IMPROVING MAJOR QUALIFYING PROJECT FORMATION IN THE WORCESTER POLYTECHNIC INSTITUTE BUSINESS SCHOOL

A Major Qualifying Project Report:

submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

Enzo Borges

Michael Levene

Allison Spratt

Submitted to:

Professors: Renata Konrad and Andrew Trapp

Worcester Polytechnic Institute

Abstract

The goal of this project was to improve the Worcester Polytechnic Institute (WPI) Business School's Major Qualifying Project (MQP) formation process. As the WPI Business School grows in size, it was identified by stakeholders that an efficient way to support MQP matching for the growing school was necessary to support team formation. After research into the purpose and formation of capstone projects at other universities and interviews with key WPI stakeholders, the team identified that optimization modeling could support MQP matching in the WPI Business School. The team developed an Excel-based tool with a built-in optimization model that maximizes student project preferences and takes into account factors such as student teammate preferences and team size. This tool serves as a preliminary step that with further modifications can support initial MQP team formation for the WPI Business School.

Table of Contents

Executive Summary

The Worcester Polytechnic Institute (WPI) Business School uses a manual process each year to match each Business School student to a Major Qualifying Project (MQP). The WPI Business school was looking into methods that may improve the MQP team formation process, especially as the school increases in size. An optimization model was created that currently produces teams with an average student satisfaction between 60% and 70%. This report outlines successful optimization modeling techniques and recommendations that could be developed further in order to assist the matching process in the future.

Background

Capstone project formation can be completed using a variety of methods. As each university's programs have their own goals and scopes, project formation will vary across different universities. Many universities have found that optimization modeling can support capstone project team formation. Three existing optimization models were used as inspirations to build from to create a model capable of initial MQP team formation.

Authors	*University*	*Application*	*Need of existing model that may differ from WPI needs*
Magnanti and Natarajan	Singapore University of Technology and Design	Form multidisciplinary teams in the last two terms of the year	Multidisciplinary teams are a must at SUTD
Lopes, Aronson, Carstensen, and Smith	University of Arizona's College of Engineering	Form senior design capstone projects	Preferences of advisors taken into account
Anwar and Bahaj	University of Southampton's Department of Civil and Environmental Engineering	Assign students to groups projects in their fourth year	Team overall GPA is balanced across projects

Table 1: The table provides a summary of the research papers that were reviewed to serve as inspiration to the creation of our model and shows their main differences from the needs of the WPI Business School model.

Objectives and Goals

The overall goal of this MQP was to identify possible improvements to the MQP matching process of the WPI Business School. To do so, the following goals were set:

1. Understand the current MQP formation process.
2. Research existing capstone design and team formation methods of other universities.
3. Review current data collection practices for current WPI Business School student MQP preferences.
4. Developing a mathematical model representative of the project formation process to match students to projects.

5. Implement this mathematical model in Microsoft Excel.
6. Evaluate the effectiveness of the model

Methodology

To identify potential improvements to the WPI Business School MQP formation process, the team conducted interviews with stakeholders, and developed and tested an optimization model on both synthetic data and previous WPI Business School MQP preference survey data. We proposed a model which is capable of using this data to create preliminary teams for review by MQP coordinators. This model can be found in Section 3.6.

Results and Conclusions

The created optimization model was able to take the results of WPI Business School MQP preference survey data, both synthetic and anonymized real data, and match project teams to topics.The synthetic data that was created based on an altered version of the preference survey allocated around 95% of students to their top-choice MQP while staying within the applied limitations.

Results	
Students in Process Optimization	4
Students in Health Care Issues	3
Students in Work Methods Improvement	3
Students in Production Planning	5
Students in Supply Chain Management	5
Students in Information Systems	3
Students in Facility Design and Location	4
Number of Student Groups	7
Combined Preference Score	5000
Maximum Score	5270
% of the Max	95%

Figure 10: A summary of the results from running the model with user-generated data

When the model was run with anonymized student data from the MQP preference survey of 2021 and 2022 (the classes of 2022 and 2023, respectively), the model was able to find an answer within constraints for both datasets. The 2021 data was able to create teams that were accurate to the preferences of each student who filled out the survey's top preference, and the 2022 data could create teams that met the student's topic preference around 84% of the time.

Results		
Year	2021	2022
Total Number of Students	56	40
Students in Manufacturing	8	8
Students in Supply Chain	8	4
Students in Business	3	3
Students in Finance	8	3
Students in Environmental	3	3
Students in Tech	3	3
Studets in Healthcare	8	4
Students in Optimization	8	4
Students in Operations	7	8
Number of Student Groups	15	11
Combined Preference Score	3900	2400
Maximum Score	3900	2850
% of Max	100%	84%

Figure 14: 56 Students were considered in the data 2021 data and 40 students were considered in the 2022 data. The number of students matched to each project topic, the number of student groups, and the preference scores are also shown.

When used with suggestions for the MQP preference survey deployed to students, the model can be used as a basis for further exploration of using optimization modeling in the MQP formation process.

1. Introduction

Worcester Polytechnic Institute (WPI) is internationally recognized for its research and its project-based learning and applications of its curricula to the professional world (The New England Council, 2015). Each WPI student is required to complete a capstone project called the Major Qualifying Project (MQP) as part of their degree requirements. In 1970, WPI faculty voted to implement this requirement as an integral part of the "WPI Plan", the rigorous and project-based model of undergraduate learning that WPI uses, which positions students to stand out in the applicant pool after they graduate (Looft, 2008; The WPI Plan, 2021). Each student must complete an MQP related to their major(s), and each project must be advised by at least one advisor in their major's discipline. This project experience is one that places WPI on leaderboards for undergraduate senior capstone experiences in surveys of American universities (Colleges With Great Senior Capstones, 2021). The MQP fulfills the criteria for Accrediting Engineering Technology Programs (ABET) (Looft, 2010), which ensures that a university program "meets the quality standards of the profession for which the program prepares graduates" (ABET Accreditation, 2021). The MQP is an opportunity for upperclassmen who have completed certain educational requirements to connect in project teams with professors, industry, and other educational institutions locally and abroad to complete a project that applies degree-specific theory to practice. A successful MQP "demonstrates how to communicate effectively; understand the scientific, social, and ethical dimensions of the problem; and demonstrate knowledge appropriate to the specific major" (Major Qualifying Project, 2021).

The purpose of the MQP project is a professional design project or a research experience. Students often have the ability to choose their groups, request certain professors to be their advisors, and even create their own project. Project partners, referred to as sponsors, typically include businesses, nonprofit organizations, or government agencies. Projects can also be directly involved with WPI faculty research. Faculty and sponsors are also invested in the MQP process, as advising these projects are part of the faculty teaching responsibility, and sponsors may use these projects to find potential hires and engage with their community.

The process of selecting teams and assigning MQPs, or the MQP matching process, is not standardized and varies greatly between departments. Some departments at WPI, such as Electrical and Computer Engineering (ECE) and the Biomedical Engineering (BME) departments, have centralized methods and processes to advertise MQP project topics available to students on the WPI website by advisor or by sponsor (*BME Major Qualifying Project*, 2021.; *ECE MQP Advisors*, 2021). In contrast, the WPI Business School does not have a comparable method or process. The lack of a standard MQP matching process at WPI is further complicated as the process also needs to cater to interdisciplinary students and projects. As new challenges with the MQP team matching process arose during and as a result of the COVID-19 pandemic, departments have needed a process that will be deployable and flexible under a variety of circumstances.

Opportunities exist to improve the matching process between students and MQPs in the WPI Business School. This project was formed to address concerns from the WPI Business School about matching students to MQPs, and the variability in the process each year. The **goal** of our MQP was to identify improvements to the MQP matching process in the WPI Business School. We proposed a new systematic method to facilitate the matching and selection process that is applicable to the WPI Business School. The team deliverable was a new method of MQP matching using optimization modeling and a set of recommendations regarding communication around the MQP formation and matching process.

To accomplish our goal, we set and accomplished the following **objectives**:

(1) Understand the current process. We conducted faculty interviews to understand and map the existing process for MQP team formation in the WPI Business School, as well as other departments at WPI. This allowed the team to understand the current state of the process and begin to identify areas for improvement. To document the research, a process map and fishbone diagram were made to outline the current WPI Business School process, as well as identify issues with the current process.

(2) Research existing capstone design and team forming methods from other universities. To create an effective solution for WPI's needs, it is worthwhile to identify how other schools and organizations address the team formation problem. By researching existing solutions, the team gained valuable insight on how to address the identified needs of WPI's MQP formation. The team identified multiple external models that perform a similar function and use those models as a starting point for generating a solution approach for WPI.

(3) Review current collection of relevant student data. Revise and create additional questions to be included in the annual WPI Business School MQP survey of junior students to collect relevant data and can be easily manipulated within Microsoft Excel. The present survey yields results that are non-standardized, and incomplete representations of student preferences.

The goal of the new survey is to design an efficient method to extract specific data regarding student preferences, and in a format that is easily transferred to the model.

(4) Develop a mathematical model to match students to projects. Develop a model representative of the project formation process. Organizational constraints served as the starting point for developing the model and needed to be identified. Documenting the objective function, decision variables, and constraints in written English, as well as in mathematical terms, allowed the team to create a model that accurately represents the constraints and satisfies the requirements of the model.

(5) Implement the mathematical model in Excel. The optimization model developed needed to be implemented into OpenSolver, an Excel add-on. This interface could use data gathered from the redesigned survey, and was able to solve a mathematical model to meet stakeholder needs. The model will ideally serve as a baseline model for further extension to viably supplement, or eventually replace, the current MQP team formation process to increase stakeholder satisfaction and most importantly, ensure that all students are accounted for when teams are being formed. The model aims to maximize the preference scores of the students based on results from the survey.

(6) Evaluate the effectiveness of the model. We conducted analysis on the results of the model using the simulated data and the data provided by the existing WPI Business School survey. This included creating recommendations for future work, as well as how to manage the

data provided from the WPI Business School. The analysis summarizes the effectiveness of the optimization model and highlights its strengths and weaknesses. The recommendations are documented for future WPI Business School projects or MQP formation use.

2. Background

This section describes the importance of capstone projects and how they benefit undergraduate students' learning outcomes. We investigate how optimization methods can complement the senior capstone matching processes. Finally, this section highlights the existing process of the WPI Business School to form these MQP teams, and some challenges faced by faculty and students during the process of matching students to MQP teams.

2.1 The Importance of Capstones and Senior Projects

The objective of any capstone project lies in putting into practice what a senior-level undergraduate student has learned in class or through research. Undergraduate research has a high impact on the result of undergraduate outcomes, as capstone projects specifically foster independence and professionalism among students (Dowd et al., 2015). Such professional research opportunities also allow undergraduate students to apply field-specific knowledge and have been shown to improve critical thinking and peer-reviewing skills (Dowd et al., 2015). These peer-reviewing skills are seen to benefit both the outcome of the multi-semester projects (Weaver et al., 2016) and the outcome of the overall scientific literacy and skills in writing used by the undergraduate students (Geithner & Pollastro, 2016). A significant part in any capstone project is report writing. Using writing skills to provide evidence to prove a thesis has been shown to improve student academic outcomes and quantitative abilities when these writing skills are utilized over a multi-semester capstone series involving analytical research (Weaver et al., 2016).

Individual characteristics of STEM undergraduate students, including their personal dispositions, motivation, and intrapersonal competencies, are impacted by their learning and professional experience. These characteristics, when measured over time across a sample of students at six universities throughout the United States who undertook STEM-based capstone thesis writing courses, were shown to have a potential causal relationship to improved outcomes in positive learning dispositions (Dowd et al., 2019).

At WPI, efforts have been made to improve project opportunities for students. A 2014 MQP looked to improve sponsored projects at the school and found that the use of personal connections among project sponsors, professors, undergraduate students, and alumni connections within the WPI community was often the aspect that created the availability of sponsored projects (Angeliu et al., 2014). The capstone project improves learning outcomes, quantitative and analytical abilities, writing skills, and motivational outcomes for undergraduate students.

2.2 The Design of a Project Matching Processes

Various strategies and processes exist to match students and capstone projects. An important aspect to consider during a matching process is the team composition and overall satisfaction of the students within the group. Teammates with complementary strengths, goals, and work styles are likely to have a positive team project experience (Pearlstein, 2021). Pearlstein's (2021) study explores the benefits of professor-formed teams versus student-formed teams for capstone projects within the Stockton University Business School. The study found that professor-formed teams saved time and reduced stress on students, but students were discouraged that they were left out of the decision-making. For student-formed teams, the process took much longer and some students were left out because most groups were formed based on social connections (Pearlstein, 2021). The experimental process aimed to combine the two former processes to extract the benefits from each. First, each student was required to make a 2-minute presentation about themselves to their classmates. This ensured that everyone in the class had a unique opportunity to introduce themselves and a chance to learn more about their classmates. This process is conducive to both face-to-face and online formats and supports all students, including those who may not have preexisting social connections with their peers. Next, the professor selected the top students to act as Interview Leaders and conduct short interviews of each of their peers. The interviews are meant to be beneficial to both people as the Interview Leader is able to explore the strengths and goals of their peers, meanwhile the interviewee is able to identify if the Interview Leader is someone with whom they would like to work with. The Interview Leaders were seen as crucial to the process because they guaranteed at least one strong student per team to ensure balance, and also allowed the students to facilitate the team formation. Throughout the interview process, each student completes a worksheet in which they eventually rank their peers and other preferences. The final step is when the professor collects the ranked worksheets and begins forming teams. For this case, the process was entirely manual and based on factors such as giving each student their highest choice possible, giving Interview Leaders their first choice, and pairing outliers who were rated at the bottom. Lastly, the professor is able to calculate an average rank and share that confidentially with the students if they choose to do so. Pearlstein notes, “This helps students and professors strategize ways to improve their interviewing skills, as well as understand why they may not be working with their first choices” (Pearlstein, 2021). At the conclusion of the experiment, over 70% of the 279 students who completed the surveys mentioned that they preferred the experimental method over professor-formed and student-formed teams. It is evident from this experiment that the majority of the Business School students preferred to know more about their peers and have a voice in the team formation process. There is a limitation to the extent of empirical evidence of potential generalizability of it to other departments because this experiment has only been tested on a capstone business course. Although this process is time-consuming, the tangible benefits could certainly be seen if a similar process was utilized in smaller departments at WPI, especially within the Business School.

A different process was used to match senior capstone teams at Eastern Washington University in which a linear programming approach was utilized to reduce lead time in forming groups. Previously, students at this university would submit their top five choices of project, and faculty would manually group students into teams which was reported as “time-consuming” and “ineffective” (Michaelis & Bae, 2019). In response, a mixed-integer linear programming was developed to optimize the team formation process. The length of the process was reduced from two days to less than an hour. Given that project choice and reduced lead time for team formation are possible areas for improvement in the current WPI MQP process, this case highlights the potential benefits of using a similar model. It is important to note that the MQP matching process is more complicated than simply forming teams, due to other variables such as advisors, projects, student majors, and faculty and undergraduate interests.

2.3 Optimization Modeling

A project matching process can be considered as a mechanism that has many different working parts, or systems, to achieve the goal of successfully matching students to their desired choice of project. When considering a process that has many decisions, making optimal decisions is complicated especially if they are constrained by predetermined factors (Diwekar, 2020). One way to achieve optimal results while meeting specified conditions is through optimization methods. Practical situations that contain systems, such as with project matching processes, may be represented as mathematical models which contain a function that maximizes the desired benefit (Rao, 2019). With such a representation, a project matching process could be modeled as an optimization model once a suitable objective function is identified.

Other universities report using optimization to match students to capstone projects. For instance, Singapore University of Technology and Design adopted a discrete optimization model to match seniors to capstone projects and found that 78% of students were assigned to their top three project choices (Magnanti & Natarajan, 2018). As mentioned earlier, Eastern Washington University adopted a mixed-integer linear programming optimization model to match a group of 230 seniors to projects and using this model found that 74% of students were given their top project choice while 94% of students were given one of their top three choices (Michaelis & Bae, 2019).

Each project matching process is unique due to different project objectives, varying university cultures, and different needs between departments. As such, existing mathematical optimization models can only motivate, but not be applied to, the WPI case and will require a unique mathematical representation. Table 1 summarizes the findings of the three studies using optimization approaches to form capstone project teams, and illustrates why the approach cannot be applied to WPI. Learning about the construction of their models was insightful to create our own model. The three studies are:

(1) A 2017 paper by Thomas L. Magnanti and Karthik Natarajan titled "Allocating Students to Multidisciplinary Capstone Projects Using Discrete Optimization" discusses the use of

discrete optimization modeling in the formation of capstone teams through constraints reflecting the bounds of the many-to-one matching problem. The authors write about the Singapore University of Technology and Design (SUTD), and their recently deployed model used to match students to multidisciplinary capstone teams. The main difference from our model is that multidisciplinary teams were an obligated criteria for SUTD.

(2) “Optimization Support for Senior Design Project Assignments”, by Leo Lopes, Meredith Aronson, Gary Carstensen and Cole Smith from 2008, discusses the creation of a mixed-integer program (MIP) for the formation of students to the University of Arizona’s College of Engineering capstone projects (Lopes et al., 2008). The main difference from the created MIP from our model is that advisors’ preferences for specific students were used as inputs and were considered.

(3) “Student project allocation using integer programming” by Arif A. Anwar and AbuBakr S Bahaj from 2003. Using the University of Southampton’s Department of Civil and Environmental Engineering for application of their model, the paper presented an approach that used mixed-integer linear programming that uses an objective function and defined constraints to explicitly define their problem of student matching to capstone projects (Anwar & Bahaj, 2003). The main difference from our model is that they balanced the overall GPA between all student teams.

Authors	*University*	*Application*	*Need of existing model that may differ from WPI needs*
Magnanti and Natarajan	Singapore University of Technology and Design	Form multidisciplinary teams in the last two terms of the year	Multidisciplinary teams are a must at SUTD
Lopes, Aronson, Carstensen, and Smith	University of Arizona's College of Engineering	Form senior design capstone projects	Preferences of advisors taken into account
Anwar and Bahaj	University of Southampton's Department of Civil and Environmental Engineering	Assign students to groups projects in their fourth year	Team overall GPA is balanced across projects

Table 1: The table provides a summary of the research papers that were reviewed to serve as inspiration to the creation of our model and shows their main differences from the needs of the WPI Business School model.

The research by Lopes, Aronson, Carstensen, and Smith, specifically, will help us to create the mathematical formulation of our model. For example, every student must be assigned to exactly one project (Constraint 2, Section 3.4) will be the same as one of the constraints used by Lopes, Aronson, and Carstensen, and Smith because it logically fits well in our model. However, our final mathematical formulation differs significantly from our inspirations due to the differences between the context and goals of each case study. Some differences in the model needs from potential needs of the WPI model are listed in Table 1.

2.4 Identifying How MQP Teams are Matched in the WPI Business School

The WPI Business School offers four Bachelor of Science majors: Business, Industrial Engineering, Management Engineering, and Management Information Systems (MIS). There are also six available minors open to any undergraduate student at WPI: Business, Entrepreneurship, Financial Technology, Industrial Engineering, Management Information Systems, and Social Entrepreneurship. Students of these majors and minors "use the powerful combination of business and STEM to derive impressive, stakeholder-driven outcomes" (WPI Business School, 2021).

Interviews were held with three professors who play various roles in the WPI Business School to gain an understanding of the formations in all departments of the Business School. The purpose of the interviews was to explore the perspective of the school's administration of how the MQP teams are formed, especially with the number of departments within the Business School. The full list of questions used in these interviews is found in Appendix A. The professors interviewed are Professor Diane Strong, Professor Sharon Johnson, Professor Adrienne Hall-Phillips, and Professor Walter Towner.

Our first interview was held with Professor Strong, the Department Head of the Business School and professor of MIS and Data Science. Professor Strong has many years of experience in an advising role for MIS students, as well as matching MIS students to their MQPs and advisors. The procedure she spoke of is done by pulling a list of all students completing the MIS degree and identifying students who will be eligible for a MQP in the following year. It is important for her to forecast the number of eligible students in the following year because that gives the department more time to ensure there is enough faculty to advise all of the students. At times, there are circumstances that require a faculty member, such as Professor Strong, to reach out to the appropriate parties and ensure that those students will be eligible before the MQP begins. Typically, eligible students for the upcoming year have completed an Interactive Qualifying Project (IQP) and have sufficient scheduled credits to become a senior. By validating students' eligibility, the department knows the number of students and faculty that will be participating in a MQP each year. This is the first step in ensuring that students are accounted for and the matching process will go smoothly.

A second interview was conducted with a WPI Business School professor, Sharon Johnson, who plays two roles in the MQP process: both as an advisor to MQPs, and as director of the Industrial Engineering program. To begin the MQP matching process, she sends out at least one survey to the existing junior class of the WPI Business School in January or February of the year preceding the school year that the projects would be completed. Professor Johnson bases many of her matching responses on the interests the students mention in the survey. This Qualtrics survey includes questions regarding the students' majors, concentrations, technical interests, whether they have any individuals they would prefer to work with or if they have a team already formed, and if they would like to request to work with a particular professor. As some teams and advisors are already formed at the time this survey is sent out, Professor Johnson is able to go through the partially formed teams and students without existing teams and begin to form tentative MQP groups. Next, students are contacted to gauge their interest in working on these particular tentative projects and teams. At the same time, she is also reaching out to different faculty to gauge their interest in advising different projects and teams. Much of this work for the 2021-2022 project year was done through Microsoft Excel in the weeks after responses came back from the initial survey. However, it was noted that each year the process is done slightly differently. In 2021-2022 MQP formation, Professor Johnson found that fewer students formed their own teams compared to previous years and attributed the anomaly to the remote nature of collaborating during the COVID-19 pandemic. It was noted that in the past, the majority of students formed their own teams, and much of the process of project matching was based on finding an advisor and project for the team. Professor Johnson also mentioned that the Business School has become a much more centralized system in terms of MQP team formation in the last five years, but there are some aspects that are still decentralized such as individual professors meeting with students to plan projects or vice versa as opposed to the heads of the department assigning projects to professors and teams.

We also interviewed Professor Adrienne Hall-Phillips, the director of undergraduate programs and professor for the Business School. The MQP matching process within the WPI Business School begins with a meeting between faculty and juniors between January and February, which is during WPI's C term academic period. The meeting is made to further educate WPI Business School students about MQP formation. Similar to Professor Johnson, Professor Hall-Phillips notes that a survey is sent to students between January and February to learn about students' preferences. Students are then split up by majors. While this is happening, Professor Hall-Phillips contacts faculty from the Business School to learn who is available in the following year to advise and co-advise projects. Professor Hall-Phillips mentioned that in most cases, there are enough existing projects for students. If there was a scenario in which there would be more students than projects to be assigned, faculty would reconvene to create new projects and ensure all qualified rising seniors have a MQP for their next academic year. In addition, she stated that the use of an online portal, such as eProjects 2.0, to showcase projects is a welcomed idea. Advisors would be able to post projects and their descriptions while students would be able to explore their opportunities better and filter their options by major and project topics.

An interview was also held with Professor Walter Towner, a professor of Industrial Engineering in the WPI Business School. Professor Towner was in charge of MQP matching for the WPI Business School when he first started teaching at WPI, before Professor Hall-Phillips and Laurie Stokes, the Associate Director of Business Programs, became the team leads for the MQP formation process. Professor Towner outlined the process he used to form MQP teams, which included hand-writing names of students on a whiteboard in his office and forming around twenty MQP teams of the forty to sixty existing students of the WPI Business School. As the Business School grew in size, writing the names of students by hand was no longer a viable option for forming MQP teams. This was when the formation of teams began to happen on online documents such as Excel sheets for ease of use with a larger scale of students. Professor Towner also expressed that as the WPI Business School grows, it may become even more important to showcase at least “a list of what the professors are interested in” (Towner, Walter).

The team also interviewed two individuals involved in the MQP formation process from departments at WPI outside of the WPI Business School. Professor Kristen Billiar, the head of the Biomedical Engineering department, described a day where potential advisors pitched available projects to the students of the department. He noted that although this process allowed all of the students of the department to view a description of each project and hear from the individuals advising the projects, students and professors often noted that this process was time consuming for both the students and professors involved. He also mentioned that many of the bottleneck points in the process involved the manual steps of putting teams together and the time involved in communicating with everyone involved. The Biomedical Engineering department also uses a spreadsheet to manually match preliminary MQP teams. The team also interviewed the MQP coordinator of the Computer Science department, Professor Robert Walls. Professor Walls explained that the Computer Science department also holds a project opportunities meeting for students to hear from advisors about the available projects, but mentions that not all of the available projects are pitched during this meeting as some professors prefer to pick individual students for their projects. He mentions that in the Computer Science department, professors are also free to choose their own process of team formation and which projects and students they choose to advise.

From these interviews, the steps in the existing MQP matching process in the WPI Business School were outlined in a process map. Figure 1 outlines the major steps in the existing MQP formation process in the Business School. The steps that the Business School is responsible for are shown in red, and the steps where faculty are waiting for student responses or awaiting student decisions are shown in blue. Steps preceding or which are the result of the process are shown in purple. The steps in the process map that may need to be repeated multiple times occur in the months of March to April, when tentative teams are sent to both students and advisors, and both students and advisors must agree to a tentative team before it is finalized.

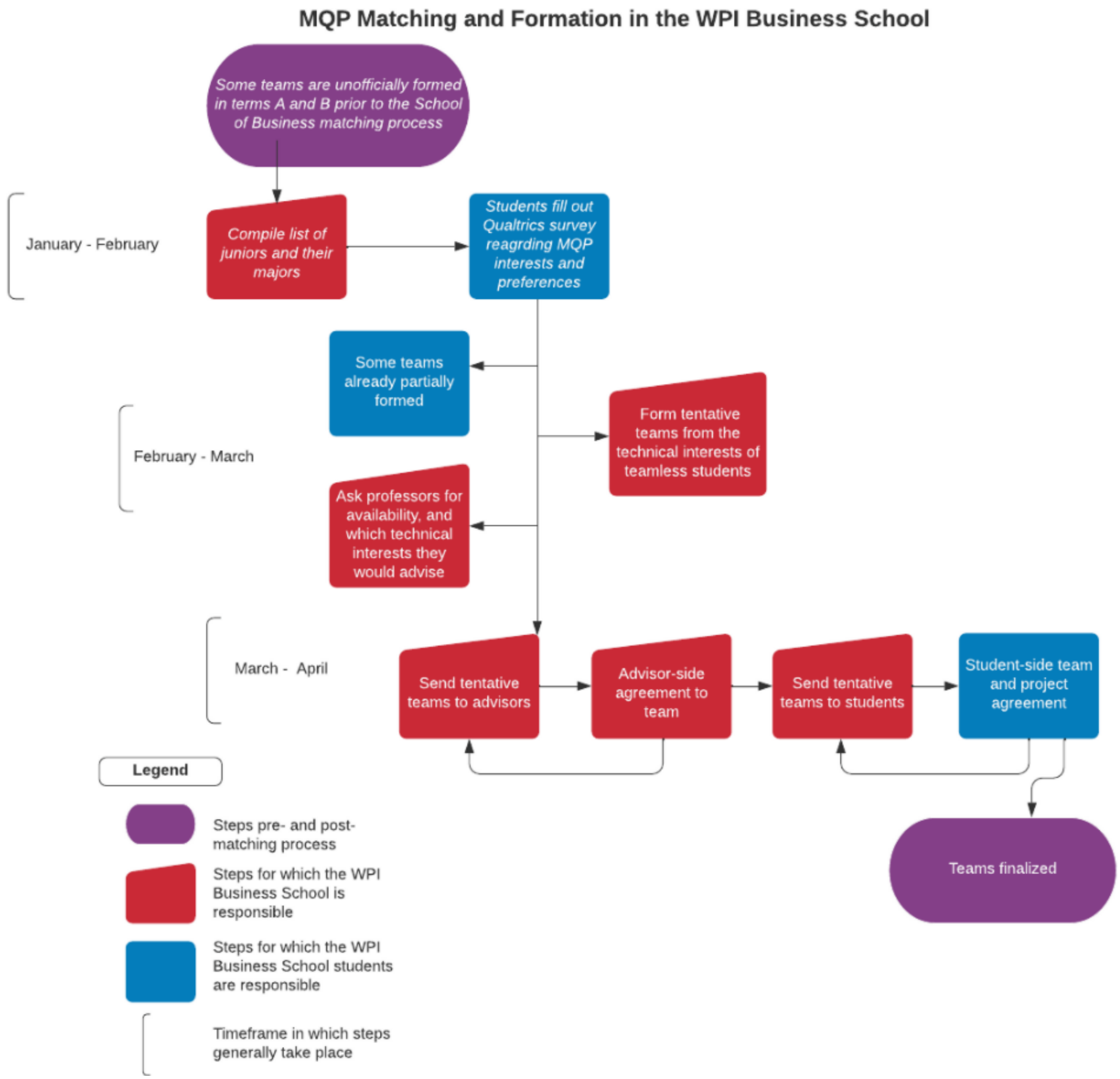

Figure 1. The existing process of MQP matching and formation in the WPI Business School.

This process map does not account for students participating in what is called an 'off-campus MQP' at one of WPI's Project Centers. These students apply to a project center in the November preceding the academic year in which the off-campus MQP is to be completed (*Major Qualifying Project (MQP)*, 2021). The process map excludes students who are interdisciplinary students outside of the Business School; those who do not have an MQP by D term of the year preceding the year the project is to be completed; and those whose project plans shift during the summer preceding their project year.

2.5 Challenges with Existing MQP Formation Process in the WPI Business School

The current process for forming MQP teams and matching students to advisors and projects is considered by faculty to be unstandardized and inefficient. The first main problem arises before the matching process begins. Some students may not be even aware they are responsible for identifying MQP opportunities, forming teams, and speaking to advisors. This lack of awareness means that some students will miss the meeting in the WPI Business School that takes place each C term to introduce the MQP and deploy the MQP survey. As a consequence of not filling out the survey indicating their preferences, students will be placed in a team that may not be of their preference. Such an assignment could complicate the matching process because students may attempt to switch teams or switch projects at a late date.

The second issue is that currently no central place exists to showcase projects and present advisors to students across all departments. The WPI Business School has previously discussed using eProjects 2.0 to allow students to explore project options. eProjects 2.0 is a website that serves as a portal to facilitate the process of students selecting projects and advisors creating projects. It is currently used by some WPI faculty to explain what a project has to offer. The WPI Business School has no established procedure to use this resource.

The third issue that exists before the matching process begins is that each student has an individual academic background. There is a need to assess the extent to which students have met the required criteria and are able to work in an MQP group. This is useful information to the WPI Business School because it serves as a way to forecast how many students will require projects to join. Program staff in the School's department must manually review rising seniors' academic records to ensure that the students have (i) taken their core major-related courses and (ii) completed their IQP. If a student has not met these two criteria, a member from the Business School must directly correspond with the student to assess their plan for graduation. This academic background check procedure and follow-up communication with students may take extensive time.

From the interviews conducted with faculty, the team found that the WPI Business School survey does a reasonable job at gathering student preferences; however, it was noted by Professor Hall-Phillips that a more categorical output of data from the survey could make the management of student data more efficient. The manual process of matching students was also described by Professor Strong and Professor Johnson as time consuming, especially as communication between students and advisors is prolonged by groups of students talking to many different sets of advisors, often leading to confusion among students and advisors as to which student teams are paired with which advisors.

Once survey results are collected and the matching process begins, there can be cases in which students may choose to change projects, resulting in department members having to shift team members. In other circumstances, projects may possibly get canceled or postponed for reasons beyond students' control, such as new initiatives in the sponsoring organization. When this happens, advisors provide a new project to the respective team. Such changes can result in lengthy email exchanges between students and people who are responsible for the matching process. Students may also be slow to respond to emails sent by faculty members, or may be traveling abroad for IQP during the MQP planning period and not responding to email. Furthermore, there could also be difficulties when handling data of group members' structure and their project topics, as there is not a standard procedure established by the Business School.

Students may also be mistakenly left out of the initial matching process. According to the interviewees, it has been observed that this tends to be the case for students who have multiple majors or are part of a major that has a smaller department. In this case, the student would eventually still be given a project and would be accommodated to a proper team. However, it is still a bottleneck that can slow the matching process.

Another large concern with the MQP matching process is that students and faculty are not working on projects that are of interest and inspiration to them. Most departments at WPI have different methods to collect data from students and advisors about their preferences and areas of interest, as there is no standard method established by WPI. For students, preferences typically include the ability to express interest in working with certain peers or advisors. As informative as this data could be, if it is not processed correctly, it will yield poor MQP matching for students. To make data-supported decisions, this part of the process has to have clear data points that are necessary for matching and all departments should gather data relevant to their program. For instance, for each student it would be beneficial to establish the general topics of interest, the advisors they hope to work with, and the students they would prefer to have on their teams.

Figure 2 outlines a fishbone diagram of the challenges identified over the course of team formation. The diagram highlights pain points throughout the current process and provides details about specific issues that arise for each part of the process.

The main issues identified through faculty interviews are: the lack of a project list or project topic list for a student to use to search for an MQP; academic background checks; students not responding to the MQP survey at all; matching students with other students and with advisors; accommodations that may need to be made; and changes that may occur after project teams are formed.

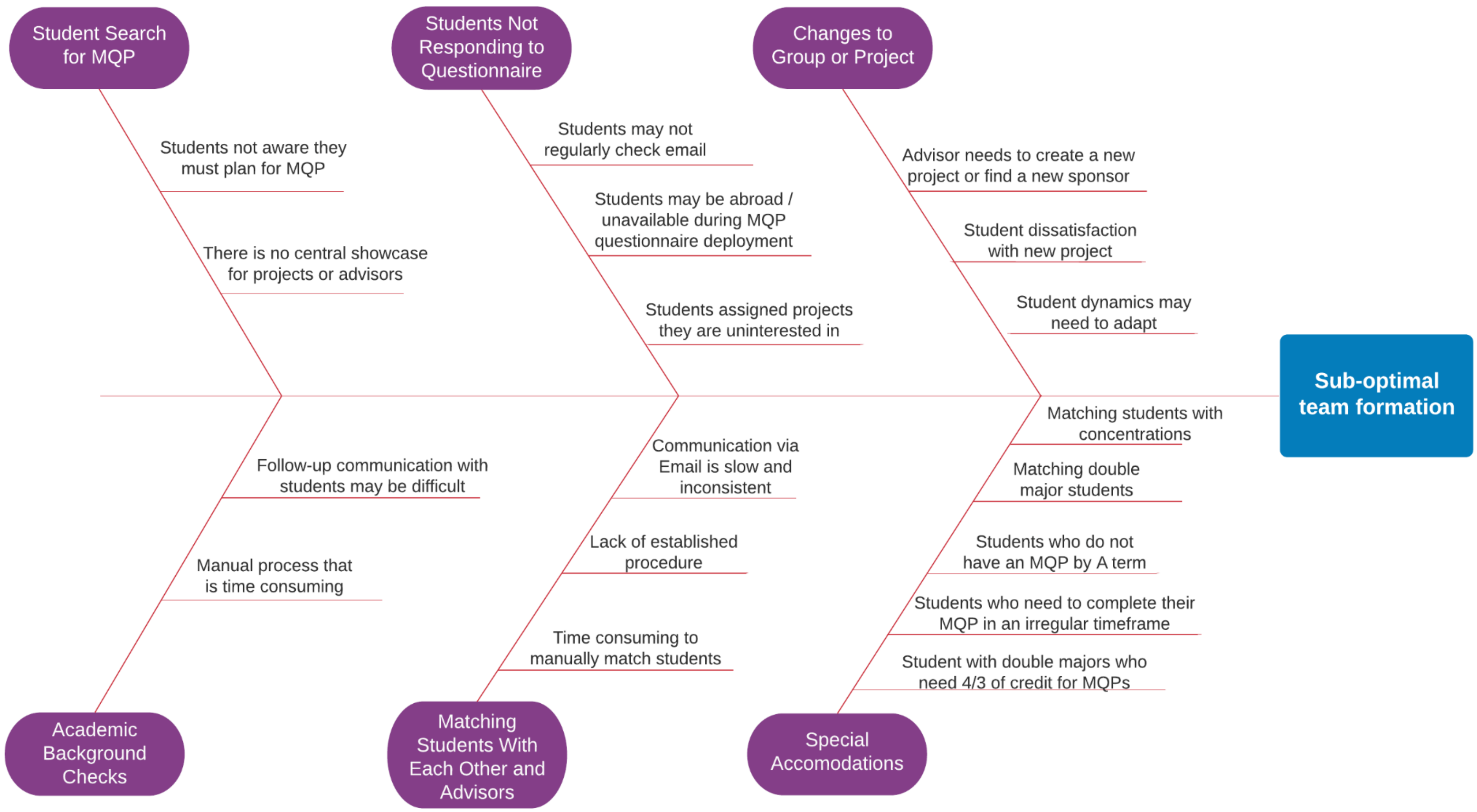

Figure 2: Issues that can be found during the process of MQP matching and formation in the WPI Business School

3. Methodology

This section features the methodologies that were used by the project team. Standardized, open-ended interviews with faculty were used to gain more information about the MQP matching and formation process, and the existing survey the WPI Business School utilizes to learn about student MQP preferences was evaluated and redesigned for use in an optimization model. The goals of our optimization model were established based on these steps. In addition, a set of assumptions were outlined to help define the scope of the model. The optimization model was created based on these constraints, and data was generated for the model.

A Gantt chart, available in Appendix C, was used to ensure tasks were completed on time. The A term section of the chart details in which weeks the goals of the project were created and background topics were researched, and when interviews with professors of the WPI Business School took place. Throughout this term we also created the MQP formation process map for the WPI Business School and identified bottlenecks in the process. We completed the term with the creation of the project background and methodology, and the team wrote out the constraints that would be needed in an optimization. In B term, the team finished up the interviews with professors and began to create and prioritize mathematical model constraints. While developing this linear optimization model, we also evaluated the existing survey to the WPI Business School that is used to collect project preferences from students and created suggestions based on the possible inputs to the developing optimization model. From the suggestions to the model, mock data was created and run through the model. Analysis of this data was done, and the methodology was updated as the project progressed. In C term, we continued to update the methodology and recommendations to the WPI Business School. After receiving the WPI Business school data and anonymizing it, this data was run in our model. We made adjustments to the optimization model based on the analysis of this survey data, and edited the model for ease of use. Finally, we wrote up our results and analysis and prepared the presentation. The full Gantt Chart is available in Appendix C.

3.1 Interviews with the WPI Business School

The team first interviewed stakeholders in the WPI Business School to identify issues in the current MQP formation process. The team used interviews to further understand the process and identify possible issues and bottlenecks involved in team matching. This allowed us to produce an accurate and detailed account of the process undertaken by the faculty and staff of the WPI Business School. The team first interviewed individuals from the WPI Business School in the areas of MIS, Data Science, Marketing and Consumer Behavior, and Industrial Engineering. The interview format was a standardized interview with a fixed list of twelve questions, conducted in an open-ended style to facilitate conversation between the interviewers and interviewees. This allowed the information gathered from the interviews to be sorted and compared using Microsoft Excel. The interviews were conducted on Zoom, and recorded with interviewee permission to be transcribed for reference and analysis. The list of interview questions asked can be found in Appendix A.

The team initially interviewed Professor Diane Strong, Professor Sharon Johnson, Professor Adrienne Hall-Phillips, and Professor Walter Towner. Each professor was interviewed with a list of questions which included the key steps in the formation of MQP teams and any deadlines associated with these steps, the biggest difficulties in team matching and formation, the value of the MQP, whether it is required for professors to advise MQPs, and the practicalities of professors posting project descriptions on eProjects 2.0.

3.2 Interviews with other WPI Departments

To gain perspective on how MQP teams are formed in departments that operate differently than the WPI Business School, the team also interviewed professors from the Computer Science (CS) and Biomedical Engineering (BME) departments. These departments were chosen for their difference in size compared to the WPI Business School to determine if there was a correlation between the size of the department and the process of forming project teams. In addition, the interviews with other departments sought to identify strengths and weaknesses in other project formation strategies that our team would be able to take into account when forming our own strategy. The same question set used for the interviews with the WPI Business School faculty were used for the interviews with the CS and BME departments.

While speaking to various department heads, the team learned that there are significant differences in the way teams are formed. In the Computer Science department, for example, there is a project pitch day where the professors have the opportunity to pitch their available projects to all of the students. Even more unique is that the professors of this department determine what their projects are ahead of time and are able to attract students who are interested in those specific projects, whereas in the Business School, the students are choosing an advisor based on a larger category of topics that they advise rather than specific projects. Furthermore, in the CS department, the students then meet with the advisors of projects they are interested in and the advisors will typically conduct an informal interview with the student.

3.3 Evaluating the Existing Business School pre-MQP Survey

Our team restructured the Qualtrics survey sent to WPI Business School students with two goals in mind. The first goal was to redesign the questions so that the data from the survey is more categorical. For example, instead of students typing out the names of faculty they may be interested in working with, the survey has checkboxes for all of the available faculty. This will provide data that is far easier to sort and manage compared to allowing students to type their own responses. It eliminates the risk of a student misspelling a name or inputting advisors that may not be available for the upcoming year. The second goal was to change the format of the questions so that the answers to the survey result in a data structure that is convenient to use in the model. By redesigning the data outputs of the survey, the team streamlined the process of grouping students based on the success criteria of the faculty and department. Although the current data structure is sufficient for manual matching by department heads, the data is challenging to format for our model. These difficulties are further explored in our analysis of the data received from the 2022 survey.

3.4 Optimization Model Goals

This optimization model was created with the intent to fulfill certain criteria, such as allowing students who wish to be partnered with each other to do so, and to ensure that the model fairly weighed each student's preferences in regard to topics. To achieve this, a few key assumptions were used to make this initial model. The full list of assumptions is included in Section 3.5. We also did not yet model for differences in majors or the additional majors outside of the WPI Business School that may take part in or be required for specific projects the WPI Business School creates. We also made the model to ensure that individuals who want to work together are assigned together to be able to do so, and set team size between lower and upper bounds, which in this model was taken to be between 3 and 5, respectively.

To begin building the model, we wrote criteria to reflect the goals of the model. We decided on the general objective To be as comprehensive as possible with the model and constraints covering all eccentricities, while writing a descriptive paper detailing the model. We developed an Excel model to represent the results of this thought experiment, resulting in actionable items as well as feedback and recommendations for the WPI Business School to use for the improvement of MQP team formation and matching.

The following goals were set:

1. Analyze the current process to develop soft constraints that allow the matching process to be more flexible and easily fine-tuned. For this type of optimization, the weights will need to be partitioned in a way that accurately reflects the needs and desires of students, faculty, and the department. Typically the MQP coordinator is able to decide what is most important when matching the groups and using this model should be no different. Easy to understand sliders and adjusters can intentionally partition the weights of the model the way the MQP coordinator sees fit.

2. Create the model with the ability for the MQP coordinator to manually interact with the model in such ways as assigning partners, projects, and group sizes that can remain locked throughout the model. When running the model, certain aspects could be altered given certain circumstances such as adding an additional member or advisor to a group

that is already formed. However, predetermined teams should not be split apart or receive new topics unless a manual change is conducted after the model arrives at a solution.

3. Create a dashboard in Excel that is easy to understand for the MQP coordinator to manipulate the results in real time. Automate the dashboard as much as possible so that the dashboard is intuitive for the coordinator and requires little training to use.

4. Finding an exact assignment will likely be near impossible, rather, by setting upper and lower bounds for acceptable solutions the model will be able to identify high quality solutions with less manual intervention. Flexible solutions will allow for a larger range of solutions, which will greatly benefit the MQP coordinator when selecting what they think is the best solution.

These goals allowed for the model to be adjusted based on changing topics, student preferences, and to be used by any individual with little training. Despite these goals, it is still important to allow the MQP coordinator to make the final decision even if it is “suboptimal”. The matching process has always had a very personal touch within the Business School and it has become clear that some of that must remain in the system. The MQP coordinator will retain the right to manipulate teams as done in the past at any point in the modeling process.

3.5 Model Assumptions

Before creating the model, a series of assumptions were made to define the scope of the model. The following list of assumptions were derived from information gathered in interviews and recommendations from stakeholders.

1. All students will complete a traditional, three term MQP throughout A, B, and C term. The majority of students complete MQP in this timeframe, so the model will operate assuming that any student can be placed on any of the teams. The model does not account for students that seek or require an alternate MQP duration, so the person forming teams will need to manually address those students. The survey that is sent to students will ask whether they are completing a typical three term MQP and it will be very clear which students will need to be dealt with separately.
2. If two (or more) students want to work with each other, they should be placed on the same team. After speaking with stakeholders, it was evident that they all believed there are benefits to allowing students to work with people of their choice. The model ensures that students who indicate preferred partners will be on the same team as those students. It is important to note that although there are benefits to guaranteeing partners being on the same team, this does have the potential to lower the satisfaction of individuals and teams as a whole. For example, if two students want to work together, but their preferences are opposite of one another, the model will seek to find a mutually preferred project that would decrease the satisfaction of at least one of the students compared to their top choices. For MQP groups, the Business School typically only allows a team size of between three and five students.
3. The average satisfaction for each student should be maximized rather than the average satisfaction of each group. If the model was to maximize the average group satisfaction, that means the result could have students within the same group that have extremely high

satisfaction and extremely low satisfaction. Rather, if the model maximizes the average individual score, students will not be treated unfairly by the model.

3.6 Mathematical Modeling and Optimization Model

Optimization Model:

Sets:

- $\mathcal{P}$: set of all projects topics, indexed by p.
- $\mathcal{S}$: set of all students, indexed by s.
- R: set of all student pairs in $\mathcal{S}$ who wish to be assigned to the same group of a project topic.

Parameters:

- ps_p: project topic preference score if project $p \in \mathcal{P}$ has a student assigned to the project. The total project topic preference score of student-project team match is maximized by the model.
- f_{sp} (nonnegative): preference penalty of assigning student $s \in \mathcal{S}$ to project p, equal to $(5 - q_{sp})^3$ if student s ranked project topic p; otherwise, equal to 1,000).
- L_p^- (positive integer): lower bound on the number of students assigned to project $p \in \mathcal{P}$.
- L_p^+ (positive integer): upper bound on the number of students assigned to project $p \in \mathcal{P}$.
- q_{sp}(nonnegative): preference ranking of assigning student $s \in \mathcal{S}$ to project $p \in \mathcal{P}$.

Decision Variables:

- x_p (binary): equal to one if and only if project topic $p \in \mathcal{P}$ is staffed.

- y_{sp} (binary): equal to one if and if only if student $s \in \mathcal{S}$ is assigned to $p \in \mathcal{P}$.

Maximize $\sum_{p\in\mathcal{P}} ps_p x_p$ (1)

subject to the following constraints:

$$\sum_{p\in\mathcal{P}} y_{sp} = 1 \ \ \forall s \in \mathcal{S}, \tag{2}$$

$$y_{s_1 p} = y_{s_2 p} \ \ \forall (s_1, s_2) \in R, p \in \mathcal{P}, \tag{3}$$

$$L_p^- x_p \le \sum_{s\in\mathcal{S}} y_{sp} \le L_p^+ x_p \ \forall p \in \mathcal{P}, \tag{4}$$

$$y_{sp} \in \{0, 1\} \ \forall s \in \mathcal{S}, \ p \in \mathcal{P}, \tag{5}$$

$$x_{sp} \in \{0, 1\} \ \forall s \in \mathcal{S}, \ p \in \mathcal{P}, \tag{6}$$

After finding an optimized solution, a threshold can be assigned in order to minimize the penalties of the solution. The threshold determines the factor of the optimized solution that is still acceptable when minimizing the penalty function. This ensures that the combined preference score stays above the designated threshold while the model attempts to increase student satisfaction in an alternative way. The following function and assumption describe how this works.

$$\text{Minimize} \sum_{p\in\mathcal{P}} f_{sp}, \tag{7}$$

With the following assumption:

$$0.9(\sum_{p \in \mathcal{P}} p^{sp}) \leq \sum_{p \in \mathcal{P}} p^{sp}new \leq \sum_{p \in \mathcal{P}} p^{sp}$$

Objective Function and Constraints:

(1): Objective function that maximizes the sum of preference scores for each student;

(2): Each student must be assigned to exactly one project;

(3): Teammates that want to work together will be assigned to the same team;

(4): The team size is limited to a minimum of 3 and a maximum of 5;

(5): The final score is the summation of all of the individual scores for each student after they are assigned to a project;

(6): By setting this variable to be binary, the rest of the functions can be manipulated correctly;

(7): Minimize the sum of penalties while still remaining above the total preference score threshold set by the user who is running the model, most likely the MQP coordinator.

Each year the WPI Business School deploys a survey to existing students, usually in their third year at WPI, to gather information regarding the students' preferences of partners, topics, and advisors for their MQP. They use the answers from this survey to manually allocate students to teams for review by potential advisors. For our model, it was necessary to create a survey that would serve as a means to get the students' responses and use it as input. To do so, we analyzed the current survey used by the WPI Business School and used it as a basis for questions that we were going to include in the survey for the model. The answers to the survey were exported to Excel and served as raw data.

The survey that we created was constructed using Qualtrics XM (*Qualtrics Experience Management*, 2021), a software platform which can create surveys and export survey data to other software. The questions included in our survey are shown in Appendix B. Some of the questions that we made for our survey were administrative questions for MQP coordinators to more easily track student information. For example, Question 1.3 requests for the student's ID number for student identification. The question also asks whether the student has completed their core and concentration courses. This is helpful to the MQP coordinators to better understand if a student is ready to start a MQP project. The administrative questions are not needed for our optimization model but may be useful for MQP coordinators to more easily keep track of students.

The mock Qualtrics XM survey that we made was for the purpose of easily exporting responses from real students data to our model. However, at the time this model was created, the survey was not yet sent to existing 2023 undergraduate students. We generated data to mimic how the Excel exported data would appear if the survey was distributed to students. Our model still represents a real-life scenario with a list of teams, and a list of scores respects the constraints established.

Our model required an Excel tool to define the objective function and constraints of our model. First, we downloaded and installed OpenSolver, an optimizer tool available for Excel. Then, we generated a list of random, synthetic WPI student usernames. WPI usernames are created by using the initial letter of the student's first name, followed by the initial letter of their middle name, and ending with their last name (The WPI Hub, 2019). For instance, if the student's name is John M. Doe, his WPI username would be, "jmdoe." In our Qualtrics XM survey, Question 1.4 would serve to acquire this information from students. We created a list of 56 usernames, the average number of WPI Business School students who are assigned to a Business School MQP, and compiled them together as shown in Figure 3 with some of the usernames we used.

As previously mentioned, one of the model's objectives is to ensure that if two or more students want to work together, that they end up on the same team. To implement this in our model, we added extra columns to indicate student usernames for teammates. Figure 3 shows the columns that were added. Each student username can be associated with up to four teammates. Assumption 2 in Section 3.5 explains why MQP students should not have more than four teammates. In our Qualtrics XM survey, Questions 3 to 3.3 would gather teammates' usernames.

Next, we used the usernames that were generated and matched them to the other usernames, creating teams based on the order the names were generated. The usernames that were matched are represented to have a preference to work with these students. In total, we created one team of 4 students, two teams of 3 students, and three teams of 2 students. The rest of the usernames were not matched together beforehand, so they are considered as not having preferences for teammates. Figure 3 illustrates the table we created.

Then, we added a column for each of the project topics, which will later have associated scores indicating how much the student would like to work on that project topic. We included seven options for project topics. We decided to include commonly known topics that are usually covered in the WPI Business School's MQPs. Figure 3 illustrates the table after we added the project topic tabs.

WPI Username	Teammate 1	Teammate 2	Teammate 3	Teammate 4	Process optimization	Health care issues	Work methods improvement	Production planning	Supply chain management	Information Systems	Facility design and location
acampbell	agreig	aherrera	aknights								
agreig	acampbell	aherrera	aknights								
aherrera	aknights	agreig	acampbell								
aknights	acampbell	aherrera	agreig								
amiller											
anderrick	areader										
areader	anderrick										
aschofield											
atravis											
dchaney	bparra	cbuchanan									
bparra	cbuchanan	dchaney									
cbuchanan	bparra	dchaney									
cdvillegas											
daboone											
dchaney											
djames	dmenglish										
dmenglish	djames										
fburnett											

Figure 3: A list in Excel with some of the synthetic WPI usernames we generated that represents students. Options to include usernames of teammates were added. A WPI username can be associated with up to four other usernames which would be the teammates. In total, we created one team of 4 students, two teams of 3 students, and three teams of 2 students. We also added extra columns for project topics. In total, there are seven available project topics for students to indicate their preferences.

For our next step, we generated random project preference scores for each username. To generate the project preference scores, we used the Excel “RAND” function and then rounded the resulting values to the nearest tens place, using the “ROUND” function to make it easier to visualize. In our Qualtrics XM survey, Question 4.1 would collect this input from students. Students would be able to use sliders which indicate a score from 0 to 100 for each project topic. Figure 4 shows the table with the random generated scores.

WPI Username	Teammate 1	Teammate 2	Teammate 3	Teammate 4	Process optimization	Health care issues	Work methods improvement	Production planning	Supply chain management	Information Systems	Facility design and location
acampbell	agreig	aherrera	aknights		70	20	80	60	70	30	20
agreig	acampbell	aherrera	aknights		10	0	70	100	30	80	20
aherrera	aknights	agreig	acampbell		70	100	100	80	30	80	50
aknights	acampbell	aherrera	agreig		100	50	100	70	0	60	30
amiller					100	0	60	20	60	100	60
anderrick	areader				50	20	0	20	70	50	40
areader	anderrick				30	80	60	70	50	100	0
aschofield					100	20	30	30	20	100	90
atravis					70	20	30	100	40	50	100
dchaney	bparra	cbuchanan			0	80	60	100	100	40	0
bparra	cbuchanan	dchaney			60	60	0	50	50	40	30
cbuchanan	bparra	dchaney			0	30	80	30	20	80	40
cdvillegas					100	30	30	100	40	0	60
daboone					100	10	40	40	40	100	80
dchaney					80	70	80	70	70	20	0
djames	dmenglish				90	0	70	50	100	70	40
dmenglish	djames				30	100	60	20	60	100	100
fburnett					60	50	40	0	0	50	70

Figure 4: The screenshot shows the project topics with the preference scores associated with each username. Each row is associated with one username and it represents the scores that each student username would have for each project topic. The scores were generated using Excel "RAND" function. Then, to make it easier to visualize, we used the "ROUND" function to round the scores to the nearest ten.

Our objective function (1) seeks to maximize the sum of preferences scores, but it will only add the scores associated with the project topic to which the student was placed. To make this possible, the table for the student preference scores had to be multiplied by a new table of binary variables, 0 and 1 (constraint 6). Each row, associated with a username, would contain only one cell with the value of 1, meaning that the student must be placed in a project and can only be placed in exactly one project (constraint 2). With the student placement table, we were able to take the sum of products of the student preference scores table and the student placement table using the “SUMPRODUCT” Excel function. Hypothetically, if all students were placed in project topics that each student scored as 100, then the maximum preference score would be 5,600 as there are 56 students. A perfect score, 5,600, represents an instance where all students would be placed in their most preferred project topic. Figure 5 shows the table for student placement that was added and Figure 5 shows the “SUMPRODUCT” cell and how we defined it as the objective cell in OpenSolver.

We also had to define the cells of the student placement table as the decision variable cells, as they are the cells that the model will alter to satisfy the constraints. In OpenSolver, Figure 6 shows how we defined the cells of the student placement table as the variable cells and how we defined them as binary values.

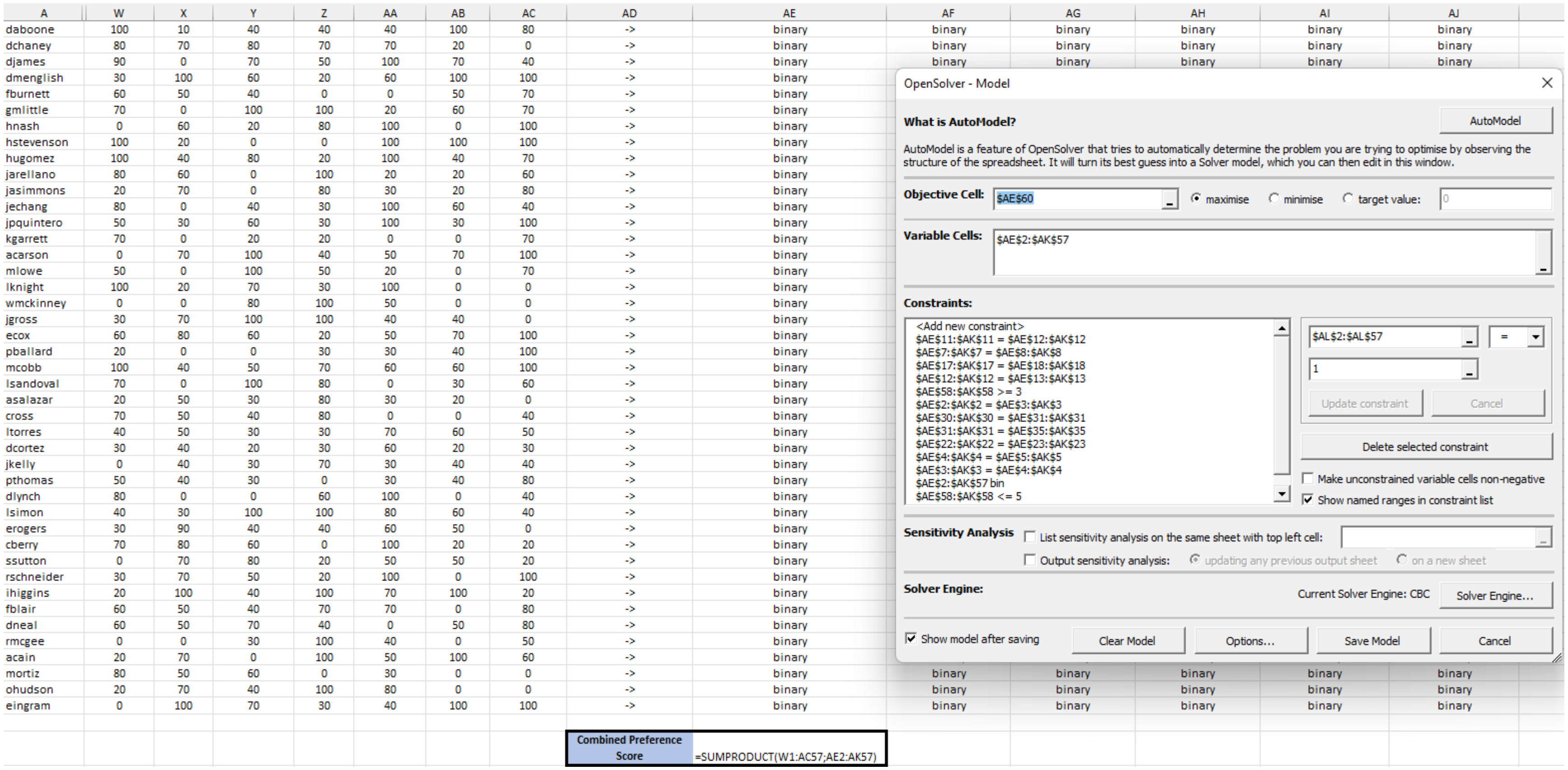

Figure 5: The screenshot shows how we defined the cell in OpenSolver, highlighted in blue, as the objective cell of our model.

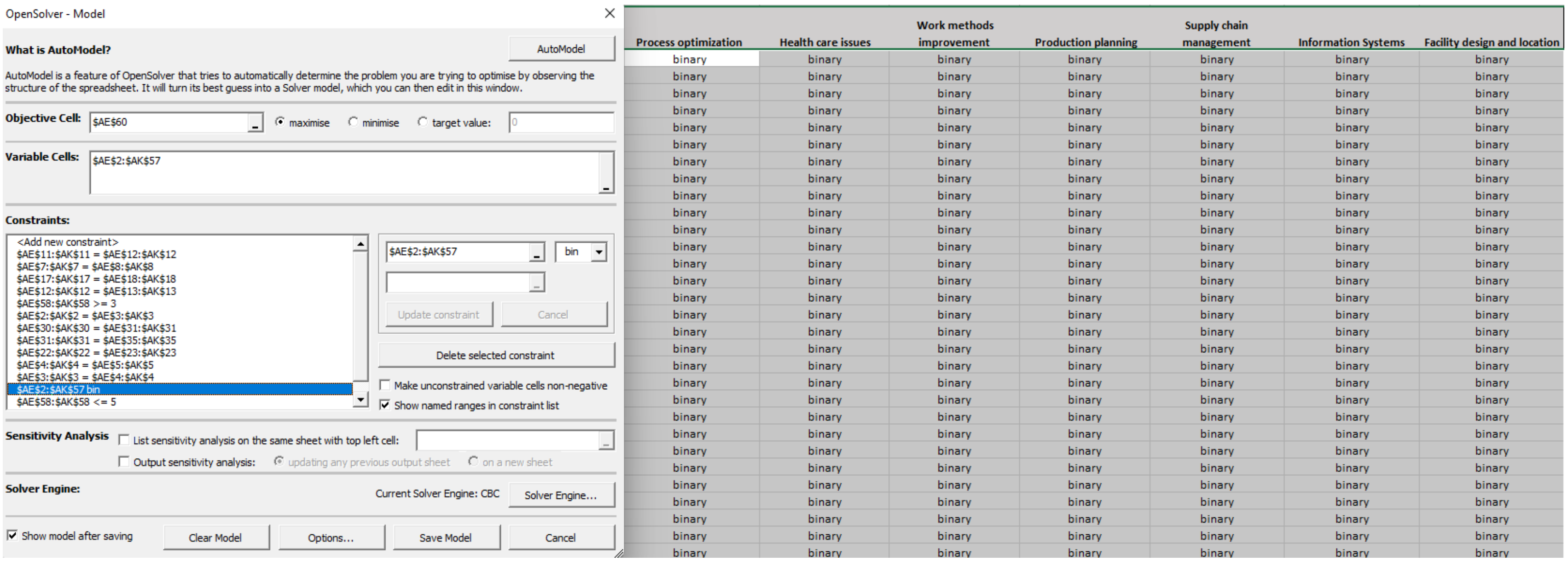

Figure 6: The screenshot shows how we defined the cells of the table the student placement, highlighted in blue, as the variable cells in OpenSolver along with how we set the constraints to define the cells of the student placement table as binary in OpenSolver meaning they can only have values of 0 and 1.

To ensure each row of the student placement table would have only one cell with the value of one, we added a column at the right end of the table, shown in Figure 7, that takes the sum of each row while also having to write a constraint in OpenSolver that dictates that the sum of each row must be equal to 1.

Next, we had set how many students would be allocated for each project topic. We created a new row at the bottom of the student placement table that would take the sum of each column which would give the number of students for the project topic creating the team. The team size could not be less than 3 students and could not go over 5 students (constraint 4). Figure 7 shows when we added the row for team size and how we set the team size constraint in OpenSolver.

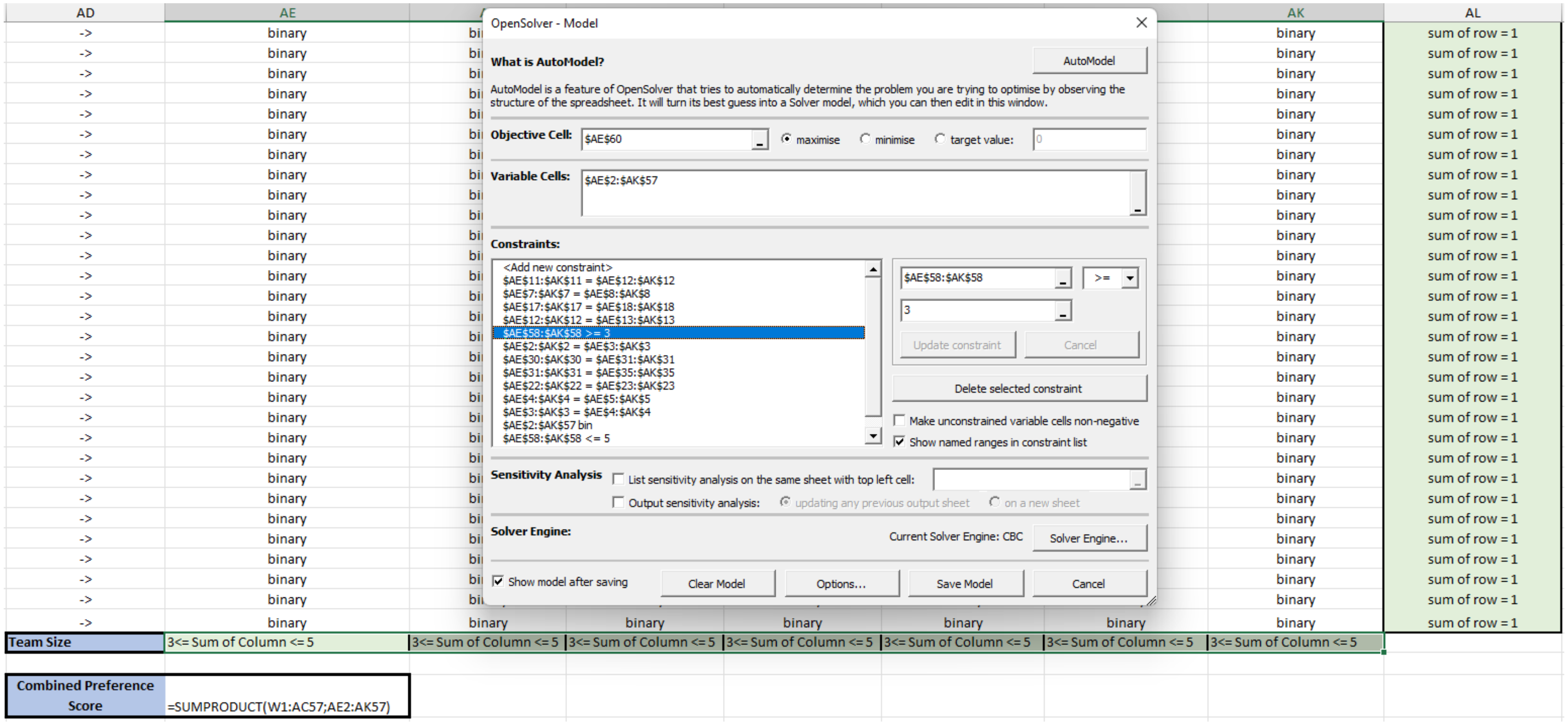

Figure 7: The table on the right was added for student placement. The "Sum of Row" table was also created to ensure that the sum of each row will be equal to 1, meaning each student is assigned to only one project. The screenshot shows the set constraints in OpenSolver that dictates the sum of each row of the student placement tables must be equal to 1 (constraint 2); along with the team size row that we added at the bottom of the student placement table. Each cell in the row takes the sum of the column which gives the team size for each project topic. We also created two constraints in OpenSolver that dictate that the minimum number of students per project topic has to be 3 while the maximum has to be 5.

To ensure that students who want to work together would work in the same team (constraint 3), we had to add extra constraints. In OpenSolver, we dictated that the rows in the student placement table for the usernames that have a preference to work with each other must have the same values. This means that for those students, the values of ones and zeroes in the student placement table will be identical, placing them in the same team and the same project topic. Figure 8 illustrates how to define this constraint.

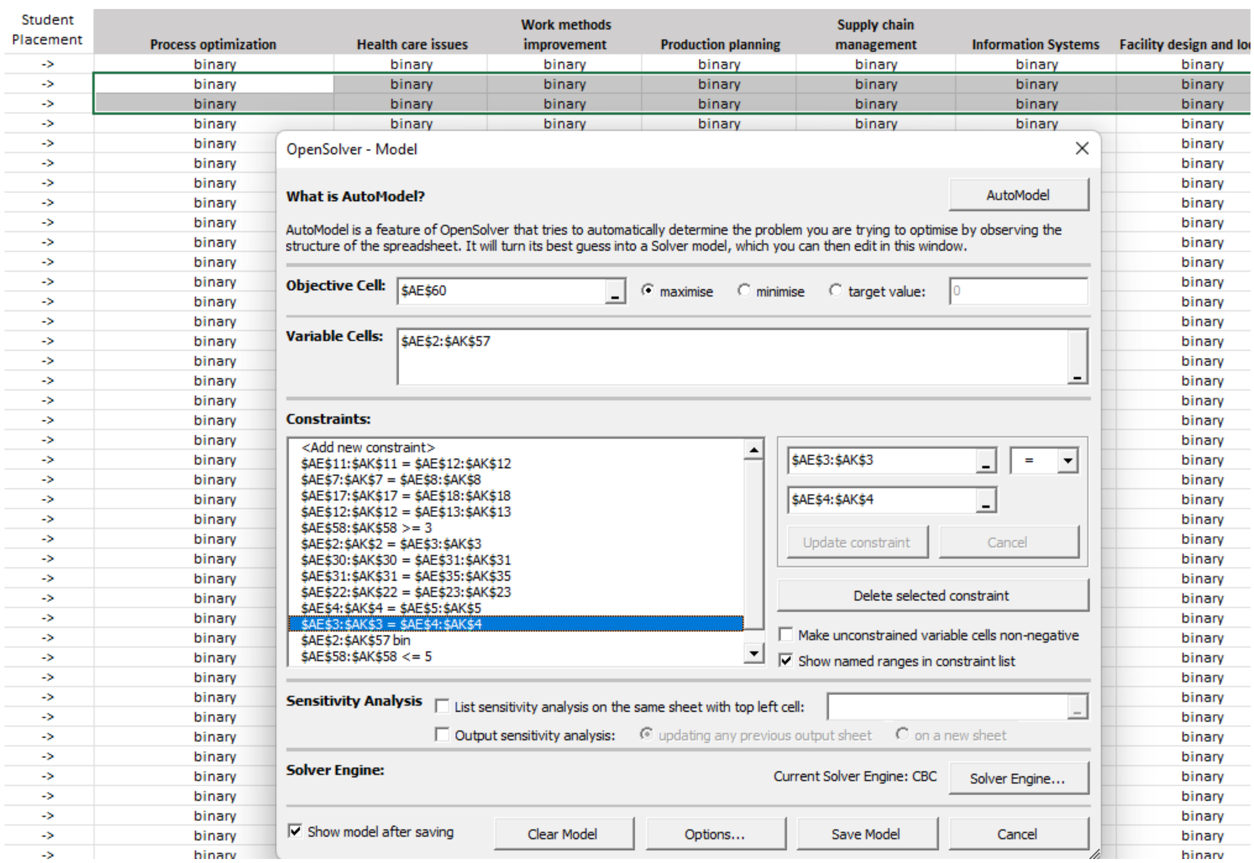

Figure 8: The screenshot shows how we set constraint 3, highlighted in blue, for two students that want to work together.

Lastly, we wanted to create an intuitive way to interact with the model to provide an additional method to increase the satisfaction of students. Using a concept from the aforementioned paper written by Lopes et al. as seen in Table 1, the team created a separate instance of the model that incorporated a penalty function (Lopes et al., 2008). The goal of the penalty function was to accurately capture the increasing dissatisfaction a student would have when receiving their first choice versus their second, third, or even fourth choice. The team used the same penalty function from the University of Arizona model, but had to scale it to fit our data. The penalty function is written as $Penalty = (\frac{(100 - Individual\ Score)}{20})^3$. First the function scales the penalty down to a number between zero and five. Next, the penalty is raised to the third power to account for the exponentially increasing dissatisfaction of a student as the individual score is lowered. If a student has an individual score of 100, then the penalty goes to zero. Regardless of the individual score, the penalty calculated becomes another way to measure how well the model places the students.

After a penalty has been calculated for each student (a number between 0 and 125), the sum is calculated. The sum of penalties now represents a new score for the model. Since the penalty is a negative experience, the next step is to minimize the amount of penalties the students incur. To do this, a constraint (7) was created to minimize the sum of the penalties after the original model has been run. All other constraints were kept the same to ensure that group sizes were constrained the same way and that everyone was still assigned to a project. However, it became obvious that this would rearrange the teams in a way that would always lower the Combined Preference Score calculated from the base model. The last step was to add a tradeoff between minimizing the penalties, while still maximizing the Combined Preference Score. The solution was to create a Combined Preference Score threshold that would stop the model from going below a certain Combined Preference Score threshold while minimizing penalties. The threshold was designed to be a factor of the original Combined Preference Score calculated by the base model. On the interface, a slider was implemented that allows the user to determine that factor which automatically constrains the model to keep the new Combined Preference Score above the threshold. Ultimately, the factor should be manipulated by the user to find a balance between preference scores and penalties because that balance is very subjective and would likely change each year.

4. Analysis

Experimentation was conducted on the models using a variety of data sources. The model was tested on user-generated data, data from the previous year (2021), and data from the current year (2022). The process of preparing data from the WPI Business School required the team to make assumptions and adjustments to the data to run the model. An analysis was then conducted on the results of each experiment to understand more about the usability and effectiveness of the model.

4.1 Model Analysis With User-Generated Data

To fully understand how the model would operate from beginning to end, a user-generated dataset was used to simulate a realistic data structure that could be used in the model. The mock data was created by using the updated WPI Business School survey (Appendix B) to replicate the exact data structure that would be received from that survey in the future. The inputs for the survey were meant to replicate typical answers of a student taking the survey. In addition to creating the data, this allowed the team to identify aspects of the survey that needed to be constrained further to ensure accurate and consistent data from each student. For example, when naming other students to work with, the question now prompts them to use the WPI username of each student, rather than simply their name. Since our model requires student identifiers to be exactly the same when mentioned, this eliminates the chance of students putting down the nickname of a friend or misspelling their full name.

Once the mock data was generated using the survey, the team had to verify that the survey results would be easy to manipulate in Excel to provide the appropriate information in the correct structure for the model. At this stage, the team was aware that some post processing must occur to format the results of the survey properly and in a user-friendly interface. Although the team was able to do this manually, an autonomous solution was not developed. The entire process of using the model is meant to be intuitive and user friendly, so this is an area for significant improvement. By leaving more tasks up to the user, there will inherently be more room for error and user confusion while interacting with the model, regardless of the difficulty of the tasks. Automating the post processing, as well as other future tasks within the model, are explored further in Section 5, Conclusions and Recommendations. The resulting data table (Figure 7) was then used to run the model as described in Section 3.6.

To measure the success of the model, the team evaluated the model and its results based on the usability of the tool, the ability to accurately represent the constraints, the relevance of the results, and overall strengths and weaknesses of using the tool.

As described previously, steps had to be taken within Excel after receiving the data to run the model and interpret the results. The documented steps in Section 3.5 show what needs to be done to run the model. However, some of these steps are eliminated for future users by preparing the Excel file with proper formatting and predetermined cell referencing. The Excel file for the data-generated model can be accessed in this link: Data-Generated Model.xlsb. For example, when the data from the survey is uploaded into the worksheet starting in cell A1, the cell referencing on the next worksheet helps automatically generate the table and interface that will ultimately yield the final solution and who is assigned to each team. Although cell referencing is a powerful tool to help automate tasks and reduce errors, it has to be done very carefully to be effective. Specifically, the number of students (rows in Excel), and number of projects (columns in Excel) change annually. The Excel file cannot simply use a preset table size with references because it would not be able to account for the changes from year to year. Either the file has to be capable of handling any realistic number of students, and then the coordinator will manually remove the extra rows and columns, or the tables and cell references need to be formatted to be more elastic based on the data it receives. In general, the model does not require much skill to use, however, there are many steps that need to be done correctly in order for the model to run. If the user deviates from the specific step-by-step process, there is no guarantee that the model will be able to function appropriately. Although usability improvements can be made, the tool should allow most users that are familiar with Excel to run the model successfully.

After examining the usability of the tool, the team wanted to ensure that the results generated from the model accurately represented the constraints of the model and its real-world applications. As the modeling constraints were created iteratively with input from stakeholders, and carefully inputted into Excel, the final model is able to accurately represent these constraints.

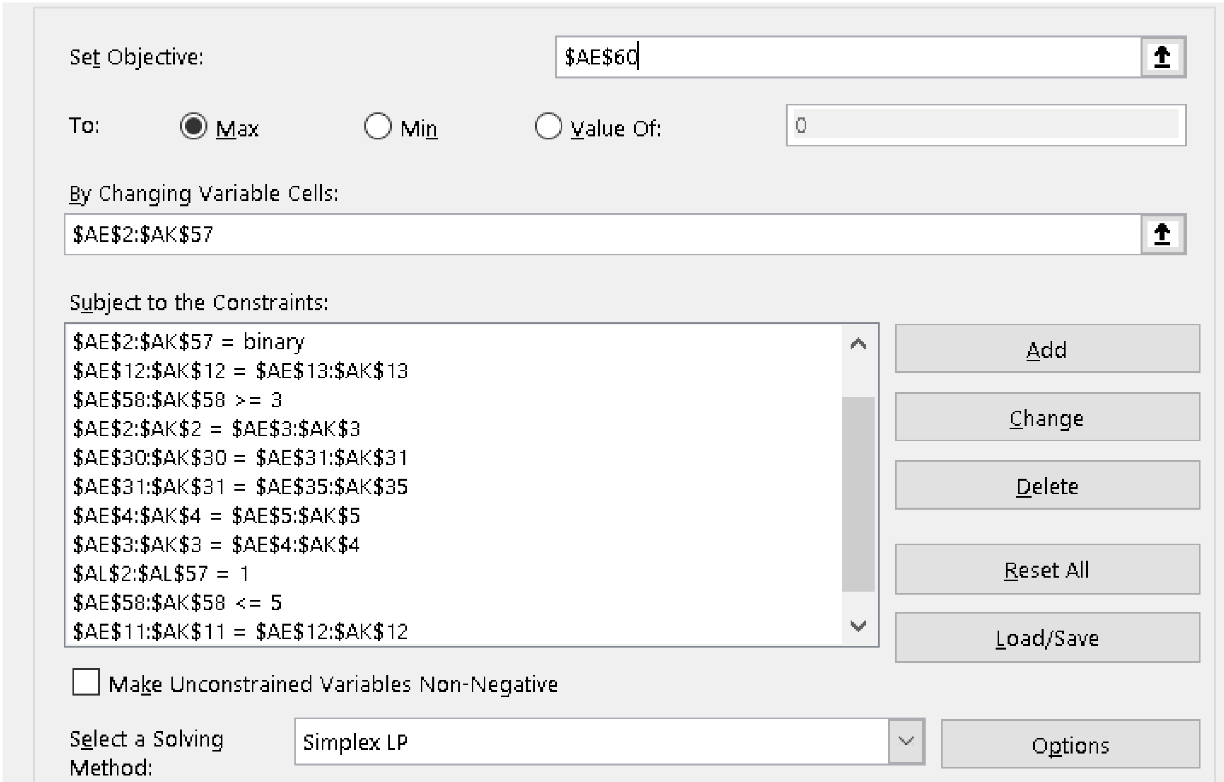

Figure 9: The constraints that are used in the model for the mock data. When the model is run, each of these constraints are accurately reflected in the results.

In addition to accurately representing the constraints, the results of the model should also reflect the relevant solutions required from the stakeholders. The score that is calculated by the model was a metric created by the team to represent an estimation of student satisfaction. After running the model and interpreting the results, it became necessary to evaluate the relevance of this metric, and the model as a whole. The results of the model are summarized in Figure 10.

Results	
Students in Process Optimization	4
Students in Health Care Issues	3
Students in Work Methods Improvement	3
Students in Production Planning	5
Students in Supply Chain Management	5
Students in Information Systems	3
Students in Facility Design and Location	4
Number of Student Groups	7
Combined Preference Score	5000
Maximum Score	5270
% of the Max	95%

Figure 10: A summary of the results from running the model with user-generated data

We draw the reader's attention to the Combined Preference Score of 5,000 out of a maximum of 5,270. The maximum score is given by taking the maximum value of each student row and adding these values. This score represents about 95% of the highest achievable score. This percentage can also be interpreted as the average preference school for each student in the model. A percentage of the maximum score of 100% would represent a scenario where all students were placed in their most preferred project topic. Although the score itself does not provide much value alone, it can be compared to other iterations of the model with different preferences or constraints. For example, if the threshold factor is used, the user can clearly see how much the Combined Preference Score changes relative to the starting number and the maximum score. Although the penalties and preference scores cannot be compared directly, the user is able to use their own judgment to decide what is an appropriate Combined Preference Score and sum of penalties. The user can also manipulate the model manually (e.g., change the number of students per team) which would have visible effects on the Combined Preference Score. This metric can certainly be used to gauge the success of the model, but it does not reflect the effects on a real-world situation correctly every time.

It is also important to recognize that although the model calculates a solution, it doesn't always produce the best solution once it is implemented. Limitations were put on the model to make it feasible to create within the given timeframe. Section 5 explores the many ways the model could be further developed to implement features that would create a more realistic model. However, one crucial flaw in the model is that it is extremely difficult to gauge a student's satisfaction or happiness with a project without collecting extensive data. For our simplified model, many assumptions were made to arrive at the conclusion that students' satisfaction is dependent on the project topic they receive. In reality, a students' satisfaction is also heavily dependent on, among other things, who they work with, who the advisor and/or sponsor is, how the team meets and collaborates, and how the team is assessed. Although this model is able to effectively form teams and optimize the Combined Preference Score, further development and testing is required to determine if this tool would benefit the WPI Business School from the perspective of students, advisors, and other stakeholders.

4.2 Business School Data and Assumptions

Once we tested the model on our mock data, the next step was to implement real data. The team was able to procure data collected from 2021 and 2022 using the previous Qualtrics survey. Unlike our survey, as shown in Appendix B, the survey from 2021 and 2022 gathers student preferences in an open-ended format, rather than a score based format (Figure 11).

	P	Q
1	10. Do you have industry preferences for the content/topic of your MQP? (e.g. healthcare, manufacturing) - Selected Choi	10. Do you have industry preferences for the content/topic of your MQP? (e.g. healthcare, manufacturing) - Yes - Te
8	Yes	Finance/ fintech
9	Not Sure	
10	Yes	Healthcare
11	Yes	Automotive
12	Not Sure	
13	Yes	Optimization and maybe healthcare but open to other things
14	Not Sure	
15	Not Sure	
16	Yes	Created my own project
17	Not Sure	
18	No	
19	Yes	Manufacturing, supply chain, operations
20	Yes	Sustainability / Education
21	Yes	Manufacturing, healthcare
22	Not Sure	
23	Yes	Healthcare, manufacturing (really anything with lean manufacturing concepts)
24	Yes	Healthcare, industrial and organizational psychology, consumer behaviour
25	No	
26	Yes	I like the data analytics/data visualization; thats where i want to head in my career
27	Not Sure	
28	Yes	Lean manufacturing, manufacturing, healthcare
29	Yes	Manufacturing, healthcare, Food
30	No	
31	Yes	FinTech, Supply Chain, Optimization, Manufacturing, Lean, Healthcare

Figure 11: Open-ended survey results from students in 2021.

To run our model on this data, we had to develop a method to convert the open-ended answers into numerical scores. The following assumptions and modifications were necessary to convert this data into a format that is reasonable to run through the model.

1. There are 9 project topics in the model. These topics were chosen because they were frequently mentioned as being more desirable and are also common topics within the WPI Business School.
2. Students received a preference score based on their preferred industry/topic. If a student preferred a specific topic, we assume that the student prefers that topic far more than the alternatives. In this case, a student with a single preference would receive a score of 100 for that topic, and a score of 0 for the others. In the event that the student had multiple preferred topics, a score of 100 is assigned to all preferred topics, and 0 for the others.
3. Students who do not specify any preferences are given a score of 50 for all topics. If the student has no inclination towards a certain topic, the model should weigh all topics equally for that student. The value 50 was chosen because it represents the middle between preferred and not preferred.
4. Students who did not fill out the survey are added to the model with no preferences (a score of 50 for every topic). We learned that the class that filled out the survey in 2021 had 57 students. The data from 2021 showed that 45/57 students answered the survey (about 20% of the students did not). To make the model represent the students who did not answer the survey, the remaining 12 students were added with a score of 50 (a neutral score) for each topic.

5. Based on the number of students who did not respond in 2021, about 20% more students are added to the 2022 data. There were originally 33 students that filled out the survey, so 7 more students were added with a score of 50 for each topic.
6. Names and any other identifying information was removed to protect the identity of the students.
7. The threshold feature is not applicable to this data. As the scores for this data conversion are only 0, 50, and 100, the penalty function does not operate the same way. It would not accurately capture the magnitude of the penalty for receiving a 50 versus a 100.
8. All other constraints that were used on the mock data are applied to the data from the WPI Business School.

4.3 Model Analysis with Business School Data

At first glance of the Business School's survey data of 2021, we noticed that certain project topics had a higher demand than others from students. Some project topics had substantially more scores of 100 than others which means they are higher in demand for students. These topics were manufacturing, supply chain, finance, healthcare, optimization, and operations. As such, we had to implement a method that would allow project topics to be matched with more than one group. This is a different aspect in contrast to the user-generated data model due to the original one only allowing one group of students for each project topic. The solution to this problem was to add additional columns in the student placement table repeating the project topics that were considered as having a higher demand. Figure 12 shows the student placement table after we added the columns. In the model we designed, the student placement table is a table of binary values, 0 or 1, which indicates where students are placed after the model is solved. The team size for a project topic is given by the sum of the column. By having an additional column for a high-demand project topic the model allows for an additional group of students to be allocated to them.

Finance	Environmental	Tech	Healthcare	Optimization	Operations	Manufacturing	Supply Chain	Finance	Healthcare	Optimization	Operations
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary
binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary	binary

Figure 12: At the right side of the student placement table, columns to place an additional group in high-demand project topics were added. The projects which are considered are high-demand project topics, written in red, are the following: manufacturing, supply chain, finance, healthcare, optimization, and operations.

When examining the Business School's survey data of 2022, it was apparent that one of the project topics, manufacturing, had higher demand with at least eight students giving it a score of 100. So this also required a solution in which more than one group could be matched to project topics. Incidentally, we were also told that other project topics needed the ability to support an additional team even though it did not have a particularly high demand. In the user-generated data model that we designed, we created constraints that dictated the size of project topics for the number of students to be at least three and at most five, as shown in Figure 13. The solution to the model using the data from 2022 involved using something similar. We used the same constraints that were used in the user-generated data model, but changed the size of the student group to be greater than or equal to 3, and to be less than or equal to 8.

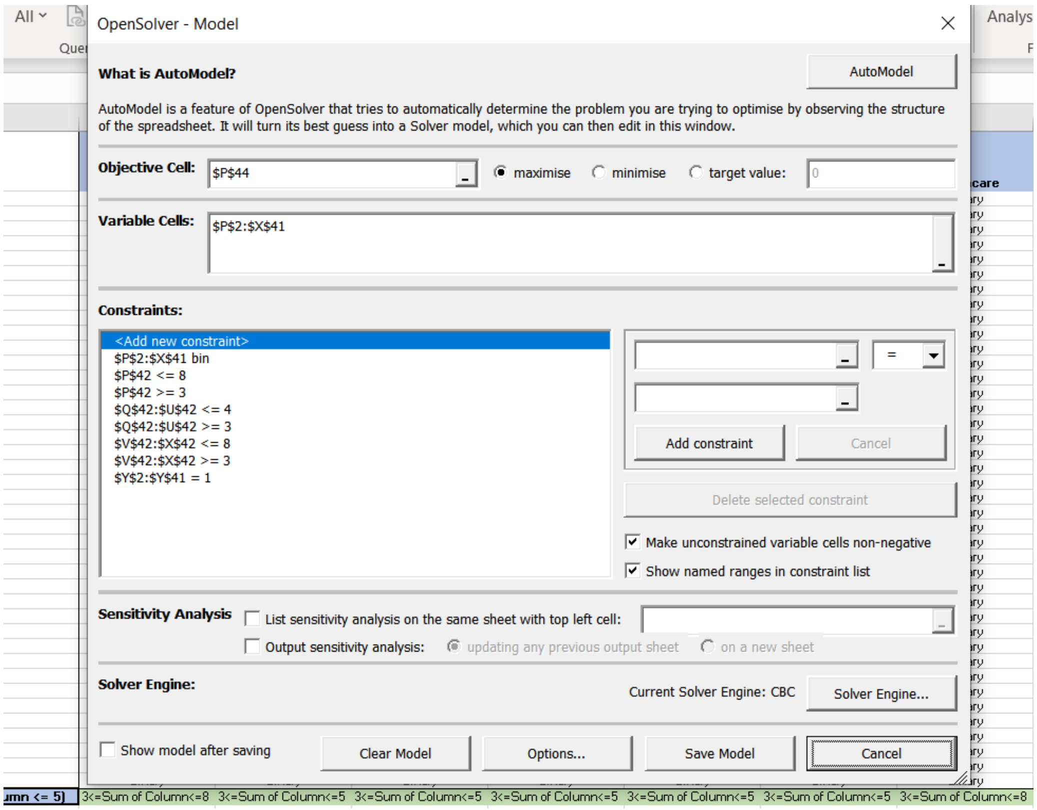

Figure 13: Constraints were added for 4 project topics which dictate that at least 3 and at most 8 students can be allocated to them.

Interviews with stakeholders revealed that MQP groups can have at most 5 students. These constraints would make it possible for more than 5 students to be matched to project topics. However, in the case of this model, if more than 5 students are matched to a project topic, the number of students would be split in half to make 2 groups. For example, if 8 students are matched to the project topic of operations, there would be 2 groups of 4 students working in operations.

The results from the model using the Business School's survey data of 2021 and 2022 are summarized in Figure 14. The link for the Excel file can be accessed here: BSchool Data Model.xlsx. The maximum preference score is dependent on the number of students included in the model. As the data from 2021 had 16 more students than the data from 2022, it is coherent for the 2021 data to have a higher Combined Preference Score. The bigger the number of students, the bigger the maximum preference score can be. Henceforth, the metric that we decided to use to assess the effectiveness of the model was the percentage of the maximum score. This score is calculated by getting the percentage of preference scores in relation to the given maximum preference score. The data from 2021 had a percentage of the maximum score of 100%, while the data from 2022 had a percentage of 84%. It could be said that the main reason why the data from 2021 had a higher percentage was due to the students being more certain about what project topics they wanted. For the 2021 data, there was a total of 79 scores of 100, while the data from 2022 only had 28 scores of 100. To increase the effectiveness of the model, the students should be encouraged to explore their options and be more decided about what projects at which they would prefer to work.

The usability of the model was very poor when we tried to adapt the results of the Business School' survey responses. The model was designed to receive input in the format of scores between 0 to 100. The answers to the Business School surveys were in response to open-ended questions regarding what preference students had to project topics, so there were no numerical scores in the data outputs of these surveys. We had to adapt and translate their answers to a format that would fit in our model. Should the model be implemented in practice, it is essential that the students indicate their preferences in the format of a numerical score. This way, students would be more accurately matched to projects, and the effectiveness of the model could be analyzed to a greater degree.

Results		
Year	2021	2022
Total Number of Students	56	40
Students in Manufacturing	8	8
Students in Supply Chain	8	4
Students in Business	3	3
Students in Finance	8	3
Students in Environmental	3	3
Students in Tech	3	3
Studets in Healthcare	8	4
Students in Optimization	8	4
Students in Operations	7	8
Number of Student Groups	15	11
Combined Preference Score	3900	2400
Maximum Score	3900	2850
% of Max	100%	84%

Figure 14: 56 Students were considered in the data 2021 data and 40 students were considered in the 2022 data. The number of students matched to each project topic, the number of student groups, and the preference scores are also shown.

5. Conclusion and Recommendations

Capstone design projects in an undergraduate university setting are the chance for an undergraduate student to apply the skills they have learned during their undergraduate studies. These projects often rely on the specific technical skills a student has learned in their major. As capstones are such an important piece of an undergraduate education, capstone team formation is a challenge that many universities face. The WPI Business school was looking for improvements to the MQP formation and matching process for the benefit of both the students, advisors, and those who form the MQP teams. Through a series of interviews with stakeholders in the WPI Business School and research into ways that different universities put together undergraduate capstone projects, the team found that optimization modeling was a useful solution for the WPI Business School. We designed a model that uses inputs from a survey inspired by the one deployed by the WPI Business School each year, which has the ability to create preliminary teams for review by the Department Heads of the WPI Business School. Using the survey's existing teammate preference features and project topic preference features, the model maximizes project preferences of students to assign students to the project topics they are most passionate about. The model was first tested on mock data generated by the team based on the edited version of the WPI Business School survey. Once the WPI Business School survey was deployed and answers were collected by the Department Heads of the WPI Business School, the team anonymized the existing Class of 2022 and Class of 2023 MQP preference data and tested our model on the data. We found that with the user-generated data, the model had an average preference score for each student of 85%, and produced average preference scores of 69% and 60% for the 2021 survey (Class of 2022 data) and 2022 survey (Class of 2023 data), respectively.

Although the model is able to accurately reflect the constraints and produce a solution, the intricacies of real-world team formation cannot be fully captured by this specific model.

As with all optimization models, certain assumptions had to be made. While this model only accounts for students who complete their project in A, B, and C terms, some projects have different timeframes. A future study could use this model as a starting point to incorporate teams who run their projects in different timeframes. Many of the limitations addressed in the model analysis could be used as a starting point for future studies. The addition of students who are incompatible with one another could be an addition to the survey and the model itself, as that was an area of the model plan the team was unable to implement. Because this is not a question currently present in the WPI Business School's survey, if this constraint to the model is deemed useful, it should also be added as a question to the survey. Any additional constraints to reflect real-world situations will also have to be incorporated into the model mathematically. For changes of the model interface itself, a future version of the model could include the ability for the user to click "Run Model", with a linked cell button, to run the model without having to find and load OpenSolver itself. This could be implemented using Excel Macro Recorder and then editing the associated VBA code. Another addition to the model that would result in a user-friendly interface would be the team outputs of the model being listed in a more intuitive way, as opposed to numbers being laid out in an array**.** The model can be further made error-proof by using the "lock cell" feature on unchanging variables, and outlining either in color or in cell comment where data should be placed by the user. To make the model run faster, there could also be additions to the model where pre-formed teams do not need to be run through the model to decrease the total amount of variables involved, but still accounted for in the total amount of students and projects available to be matched to. Lastly, a formula could be developed that would help the model determine how many projects are needed that year as a function of the number of students. The formula could also calculate which topics should have more than one project, based on the demand and interest of the students. The existing model can be further built upon in multiple ways to increase the usability and feasibility of the model for the WPI Business School to form project teams, or for further expansion into other departments of WPI. Along with these recommendations, the WPI Business School could further keep students informed of project topics, potential topics, and advisors available to them by using eProjects 2.0 or hosting a project opportunities showcase.

Project Reflections

The following project reflections present some of the views from the authors in regard to this project. These project reflections are in accordance with the criteria established by the WPI Industrial Engineering Major Qualifying Project Syllabus.

Reflection 1

Initially, our MQP revolved around designing a tool to facilitate the process of matching senior students to MQP projects. The tool resulted in an optimization model. Its application is meant to help the ones who are responsible to match students to MQP projects. To make the tool, we had to learn about the many systems that currently exist to match students to projects. We had to understand the needs of the WPI Business School and ensure those needs would be satisfied by our model. When those needs were understood, based on interviews that we had with the people working in the matching process, we created criteria that our model would fulfill.

During our design process, there was an ethical constraint to be considered. To test our optimization model, we asked for real data from past surveys sent by the WPI Business School to collect students' preferences in regards to what project topic at which they wanted to work. The data included the names of students that answered the surveys. To make privacy barriers were broken, we occulted their names because their answers are supposed to be used only internally by the WPI Business School. Other than that, our design experience was at no risk of violating any privacy issues.

The project experience brought a lot of educational value to me. I had to apply concepts learned previously from optimization courses that I took. I also used tools that I learned in past classes such as Excel and OpenSolver. The most important skill that I learned that was not directly covered by the coursework was to understand the needs of a stakeholder and ensure these needs are covered. Our stakeholder, the WPI Business School, had needs that needed to be covered by our project so we had to fully understand them to fulfill them. In the future, I believe this skill is going to be needed every time I have to meet a need from a client or a stakeholder and I plan to be really observant and open-minded to improve that skill.

To me, the most difficult aspect of the project was that we were the first MQP group to tackle the problems with the MQP matching process in the Business School. We had a lot of freedom to decide what would be the outcomes of our project, but that also made the project difficult as we faced a lot of ambiguity. However, this also came with a positive aspect: I believe I am now more capable of making important decisions and this will be very important for my career.

Reflection 2

The ultimate goal of this project was to evaluate the existing process for MQP team formation and develop an alternative that would save time, improve student satisfaction, and never leave any students out of the process. The iterative nature of designing a new process became very evident as the project developed over time. Instead of developing a deployable model for the Business school to use, the project turned into a thought experiment for what could be done, the biggest difficulties with the initial goals, how the new process could be evolved, and how the new process would be integrated with parts of the old process to be most effective.

The team designed two main components, that together, create a new process for forming MQP teams. The first component is a revised survey to send to junior year students to gain data about their preferences for their MQP. The objective of the new survey was to collect more relevant data, and that could be easily manipulated and used in an Excel model. Designing this survey meant that the team had to foresee what types of data would be most useful for Excel. The team determined that the two most important factors were to make sure the results of the survey were error-free, and that every student has an opportunity to rank their different preferences with a number system. Thinking ahead, the team knew that if students were able to type in their project preferences, they would be inconsistent with each other and typos were likely to occur which would require additional post-processing in Excel before the data was useful. This process of creating the survey was not exactly linear because the team used iterations of the survey to generate dummy data to run the model and learned that the survey questions could be altered further to reduce the amount of post processing needed before running the model.

The other major component designed was the model in Excel that was used to assign students to teams, projects, and advisors. To start this process, the team researched how other team matching algorithms function, and chose a specific model to base ours off of because of the many similarities. Next the team had to develop a set of constraints that ultimately would decide what the model would be capable of and what the scope of the model would be. To simplify the greater problem of matching the team's capabilities, certain assumptions were made when creating the model. With written constraints and assumptions, the team was then able to begin modeling. Since the team had limited knowledge on how to actually model the system, the team was constantly revisiting the constraints and assumptions to reflect what was actually possible in the model and what could be added to the model. The model was also built by starting with the most basic constraints and testing the model at each step before new constraints were added. This process was extremely useful for the team because it allowed us to learn the basics of modeling at the beginning and use the skills we were learning and apply them to the more complicated constraints. However, as more constraints were added, the interface of the model continuously changed and it was not always supportive of the new changes to the model. This meant that the team had to go back and reformat the interface so that it could support the various inputs and outputs of the model. Even once the model was "done", there was always more that could be added to the model. The final additions were ultimately the most difficult part of the modeling because they required intricate solutions to incorporate constraints that were not as obvious to include. These final additions required many iterations in a two steps forward, one step back fashion. The team was able to identify potential solutions, but as they were developed, the team was unable to foresee obstacles and had to step back and find new solutions.

Throughout the design process, the team had to keep additional constraints in mind including economic, social, and usability constraints. In terms of economical constraints, the goal was to produce a tool that is free to use. In addition, another goal of the tool is that it would save time for the person in charge of matching students together for MQPs. So ultimately, the tool would be free to use and save an employee's time, thus, saving money. For social constraints, the team had to recognize that this tool would be responsible for assigning students to MQPs which have a long-lasting impact on the student, even beyond college. While designing the model, it was important to consider the importance of team satisfaction versus individual satisfaction. Although it would be ideal for all teams to have the highest combined satisfaction, the group decided that it was even more important that each individual student's satisfaction was prioritized. This would help ensure a positive experience for all students and provide them with a meaningful and interesting project that they could learn from. Lastly, this tool was developed to be used by other people so it had to be user friendly. The team focused on this aspect last, however, an extensive step by step manual was created to help the user through the entire model. With more time and planning, the team could have cleaned up the interface and made the model easier to interact with and customize.

Looking back to the beginning of the project, the scope and objectives have changed significantly along the way. The continuous process of determining the exact direction led the team to explore more options than another project that may have more definitive guidelines from a sponsor for example. However, since the project was not concrete to start with, it led to times of frustration further on as we were not able to complete tasks that were previously determined to be important. With the help of our advisors, we should have spent more time focusing on what the process and deliverables were going to look like before starting the project.

Personally, I strongly believe that a project that challenges the team to go beyond our current skills is extremely important in preparing us for life after college. The benefit of group work is that everyone brings their own strengths which can help propel the project forward. However, especially in a structured education environment, I feel that our team’s strengths would have been much more valuable on other projects. During the Covid-19 pandemic, our team was formed by the faculty of the WPI Business School based on the survey data collected in 2021, and the intuition of the faculty and advisors. Ironically, the project that was given to us ended up being a case study of why this project could be so important.

References

ABET Accreditation. (2021). https://www.abet.org/accreditation/

Angeliu, K. M., DiPinto, M. R., Rayder, T. M., & Zhao, W. (2014). *Improving Sponsored Projects at WPI*. 55.

Anwar, A., & Bahaj, A. (2003). Student project allocation using integer programming. *Education, IEEE Transactions On*, *46*, 359–367. https://doi.org/10.1109/TE.2003.811038

Bhadury, J., Mighty, E. J., & Damar, H. (2000). Maximizing workforce diversity in project teams: A network flow approach. *Omega*, *28*(2), 143–153. https://doi.org/10.1016/S0305-0483(99)00037-7

BME Major Qualifying Project. (n.d.). WPI. Retrieved October 13, 2021, from https://www.wpi.edu/academics/departments/biomedical-engineering/major-project

Colleges With Great Senior Capstones. (2021). US News & World Report. https://www.usnews.com/best-colleges/rankings/senior-capstone-programs

Criteria for Accrediting Engineering Technology Programs, 2019 – 2020 | ABET. (2020). https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-technology-programs-2019-2020/

Diwekar, U. M. (2020). *Introduction to Applied Optimization*. Springer Nature.

Dowd, J. E., Roy, C. P., Thompson, R. J., & Reynolds, J. A. (2015). “On Course” for Supporting Expanded Participation and Improving Scientific Reasoning in Undergraduate Thesis Writing. *Journal of Chemical Education*, *92*(1), 39–45. https://doi.org/10.1021/ed500298r

Dowd, J. E., Thompson, R. J., Schiff, L., Haas, K., Hohmann, C., Roy, C., Meck, W., Bruno, J., & Reynolds, J. A. (2019). *Student Learning Dispositions: Multidimensional Profiles Highlight Important Differences among Undergraduate STEM Honors Thesis Writers | CBE—Life Sciences Education*. https://www.lifescied.org/doi/10.1187/cbe.18-07-0141

ECE MQP Advisors. (2021). WPI. https://www.wpi.edu/academics/departments/electrical-computer-engineering/major-project/advisors

Geithner, C. A., & Pollastro, A. N. (2016). Doing peer review and receiving feedback: Impact on scientific literacy and writing skills. *Advances in Physiology Education*, *40*(1), 38–46. https://doi.org/10.1152/advan.00071.2015

Looft, F. J. (2008). *CAPSTONE DESIGN AT WPI An Evolution of Projects Based Education*.

Looft, F. J. (2010). *The WPI Capstone Project: Evolving Off-Campus and International Experiences*. 4.

Lopes, L., Aronson, M., Carstensen, G., & Smith, C. (2008). Optimization Support for Senior Design Project Assignments. *INFORMS Journal on Applied Analytics*, *38*(6), 448–464. https://doi.org/10.1287/inte.1080.0373

Magana, A. (n.d.). Variations in Interview Instrumentation. *Qualitative Interviewing*, 4.

Magnanti, T. L., & Natarajan, K. (2018). Allocating Students to Multidisciplinary Capstone Projects Using Discrete Optimization. *Other Univ Website*. https://dspace.mit.edu/handle/1721.1/120563

Major Qualifying Project (MQP). (2021). WPI. https://www.wpi.edu/student-experience/resources/off-campus-projects/project-opportunities/mqp

Major Qualifying Project Search. (2021). WPI. https://www.wpi.edu/academics/undergraduate/major-qualifying-project/project-search

Michaelis, B. M., & Bae, H. (Alex). (2019, June 15). *Optimizing Capstone Team Selection*. 2019 ASEE Annual Conference & Exposition. https://peer.asee.org/optimizing-capstone-team-selection

Pearlstein, J. (2021). Experiential Exercise in Team Formation in the Capstone: Providing Students With the Information to Make Good Team Choices. *Journal of Management Education*, *45*(4), 627–651. https://doi.org/10.1177/1052562920938071

Qualtrics Experience Management. (2021). Qualtrics. https://wpi.ca1.qualtrics.com/homepage/ui

Rao, S. S. (2019). *Engineering Optimization: Theory and Practice*. John Wiley & Sons.

Student Preference Ranking Brochure. (n.d.). Purdue University. https://info.catme.org/instructor/history-research/brochures/

The Business School. (n.d.). WPI. Retrieved October 10, 2021, from https://www.wpi.edu/academics/business

The New England Council. (2015, August 11). *New Member Spotlight: Worcester Polytechnic Institute*. New England Council. https://newenglandcouncil.com/blog-post/new-member-spotlight-worcester-polytechnic-institute/

The WPI Hub. (2019, October 28). *The WPI Hub | Article | Wpi Login Name Standard And Change Standard*. The WPI Hub. https://hub.wpi.edu

The WPI Plan. (2021). WPI. https://www.wpi.edu/project-based-learning/wpi-plan

Trapp, A. C., & Konrad, R. A. (2015). Finding diverse optima and near-optima to binary integer programs. *IIE Transactions*, *47*(11), 1300–1312. https://doi.org/10.1080/0740817X.2015.1019161

Weaver, K. F., Morales, V., Nelson, M., Weaver, P. F., Toledo, A., & Godde, K. (2016). The Benefits of Peer Review and a Multisemester Capstone Writing Series on Inquiry and Analysis Skills in an Undergraduate Thesis. *CBE Life Sciences Education*, *15*(4), ar51. https://doi.org/10.1187/cbe.16-01-0072

WPI Business School | Academics | WPI. (n.d.). Retrieved October 10, 2021, from https://www.wpi.edu/academics/business

Zhu, N. (2018). Effectiveness of involving the industrial and business professions into mechanical engineering capstone course. *International Journal of Mechanical Engineering Education*, *46*(1), 31–40. https://doi.org/10.1177/0306419017718920

Appendices

Appendix A

Interview Questions for WPI Business School Faculty

1. In an attempt to make a process map, can you help us identify some of the key steps that are required and any deadlines that are associated?

2. What are the biggest difficulties or pain points when matching students to MQPs and advisors?

3. Are there always enough MQP projects already created for students or is there also difficulties in creating/finding worthwhile projects

4. If a student reaches out to you about working on an MQP (either with you, or in general) what is a typical response?

5. Is it required for professors to advise MQPs?

6. What is so important about the MQP? Why is it so valuable to students?

7. As an institution, would WPI prefer students to create and propose their own MQPs or would there be concerns that it would take away from quality, impact, or experience?

8. What does the behind the scenes of creating an MQP with a new sponsor look like from the advisor’s perspective? (time, difficulty, process)

9. Is there any other system that exists from other colleges that would be interesting for us?

10. Do you know any specific sources that would help us with our project?

11. How realistic would it be to have all advisors post their projects and a brief description on eProjects?

12. Is there anything that we didn’t ask about that you think would be relevant?

Appendix B

Qualtrics Survey

WPI Business School Student MQP Pre-Registration

Start of Block: Block 1

Q1 Please complete the following:

Q1.1 First Name

____

Q1.2 Last Name

____

Q1.3 Student ID

____

Q1.4 Your WPI username.
Example: emborges@wpi.edu is my email, emborges is my WPI username.

____

Page Break

Q2 Will you have completed most of your major core and concentration courses prior to beginning your MQP? (Students completing an MQP are expected to have all or at least most of their core and concentration courses completed)

- ◯ Yes (1)
- ◯ No (2)
- ◯ Not sure (3)

Display This Question:

If Will you have completed most of your major core and concentration courses prior to beginning your... = No

Q2.1 Please indicate which courses you have not yet completed.

____

Display This Question:

If Will you have completed most of your major core and concentration courses prior to beginning your... = Not sure

Q2.2 It is suggested to students who are unsure to first talk to advisors and look in Workday for core and concentration courses they have not yet completed.

End of Block: Block 1

Start of Block: Block 2

Q3 Are there students you would like to work with for your MQP?

- ◯ Yes (1)
- ◯ No, not yet (2)

Display This Question:

If Are there students you would like to work with for your MQP? = Yes

Q3 Please list the WPI username(s) of your teammate(s).
Example: emborges@wpi.edu is my email, emborges is my WPI username.

You can choose up to four teammates.

Teammate 1

____

Q3.1 Teammate 2

____

Q3.2 Teammate 3

____

Q3.3 Teammate 4

____

End of Block: Block 2

Start of Block: Block 3

Q4 Do you have a preference for specific project topics?

○ Yes (1)

○ No (2)

Skip To: End of Survey If Do you have a preference for specific project topics? = No

Display This Question:

If Do you have a preference for specific project topics? = Yes

Q4.1 Use the slider to indicate your preferences for project topics (100 being most preferred, 0 being less preferred).

	0 10 20 30 40 50 60 70 80 90 100
Production planning ()	
Work methods improvement ()	
Health care issues ()	
Process optimization ()	
Supply chain management ()	
Information Systems ()	
Facility design and location ()	

End of Block: Block 3

Appendix C

Gantt Chart

A Term (Aug. 2021 - Oct. 2021)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Goal formation for project							
Research into purpose of capstone projects							
Interviews with professors of the WPI Business School							
Identifying WPI Business School MQP formation process map							
Creating flowchart, identifying bottlenecks in process							
Research into matching methods of capstone projects							
Creating project Background and Methodology							
Writing potential model constraints in sentences							
Editing project Background and Methodology							

B Term (Oct. 2021 - Dec. 2021)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Interviews with professors of OIE, CS, BME departments	■	■	■				
Prioritizing model constraints by importance to MQP formation		■	■	■			
Evaluate WPI Business School survey to undergraduates		■	■				
Developing linear optimization model	■	■	■				
Finalizing MQP process maps			■	■			
Testing Model with Mock Data		■	■	■	■	■	■
Analysis of Mock Model Data				■	■	■	■
Adjusting project methodology as model developed				■	■	■	■

C Term (Jan. 2022 - Mar. 2022)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Outlining and writing final methodology for report	■	■	■				
Obtaining WPI Business School Survey Data			■	■			
Anonymizing WPI Business School survey data				■			
Testing model with anonymized data				■	■	■	
Adjusting optimization model based on anonymized data results				■	■	■	
Finalizing non-model recommendations				■	■	■	
Editing model for ease of use			■	■	■	■	■
Final MQP write-up			■	■	■	■	■
Presentation Preparation					■	■	■