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Renovating Contract Delivery Education to Bridge the Gap Towards Current Practices

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Abstract

With the growing adoption of innovative practices, accelerated construction methods, and technological advancement in the construction industry, curriculum reform is necessary to provide nexus between the current practices and construction management (CM) education. Although construction practices have evolved throughout the last decade, CM education has not yet revolutionized which sparks questions about the relevancy and efficacy of the current programs and curricula. Generally, in complex construction projects, traditional contract delivery methods have been found to limit innovative construction practices and extend the construction schedule as well as seldom provide the best value to the owner. Despite the shortcomings of the traditional contract delivery methods, the education of such delivery methods is still being taught as mainstream in CM education. To this end, an alternative technical concept (ATC) coupled with accelerated construction technique is currently being implemented to address the issues related to conventional methods of project delivery during construction. These methods have been effective to successfully replace the deteriorating infrastructures, incorporate an innovative design that fosters faster construction, and ensure delivery of the project without interruption of critical transportation services. Unfortunately, CM students are rarely exposed to such accelerated construction means as well as advanced contract delivery methods that are currently being more adopted in practices. Thus, there is a pressing need to consider a pragmatic contract delivery education in construction to bridge the gaps towards current practices. Such curriculum reform focuses on disseminating recent advanced practices while fostering the development of critical skills among CM students. To achieve this, approximately 59 undergraduate and graduate students are introduced to an advanced contract delivery module on ways of gaining competitive benefits during procurement and construction project delivery of infrastructure projects. A questionnaire survey evaluated the necessity of integrating recent, novel, and advanced construction practices in the curriculum. The obtained data is analyzed through Ordinary least square regression analysis by utilizing machine learning techniques such as Pearson's correlation heat map, train-test split, and cross-validation to develop a logistic regression model. The results indicated that factors such as comprehension of traditional and alternative project delivery methods as well as construction experience significantly influence student's inclination towards mastering skills in alternative technical concepts. Moreover, the CM students also reported that the integration of such advanced contract delivery methods in CM curriculum will provide an edge in their professional careers. The study demonstrates the feasibility of reforming core construction management curricula to incorporate current practices of the construction industry as well as nurture advanced skills and knowledge, which better prepares and equips our future workforces in their professional careers.

Keywords: Accelerated Construction, Construction Management Students, Contract Delivery Methods, Construction Management Curricula

Background and Motivation

Accelerated Bridge Construction (ABC) is an innovative bridge construction technique that has drastically improved highway construction practices through the integration of effective plans, high-performance materials, safe designs, and reducing the overall construction time of new bridges or rehabilitation of existing bridges. However, recent studies have highlighted major issues in the ABC technique which include the high initial cost of ABC, lack of standardization, inexperienced contractors, and inefficacy of traditional project delivery methods [1]. Traditional project delivery methods such as Design-Bid-Build (DBB) involve solicitation of the construction contract by the owner to deliver quality projects at a known price. As such, it has a longer project duration due to a lack of intersection between design and construction phases [2]. To reduce construction schedule and improve constructability as well as innovation, many construction stakeholders are adopting alternative project delivery methods such as Design-Build (DB) and Construction Manager-General Contractor (CMGC) that involves early contractor involvement. Moynihan and Harsh (2016) highlighted that the alternative project delivery method has gained significant market share in the past few decades as shown in Figure 1. due to the intersection of design and construction phases which shifts more responsibilities to other parties other than owners [3]. However, during the initial phases of construction, the contractor doesn't have complete plans in such a project delivery approach and these methods include higher procurement costs and stipends for proposers.

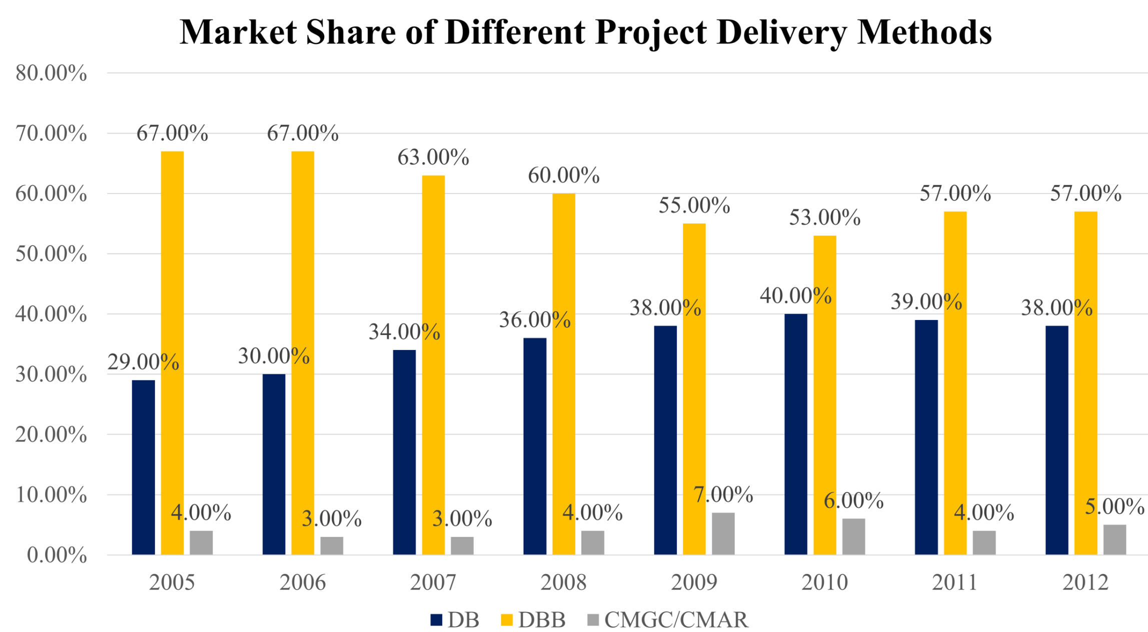

Figure 1: Timeseries for a market share of traditional and alternative project delivery method [3]

To address such issues, a promising solution is the integration of the Alternative Technical Concept (ATC) for contract delivery, which fosters alteration in baseline design of ABC method and provides efficient solutions to complex problems encountered in project delivery [4]. The use of this technique helps to: (1) reduce project costs; (2) reduce the impact on the public by the efficient flow of regional and local traffic safely; (3) incorporate an innovative design that fosters faster construction; (4) enhance quality control and inspection; and (5) encourage the integration of green techniques [5]. Since this approach encourages best-value solutions through an equal or better product during procurement, the popularity of ATC in recent times has increased and consequently boosted the number of submittals from many contractors [6]. Gransberg et al. (2014) indicated that the use of the alternative technical concept is not limited to any type of project delivery method and can be implemented regardless of technical or procurement issues of all kinds of transportation projects [8]. Additionally, some of the states allow the alternative systems to be implemented in other projects in the future such that the benefits of ATC for contract delivery and a widely applicable innovative design can be exploited. Although the integration of ATC for contract delivery of ABC project has such a positive impact, few construction stakeholders are well-equipped with knowledge and skills to work with such a method in ABC projects. Therefore, there is an urgent need for a reformed and pragmatic curriculum that disseminates recent advanced practices to foster critical skills among Construction Management (CM) students.

Construction practices have significantly evolved in terms of innovation, technological advancement, and economic expansion to better address the growing complexities of construction projects. However, CM education/curriculum is yet delayed in reforming such that CM students are rarely exposed to accelerated construction means as well as advanced contract delivery methods that are currently adopted in practices. Traditional CM courses are designed to teach students about the conventional working mechanism of the construction industry, interactions and responsibilities of different construction stakeholders, and tools available to manage and control different aspects of construction projects such as quality, costs, and time [9]. In recent years, some studies have highlighted a few initiatives which signify the importance of new course development that fosters skills to encourage innovation among CM students. For instance, White et al. (2014) highlighted the efficacy of integrating a new course, Innovation in Construction, within CM education with a focus on three key goals: (1) engaging students' in activities that improve their ability to distinguish the quality of innovations that are applicable in real-world construction practices; (2) providing in class-lectures to students' from world-renowned experts who developed innovative products within the construction industry; and (3) exposing CM students to management characteristics and tools that help innovative companies to thrive [10]. In addition to the development of courses that heightens awareness about the importance of innovation culture among CM students, there is also a pressing need for a pragmatic curriculum that educates students about advanced contract delivery practices adopted in infrastructure projects. Forgues et al. (2011) highlighted the need to shift towards rethinking how integrated practices embodied in integrated project delivery of infrastructure projects should be taught to engineers, architects, and construction managers [11]. Similarly, Lines et al. (2014) indicated that improvement in project performance and successful adoption of advanced project delivery practices in the Architecture, Engineering, and Construction (AEC) organization is significantly dependent on relevant training and education to construction stakeholders [12]. Since the success of projects utilizing alternative project delivery methods depends on the capability of the employee to work with the technique, it is imperative to educate CM graduates about the concepts early on such that it accelerates their transition in a professional career. Through bridging the gap between contract delivery education curriculum and current practices, graduating CM students may potentially become better practitioners in the evolving construction industry.

The undergraduate and graduate students in the Construction Management course are primarily prepared for developing skills and knowledge in scheduling and estimating, quality, safety, sustainability, project delivery, among others that prepare them for working in the construction industry. With increasing trends to the adoption of advanced construction project delivery methods, a reformed and pragmatic curriculum was necessary for the Construction Management students to better prepare for future careers. Thus, the authors developed a pilot module based on the CM curriculum within different construction schools to provide nexus between the current practices in construction and construction management education. This pilot module had two objectives: (1) identify the factors that directly impact students' inclination towards developing their capabilities in Alternative Technical Concepts; (2) determine students' degree of polarity (i.e., positive or negative) towards curriculum reform as well as exposure to accelerated construction means and alternative project delivery methods.

Methodology

This study utilizes a mixed-method sequential exploratory design to capture and quantify students' interest in advanced construction practices such as ATC that can potentially facilitate graduating students with the required knowledge, skills, and experience which meets industry expectations. As shown in Figure 1, the framework was implemented in a remote CM course and the authors initially developed a comprehensive module associated with the integration of ATC for contract delivery of infrastructure projects such as ABC. The content of the module focused on: (1) basic concepts including success factors and federal requirements for its adoption; (2) importance of ATC and submittal period for ATC in different project delivery method; (3) exemplary case studies highlighting successful integration of ATC in ABC and highway projects; and (4) Benefits of using ATC for economical and faster replacement/rehabilitation of deteriorating bridges. The module was partially developed based on the research finding of studies available within the Accelerated Bridge Construction – University Transportation Center (ABC-UTC) library [13]. After the integration of the module within the CM course in the Fall 2020 semester, the authors conducted a questionnaire survey to record student's perception of the necessity of integrating the recent, novel, and advanced construction practices in CM curriculum. Additionally, the survey also collected student's ability to comprehend and work with different contract delivery methods used in the infrastructure projects as well as their socio-demographic background as shown in Figure 2.

Given that accelerated bridge construction flourished significantly in the past 10-20 years through advancing research in Accelerated bridge construction-University Transportation Center (ABC-UTC), most states in the U.S. are considering this method as a standard practice. Although a plethora of research and development (R&D) activities are being conducted for improving the implementation of the ABC method, few CM graduates are aware and skillful enough to work with ATC for contract delivery of ABC projects. Moreover, to fulfill the growing demand for a skilled workforce for project delivery of such infrastructure project, the pilot framework for reformed and pragmatic curriculum followed two main guiding questions in this study: (1) What are the factors that influence students to pursue new courses that bridge construction education with current practices in the construction industry; and (2) What are the students' perceptions and degree of polarity (i.e., positive/negative) towards curriculum reform as well as exposure to accelerated construction means and alternative project delivery methods? A systematic literature review identified key factors that impact the successful integration of comprehensive modules in the contract delivery education, and these were validated through focus group discussion among industry experts. Based on experts who have worked on ATC based projects, factors such as comprehension and ability to work with different project delivery method (e.g., Design-Build, Design Bid Build, Construction Manager-General Contractor, and Integrative Project delivery method), basic knowledge of ATC concept, experience in the construction industry, and Students academic status (i.e., international student/local student) have been considered to influence the success of the curriculum.

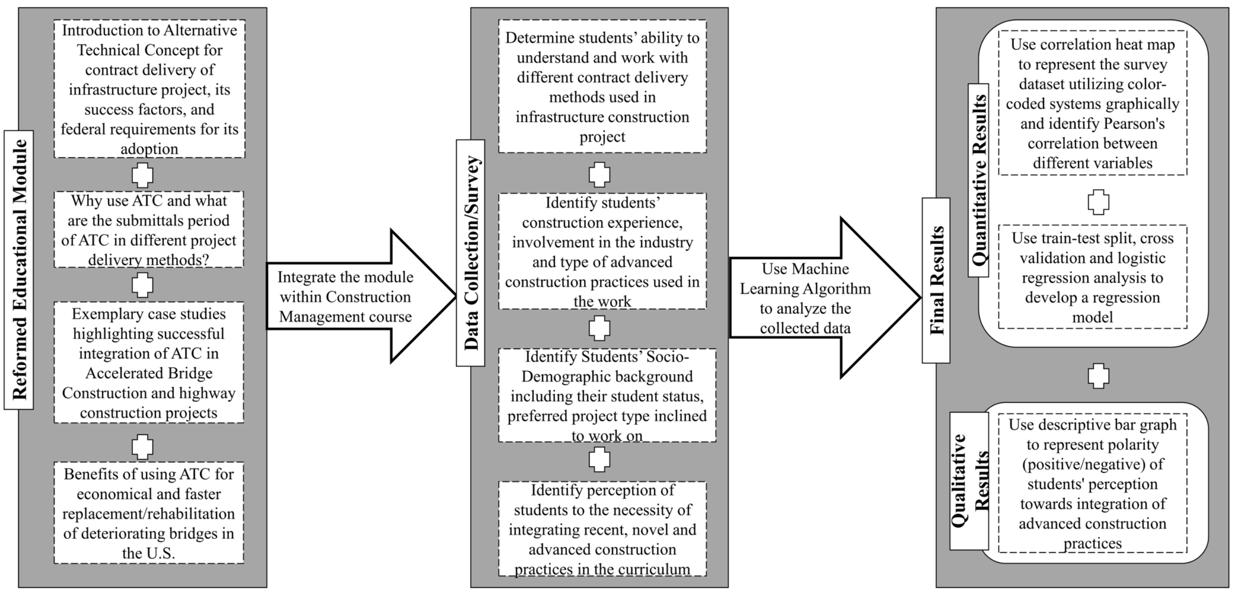

Figure 2: Research Overview

The authors conducted a quantitative analysis using a machine learning algorithm and qualitative analysis by utilizing descriptive statistics. Initially, data exploration provided a proper understanding of the main characteristics of data such as accuracy, size/amount of data, the correctness of data, potential relationship, completeness of data, and initial pattern in the data through visual exploration. In this study, a correlation heat map is used to represent the survey dataset utilizing color-coded systems graphically. The colored cells in the heat map, typically in a monochromatic scale, show a 2D correlation matrix between two discrete dimensions. Based on the obtained results from data exploration, the study utilized a relevant dataset and analyzed the obtained data with train test split, cross-validation, and use of different metrics on five different machine learning (ML) algorithms. The data mining techniques were utilized to obtain an accurate regression model for the collected data and determine which independent variable has a statistically significant effect on the dependent variable. The ML algorithm utilized train test split to break down the data into a training set and testing set. In this case, 80% training set, and 20% testing set were used for the coding. The outcome variable for the training set was used to test it on the test set and then compared against the correct outcomes to see how well it predicts. During the initialization, it is important to build empty models so that data sets can be trained and used for creating the models. These models were put into one array of models. Next, the program goes through each of the models which will use the dataset and uses the training set to build the best model that's possible which is called cross-validation. After the selection of the best machine learning algorithm, the ordinary least square (OLS) regression analysis was utilized to develop the regression model. OLS regression is a predictive modeling technique that assumes a linear relationship between independent variables (i.e., input variables used for prediction) and the dependent variable (i.e., variable to be estimated/predicted). This data mining technique is useful for determining the statistical relationship between different continuous variables. Since this is a pilot study, the confidence interval in the analysis is assumed to be 90% for the regression analysis. These data mining techniques, algorithms, and methods are extremely useful to investigate the unique patterns in a large education dataset in a short period thereby, indicating that it can be exploited for analysis of future large-scale studies in different institutions [14].

Results and Discussion

This section presents the results associated with students': (1) comprehension of advanced methods used for replacing the deteriorating infrastructures, incorporate an innovative design that fosters faster construction and ensure delivery of the project without interruption of critical transportation services; and (2) perception to the necessity of integrating recent, novel and advanced construction practices in the curriculum. The recorded data included diverse group of students: 18 female and 38 male students, reporting multiple races, such as African American, White, Asian, among others and more than half of the students having industry experience as shown in Figure 3.

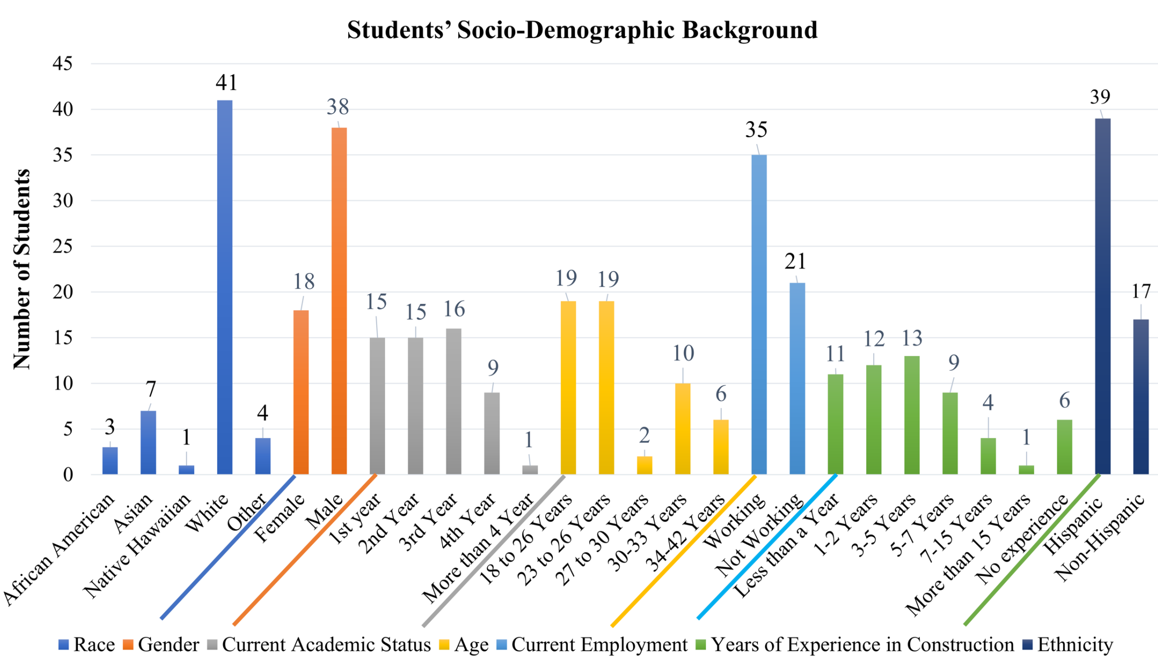

Figure 3: Socio-demographic background information of construction management students

To determine the correlation of features in the dataset used for the regression model, a heat map was developed using a data mining algorithm. Figure 4 shows a heat map in which each square shows the correlation between the variables on each axis. To explore students' comprehension of advanced contract delivery methods, students were asked to rate their ability to understand and work with contract delivery methods for infrastructure projects on a five-point scale where 1 represents no knowledge and 5 represents expert knowledge. Different contract delivery methods included in this survey are Design-Build (DB), Design Bid Build (DBB), Construction Manager-General Contractor (CMGC), Integrated Project Delivery Method (IPD), and Alternative Technical Concept (ATC). Moreover, an in-class lecture introduced students to the Alternative technical concept in which they learned about its applications as well as benefits in current construction projects. Then, students provided feedback on whether such advanced methods of project delivery should be integrated in the construction management curriculum where students provided ratings for their interest (ExgATC) on a five-point scale where 1 represents "Not interested" and 5 represents "Extremely interested". Other variables included in the regression model incorporates Student status (i.e., local student/international student) and their construction experience (CE). Figure 4 shows the Pearson's correlation values of features in the dataset where some of the variables have values closer to zero while others have values closer to 1. The heat map is also symmetrical about the diagonal as the same two variables are being paired together in the squares. The correlation values for diagonals are all 1 or dark blue because these squares are correlating each variable to itself indicating a perfect correlation. Some of the variables such as DBB-DB, CMGC-DBB, IPD-CMGC, and ATC-IPD have values above 0.5 and closer to 1 indicating that a stronger correlation exists between these variables and are more positively correlated such that as one increases so does the other. Since highly correlated independent variables may cause multicollinearity problem in regression, only DB and ATC will be selected for analysis. The multicollinearity problem in a regression model is critical since it becomes difficult for the model to estimate the relationship between each independent variable and the dependent variable independently. Other variables with correlation values closer to zero indicate that there is no linear trend between the two variables. Therefore, for the ordinary least square regression analysis, DBB, ATC, CE, and Status were included as the independent variable.

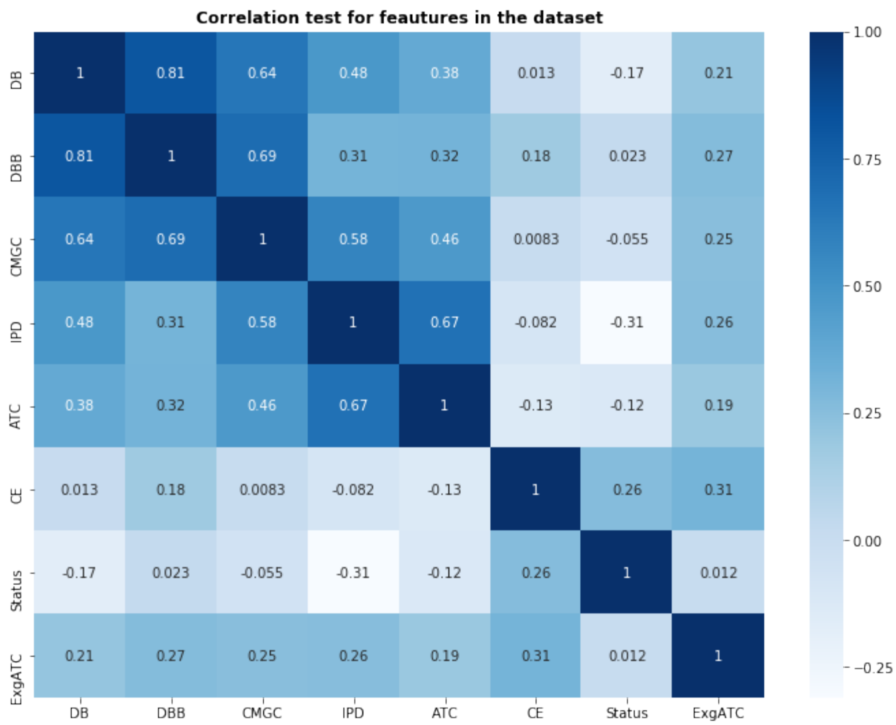

Figure 4: Pearson’s correlation heat map for a dataset of the regression model

Based on the results of the cross-validation for different models including linear discriminant analysis, K Neighbor Classifier, Decision tree classifier, Gaussian naïve Bayes, Support Vector Machine, and Logistic regression, the cross-validation score (i.e., a measure of accuracy/performance of model) and the standard deviation of each model were analyzed. Consequently, the logistic regression model had the highest value for the cross-validation score and standard deviation due to which it was selected for developing the regression model. After creating the model with the training set, the predictions are made with the test set. Figure 5 shows the summary of Ordinary Least Square regression results, which provides a comprehensive idea about the data distribution and behavior. The p-value for students’ comprehension of Design Bid Build (DBB), students’ basic knowledge of Alternative Technical Concept (ATC), students’ construction experience (CE), and current student status are 0.005, 0.063, 0.065, and 0.211 respectively. The obtained p-values of DBB, ATC, and CE are less than 0.1, which indicates that data is statistically significant for these variables. Based on the obtained results, it can be inferred that the expected growth in interest of CM students towards developing skills in alternative technical concept depends on students’ current knowledge of DBB/other project delivery method, a basic understanding of ATC, and their construction experience. Therefore, for successful integration of the reformed and pragmatic module in the CM curriculum, the instructors should ensure students have adequate knowledge about various traditional and recent project delivery method. Similarly, hands-on experience in the construction industry also plays a significant role in disseminating pragmatic concepts implemented in the ABC projects and ATC as well as improve CM students’ ability to integrate innovative solutions in the infrastructure projects. Figure 5 also shows the value of adjusted R-squared which is found to be 0.883 indicating that the regression model is able to explain 88.3 % variance of the dependent variable.

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                          OLS Regression Results
=======================================================================================
Dep. Variable:                 ExgATC   R-squared (uncentered):                   0.893
Model:                            OLS   Adj. R-squared (uncentered):              0.883
Method:                 Least Squares   F-statistic:                              83.65
Date:                Fri, 25 Dec 2020   Prob (F-statistic):                    7.01e-19
Time:                        11:15:27   Log-Likelihood:                         -69.726
No. Observations:                  44   AIC:                                      147.5
Df Residuals:                      40   BIC:                                      154.6
Df Model:                           4
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
DBB            0.5043      0.168      3.004      0.005       0.165       0.844
ATC            0.3245      0.170      1.909      0.063      -0.019       0.668
CE             0.7966      0.419      1.901      0.065      -0.050       1.644
Status         0.5760      0.453      1.271      0.211      -0.340       1.492
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Figure 5: Ordinary Least Square regression analysis results for expected growth in the integration of the ATC method in CM curriculum

For the qualitative data collection, students were asked open-ended questions that focused on: (1) desirability of integrating ATC method in either undergraduate or graduate construction management curriculum; and (2) impact of the module for graduating construction management students. The survey results indicated that only six students had learned about the ATC method in their workplace and the rest of the 50 students reported not being aware of such contract delivery practice. For the first question, approximately 22 students reported that advanced project delivery practices adopted in construction sites should be part of both undergraduate and graduate studies curricula as shown in Figure 6. While around 10 students also indicated that such methods are more complex and should only be part of the graduate studies curriculum. Since the primary goal of the ATC concept is to improve project quality, reduce project costs and propose a design equal to or better than a base technical concept, both undergraduate and graduate students may benefit from learning these concepts such that they are able to fulfill the industry expectations. Moreover, a pedagogical approach such as the integrative learning approach may be utilized to foster collaboration between undergraduate and graduate students such that it encourages critical thinking and engagement in solving real-world problems [15]. For the second question, 41 students asserted that integration of such advanced practices provides graduating CM students an edge in a competitive professional construction career. While only four students reported that the advanced and novel concepts of contract delivery should not be part of mainstream Construction Management courses and can be learned in a professional career.

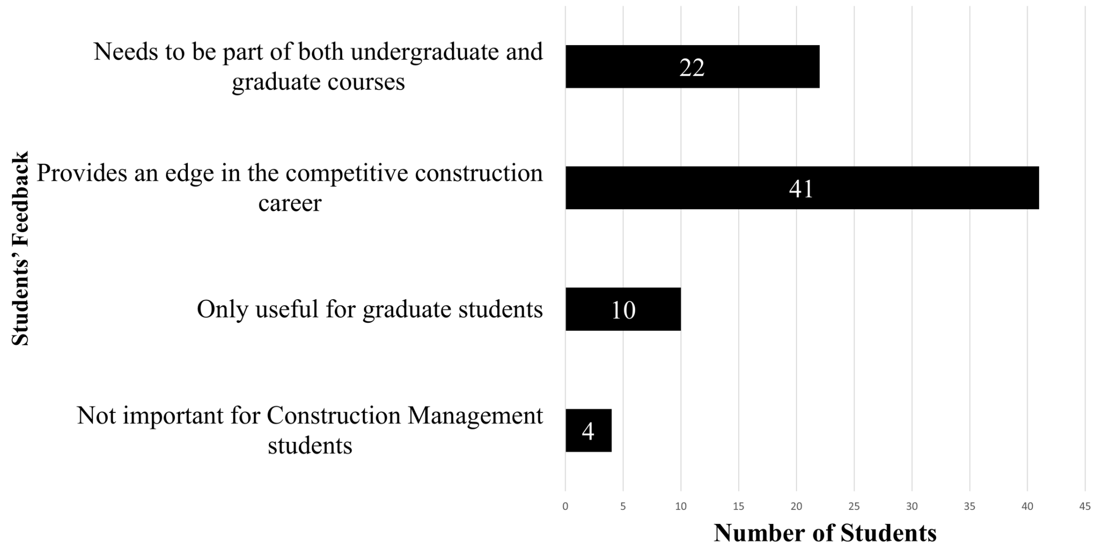

Figure 6: CM Students' perception towards curriculum reform and its impact on their professional career

Limitation and Future Work

While the authors aspired to establish a transferable, reformed, and pragmatic contract delivery curriculum the study includes some limitations including the subjective nature of the survey responses due to personal opinions and self-judgments. However, the authors believe that correlating the survey questionnaire to relevant literature supports valid conclusions and judgments. To improve the survey data and design a better curriculum, the authors aim to further integrate the module in a hybrid environment (i.e., face-face and online environment) to understand the efficacy of the reformed curriculum and activities incorporated in the updated course. Furthermore, future studies will focus on improving students' interpersonal skills and critical thinking abilities especially in infrastructure projects such as ABC through the adoption of a project-based learning method where students can collaborate, present and discuss real-life problems and challenges [16].

Conclusion

Drastic changes in construction practices are transforming the way infrastructures are planned, designed, built, and delivered. In addition to technological advancement in the construction industry, the methods utilized for project delivery of infrastructure projects is also revolutionizing. With the increase in adoption of innovative methods such as Alternative Technical Concept (ATC) in contract delivery of infrastructure projects, there is a growing demand for a capable workforce who are able to efficiently execute responsibilities in innovation-based infrastructure projects. Therefore, this study integrated a pilot module associated with current practices in contract delivery of infrastructure projects such as ABC in a CM course. The results of the study indicated that only six students had learned about the ATC method in their workplace and the rest of the 50 students did not know such construction practice. As such, it can be concluded that concepts about new practices should be integrated within the CM education to prepare CM graduates for a competitive construction career as well as encourage critical thinking for innovation in construction early on in their careers. Moreover, the study also developed an OLS regression model by utilizing a machine learning (ML) algorithm. The results of ML analysis indicated that a comprehensive understanding of project delivery methods such as Design Bid Build/alternative project delivery methods, basic knowledge of ATC, and construction experience influences students' inclination towards learning and developing skills related to current practices of advanced project delivery method. Additionally, consideration of these factors during the design of the curriculum would also ensure the successful integration of reformed and pragmatic modules in contract delivery education.

The findings of the study contribute to the existing body of knowledge on contract delivery of construction projects by highlighting the significance of education for the evolution and adoption of advanced methods in contract delivery of complex infrastructure projects. Although the integration of ATC for contract delivery may address the shortcomings of different project delivery methods, it is not widely promoted, and many construction stakeholders are completely unaware of such concepts. Therefore, the integration of such concepts in the construction management curriculum may extensively improve project delivery with the greatest potential for wide acceptance of this method in the future.

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