A subheading is aligned on the left and is set in all capital letters. The decimal section designator assures that each section and subsection in the report has a unique designation, which is useful for referencing one section from another.* ***Skip a line space before, but not after, a subheading (side heading).****]*

**3.2  [SECOND-LEVEL HEADING]**

*[If you divide a section into subsections and sub-subsections, you must have at least two subheadings in each level of headings. This preserves the hierarchical organization of your report.]*

**3.2.1  [Third-Level Heading]**

*[You can form a lower level subheading by adding another decimal to the section designator. To give further differentiation from higher level headings, set this third-level heading in bold and capitalize initial letters only. Again, skip a line before, but not after all second-and third-level headings.]*

*Organize your report to avoid fourth- and fifth-level headings. Too many sub- and sub-subheadings confuse the reader and reduce your ability to highlight the organization of the report.]*

**3.2.2  [Third-Level Heading]**

*[Again, for any level of subheadings in a section, there must be at least two subheadings at that level.]*

**4.0  DESIGN IMPLEMENTATION**

*[With line spacing set at 1-1/2, press Enter twice to skip a line after centered headings.]*

[*This section describes the challenges you met and overcame while building your prototype. Explain what modifications you had to make to the original design, and describe any innovations in technique, materials, or design practice that you performed during the prototype construction phase.*

*Sometimes student teams submit reports that contain an excellent analysis of the situation but inadequately explain all of the implications of the chosen solution. Sponsors tend to look for* results *and are appreciative of a well-documented solution. This section describes detailed design work beyond concept generation (that is, the embodiment of the design in a working prototype), and it should refer to appendices that contain parts lists, drawings, prototype construction information, and anything else that might be useful. Summarize the analysis and modeling that you used to predict the performance of your solution. Detailed derivations and calculations should be presented in the appendices. Use good judgment in placing important information (major drawings, analysis, or test data) in the text and less important supporting documentation (parts lists, detail drawings, or raw data tables) in the appendices.]*

**5.0  TEST AND EVALUATION**

*[This section describes the test and evaluation plan that you devised and conducted. Record your results and observations with great care for accuracy. Summarize your results, and show your data. Compare your results against the design specifications. Where do you fall short and why?]*

Once we established the functionality of the optimizers using the corner cases, we used sixteen test cases from the augmented uShip data to test the time and score performance of the algorithms. The data has several properties which are important to consider when analyzing the resulting data.

The first of these is that the data sets increase with the number of users. This ensures that we can measure horizontally over the test cases with a standard measure of the number of users. In addition, all of the test cases contain the same distribution of drivers and riders, which is roughly one driver per two riders. Finally, it is important to note that each test case is independent of the previous one. That is, the users in one test do not necessarily include the users from another test.

With these facts in mind, we now take a look at the test results. We will not discuss the performance of the brute force optimizer in this section, because already at the third test case, it fails to complete execution within a reasonable time frame. If we were to graph the results, they would be off the charts.

In Figure 1, we compare the score results for the bipartite matching and genetic optimizers. The horizontal axis shows each of the test cases 1-16, and the vertical axis shows the score. For the genetic optimizer, we note that the score increases more or less in a linear manner. On the other hand, it seems that the bipartite optimizer has a more irregular pattern, which changes according to the test case. Last, we notice that the ratio of the bipartite matching score to the genetic score seems to be increasing, i.e. bipartite might be “catching up.”

With these observations, we conclude that the algorithms definitely do perform differently on the same data, and that there is a clear advantage to using the genetic optimizer for test cases of up to 120 users. Further, it would be interesting to use larger test cases and determine if these patterns continue or change with the size of the test case.

**Figure 1.  Score Comparison: Bipartite Matching vs. Genetic**

Figures 2 and 3 show the number of users verses time for the bipartite matching and genetic optimizers. Figure 2 shows the time in minutes, whereas Figure 3 shows time on a logarithmic scale.

In Figure 2, we see that the time complexities are somewhat similar for both optimizers. Each of them has several rises and falls in the time. Some of the points seem to show dips in both graphs, but not all of the points are correlated. In addition, it looks like the run time increases rapidly over the first test cases, but slows down and even reverses over the larger test cases. We would need to test further with more data points and larger test cases in order to find a curve for the time complexity, but we can already tell it’s not growing too rapidly.

**Figure 2.  Time Comparison: Bipartite Matching vs. Genetic**

In Figure 3, we take a look at the same data from Figure 2, though we evaluate it on a logarithmic scale. The point of this evaluation is to compare the time complexity of the optimizers to that of an exponential curve. In a logarithmic graph, a linearly increasing graph represents exponential growth.

Sure enough, the first test cases cause what appears to be exponential growth in the amount of time taken, but the larger test cases seem to break this pattern, and follow a flat, fairly steady curve. This is good news, and confirms that our optimizers do run in polynomial time. Again, we would like to add larger test cases to confirm this pattern.

**Figure 3.  Logarithmic Time Comparison: Bipartite Matching vs. Genetic**

In Figures 4 and 5, we compare the final score with the run time for each algorithm. The motivation for this graph comes from the fact that the previous graphs suggested that the time is correlated to something other than the number of users. If each point had the absolute optimal solution, we would expect to see a linear curve for the score.

Bipartite matching seems to have dips in both scales around the same test cases. This implies that the time to complete bipartite matching is strongly correlated to the final score it produces. This result might be due to the fact that bipartite matching runs time consuming compatibility checks more frequently when it has compatible users.

When we take a look at the genetic optimizer, Figure 5, we see what looks like a near perfect linear increase in the score. Therefore, it seems, the genetic optimizer’s time complexity is not correlated with the score it produces. Further, the genetic optimizer seems to be producing a curve which reflects our expectation of a linear increase of the score with the number of users.

**Figure 4.  Run Time vs. Score: Bipartite Matching**

**Figure 5.  Run Time vs. Score: Genetic**

The results from Figures 1-5 tell us a lot about the performance and functionality of our optimizers. We were especially surprised with the irregular increase in the time required by both algorithms, and the linear increase in the score for the genetic optimizer. In addition, we established that our optimizers operate in polynomial time.

The end result, though, is more questions than answers. Can we expect these trends to continue? Will the behavior of the optimizers behave differently with test cases in the thousands of users? We will need to generate more results to test our conclusions.

*[Note that a figure is placed as soon as possible after its first reference in the text, usually at the end of the paragraph in which it is mentioned. If the figure is too large to fit on the same page, then continue the text to the bottom of the page and place the figure at the top of the next page (and tell the reader it is on the next page).*

*Notice that the figure caption is typed in bold and initial caps. Center the caption below the figure and skip a line space between the top of the  figure and the preceding text and between the caption and following text.]*

**Table 1.  [Title of Table]**

|  |  |  |
| --- | --- | --- |
| **Column 1** | **Column 2** | **Column 3** |
| **Category 1** | **345** | **58.99** |
| **Category 2** | **156** | **56.44** |
| **Category 3** | **567** | **24.33** |

*[A table, like a figure, is placed as soon as possible after its first reference in the text, usually at the end of the paragraph in which it is mentioned. If the table is too large to fit on the same page, then continue the text to the bottom of the page and place the table at the top of the next page (and tell the reader it is on the next page).*

*Notice that the table title is typed in bold and initial caps. Center the title above the figure and skip a line space between the preceding text and the title and between the bottom of the table and the following text.]*

**6.0  TIME AND COST CONSIDERATIONS**

*[State whether the project met time and budget constraints. Describe any special problems you encountered that led to schedule or cost overruns and your response to those problems.]*

**7.0  SAFETY AND ETHICAL ASPECTS OF DESIGN**

*[Assess the safety aspects of your project and how your project will address the larger ethical issues of professional engineering practice. Such issues may include danger to human life and limb, possibility of environmental damage, life-cycle recycling issues, and warning notices required for the user. What safety factors were designed into the project? How will your project serve humanity and the public interest?]*

**8.0  CONCLUSIONS AND RECOMMENDATIONS**

*[Your conclusion section is not only the culmination of your paper but also of your entire project. The conclusion recapitulates your achievements, findings, results, and any limitations or shortcomings in your compliance with specifications. The section presents a frank evaluation of how well the final solution meets the project requirements and parameters, as well as any ways in which it exceeds the project requirements.*

*In this section, list any recommendations for further studies or investigations for improving the design.*

*This section (along with the Executive Summary) is the most frequent source of grade reduction. Demonstrate your knowledge. At this point, you should be the expert on your solution. Do not be afraid to make recommendations not directly related to your specific solution. Give your view of the “big picture.”]*

**REFERENCES**

[1].... [First source reference in IEEE format. First source reference in IEEE format. First source reference in IEEE format. First source reference in IEEE format.]

[2].... [Second source reference in IEEE format. Second source reference in IEEE format. Second source reference in IEEE format. Second source reference in IEEE format.]

*[Etc.]*

*[Note that the brackets around each number (unlike the other brackets in this mockup) are required in a list of references. Each listed reference should be single spaced, with 1-1/2 space between references. This section is a listing of all references of source material. (See Item 14 of the General Specifications for Final Reports.) List the references in the same numbered order that they are cited in the text.* ***Note that this section does not have a decimal number; yet, it is a first-level heading.****]*

*[This page is the title sheet for the first appendix. All appendices must have a title sheet, with the title centered horizontally approximately a third of the way down the page. Be sure to give each appendix a descriptive title. No appendix can appear that has not been referenced in the text, and all appendices must be listed in the table of contents. This page receives the page number A-1, and the numbering system continues with A-2, A-3, etc. on the following pages.]*

**APPENDIX A – [TITLE OF FIRST APPENDIX]**

**APPENDIX A – [TITLE OF FIRST APPENDIX]**

*[Repeat the appendix letter and title on the first page after the title sheet. Place an en dash between the appendix letter and title. There are no other requirements for the appendix. Use the space in this appendix for figures, tables, coding technical details, photographs, sketches, or any other type of data that is too extensive or distracting to place in the main text, even though it is relevant and necessary information.*

**APPENDIX B – [TITLE OF SECOND APPENDIX]**

**APPENDIX B – [TITLE OF SECOND APPENDIX]**

*[Same instructions as for Appendix A. This page is the title sheet for the second appendix. This page receives the page number B-1, and the numbering system continues with B-2, B-3, etc. on following pages.]*