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A Statistical Approach to Analyzing a Graduate Curriculum for Construction Management Education

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BACKGROUND

Over the past couple of decades, the construction industry, like every other industry today, has gone through a tremendous amount of change due to technological innovation, intense market competition, and community or government regulations, among other factors. The industry has also experienced a significant downturn of revenue since its peak in 2008 and has just started to show increase in demand and revenue. However, the drastic change in the social, economic, and regulatory environment demands continuous adaptation in all aspects of the industry. Therefore, Construction Management (CM) education needs to continually assess and re-assess its curriculum and see if its program properly educates future construction leaders who will face such dynamic and continual change.

Most CM graduate programs are designed specifically for middle and upper-level management positions within the construction industry.[1] One of the major purposes of the CM graduate program is to educate and train construction professionals and managers so that they can get prepared for a successful and productive career.[2] The curriculum provides a holistic foundation of management, technology, finance, legal principles, and other valuable skills. Nevertheless, not all skills can be taught in a CM graduate program. Hence, change in the construction industry should be assessed and the graduate curriculum should be regularly evaluated to reflect this demand and change in the industry.

An analysis of the CM graduate curriculum was performed at a New England area state university to identify new course content areas. A statistical approach was adopted to analyze how the curriculum is aligned with student expectations. Multidimensional scaling (MDS) was used to explore dimensions hidden or implied in students' minds in determining how CM courses in the curriculum contribute to achieving their learning objectives and what the underlying dimensions these learning objectives are aligned along are.

GRADUATE EDUCATION IN CONSTRUCTION MANAGEMENT

Bilbo and Yeager[3] define construction education as the preparation of professionals for the construction industry. Oglesby[4] argues that the study of construction should include socio-humanistic, math and science, basic engineering and design, construction business, construction technology, and construction management. Lee et al.[5] stress that the content of existing construction courses should be constantly evaluated and updated in accordance with industry needs and technology to reduce the perception discrepancy between the industry and academia. Otherwise, the course content areas within the graduate curriculum may present a lack of subject matter acceptable to both practitioners and academia. Therefore, construction education will fall short in some aspects unless the curriculum is aligned well with the ever-changing industry needs.

Segner[6] emphasizes that graduate construction education is the next step of the evolution of construction education. The construction industry has been expressing an increased interest and support for advanced construction education. Furthermore, construction professionals are seeking Master's level graduate education to sharpen their proficiency and broaden their knowledge base. Badger and Segner[7] mention that construction professionals are looking toward additional educational opportunities insomuch as the technology revolution is placing new demands on them. Segner[6] also describes that there are two critical issues and challenges in graduate construction education: (1) tailoring graduate coursework to fit the varying experience levels of graduate students and (2) dealing with a number of students coming from different disciplines for a career change.

GRADUATE CURRICULA IN CONSTRUCTION MANAGEMENT

To improve the overall quality of graduate construction education, accrediting agencies such as the American Council for Construction Education (ACCE) have established standards and criteria for master's degree construction education programs. More recently, the ACCE defined standards and criteria for accreditation of master's degree construction education programs as follows:[8]

- Organization and administration
- Curriculum
- Faculty and staff
- Students
- Facilities and services
- Relations with industry
- Relations with the general public

Currently, the ACCE has only four CM master's degree programs accredited.[9] The number of CM master's degree programs accredited and the number seeking accreditation are expected to grow. The curriculum is an important criteria for accreditation. According to the ACCE document 103MD:[8]

> "The purpose of the curriculum is to provide an education that will lead to a leadership role in construction and to prepare the student to become a responsible member of society. The curriculum should be responsive to social, economic, and technical developments and should reflect the application of evolving advanced knowledge in construction beyond that associated with a baccalaureate degree program in construction education." (p.3-4)

In revising and developing the curriculum, curriculum analysis is essential since the information obtained from the analysis is extremely valuable for the curriculum reformation. Oliva[10] asserts that appropriate procedures for formative curriculum evaluation should be devised to determine whether or not the curriculum goals and objectives are being successfully carried out.

The ACCE requires that the goals of the curriculum must be associated with the needs of both society and construction professionals.[8] Lee et al.[5] also point out that the CM curriculum and program should be aligned with important concepts and trends in the contemporary industry. Thus, graduate curriculum should be regularly evaluated and updated to accommodate expanding requirements of the profession and advancements in knowledge.

RESEARCH DESIGN AND METHOD

A statistical approach was used to examine how the CM graduate curriculum is aligned with the needs of society and construction professionals. For this study, a survey instrument was developed to capture the students' perceptions of the CM graduate courses, focusing only on the subject matters of each course. The main objective of this survey was to construct some hidden dimensions implied in the minds of students who took or would take these courses. To support this, an exploratory MDS technique was used in this study.

Table 1. Background Demographic Information of Graduate Students

Student Status:

Full-time student	32%
Part-time student	68%
Total	100%

Student Age:

25 or under	24%
26-35	52%
36-45	12%
46-55	12%
Total	100%

The Area Student Works or Worked for:

Architectural Design	18.5%
Structural Engineering	7.4%
MEP	3.7%
Civil Works (Utilities, Highway, Bridge, etc.)	22.2%
Building Construction (Residential & Commercial)	40.8%
Material Suppliers	3.7%
Property Management	3.7%
Total	100%

Years of Work Experience in the A/E/C Industry:

Minimum	Maximum	Average
1 year	33 years	8.46 years

Sample. A conveniently drawn sample group of CM graduate students was surveyed. They were asked to evaluate each of the CM graduate courses on the survey questionnaire. The graduate students completed the survey during class. Appendix A shows background demographic information about the CM graduate program students at a New England area state university. Forty-eight students participated in this study out of eighty-five total CM major graduate students in the CM program. Table 1 presents the background demographic information of CM graduate students at a New England area state university. All students attended in two graduate level classes completed the survey.

Table 2. CM Graduate Curriculum

Core Curriculum

CM 505	Construction Project Delivery Systems	3
CM 515	Construction Law	3
CM 545	Construction Risk Management	3
CM 575	Construction Financial Management	3
TM 594	Research Methods in Technology	3

Electives

CM 425	Applied Structural Systems	3
CM 435	Construction Superintendency	3
CM 455	Construction Project Management	3
CM 525	Construction Equipment Operation and Management	3
CM 535	Sustainable Buildings	3
CM 555	Construction Project Controls	3
CM 565	Construction Labor Relations	3
CM 585	Advanced Construction Law	3
CM 596*	Topics in Construction Management	3

*(Topics of interest in the CM field not currently covered by the CM curriculum.)

Capstone

CM 595	Applied Research in Construction Management	3

Measures. To empirically measure how well the graduate CM curriculum at a New England area state university is reflecting changes in construction technologies and management trends, a survey instrument was developed. There were the following questions on the survey:

1. Please read the course catalog provided and rate how relevant the course's subject matter is to the construction industry on a scale from 1 (not relevant) to 5 (very relevant).
2. To what extent do you agree with each of the following statements on a scale from 1 (strongly disagree) to 5 (strongly agree)?
    - "I am satisfied with graduate coursework."
    - "I am satisfied with the CM graduate program."

3. Beyond the listed courses, what topics would you most like to learn about for your professional career?

The first question focused on measuring the students' perceptions on the CM graduate courses in Table 2. The second question aimed at gathering the student satisfaction ratings of the overall graduate coursework and program. The third question was to gather the students' opinions on new course topics. Forty-eight graduate students with professional experience in the construction field participated in this survey. Through the survey, each participant was asked to evaluate the relevance of graduate courses offered by the CM program to the construction industry. Even the participants who had not completed some courses listed on the survey were supposed to rate all of the courses after reading the course catalog provided because this study was focused on capturing the students' perceptions of the subject matter of the graduate courses.

Data Analysis. Based upon the ratings of the relevance measures, all CM courses were correlated; and each correlation co-efficient between two courses is used as their 'proximity' score. Thereby, the derived correlation matrix becomes input data for the MDS, which is intended to detect meaningful underlying dimensions. This statistical tool allows us to explain observed similarities or dissimilarities (distances) between CM graduate courses. Borg and Groenen[11] state that MDS is a data-analytic approach to discovering the dimensions that underlie judgements of similarities or dissimilarities among different objects. MDS also makes the data accessible to visual inspection and exploration.

Table 3. Descriptive Statistics

	N	Min.	Max.	Mean	SD
CM 505	48	3	5	4.36	0.70
CM 455	48	2	5	4.32	0.92
CM 515	48	1	5	4.24	0.97
CM 575	48	2	5	4.21	0.95
CM 435	48	1	5	3.97	1.07
CM 545	48	2	5	3.92	1.09
CM 555	48	2	5	3.91	0.84
CM 525	48	2	5	3.71	0.91
CM 596*	48	1	5	3.71	1.19
CM 535	48	1	4	3.59	0.70
CM 565	48	1	5	3.39	0.93
CM 585	48	1	5	3.09	1.16
CM 425	48	1	5	2.97	1.16

Note: *The topic of this course was 'Safety Administration'.

RESULTS AND DISCUSSION

The students were asked to rate the degree of relevance of each CM graduate course on a scale from 1 (not relevant) to 5 (very relevant). TM 594 (Research Methods in Technology) and CM 595 (Applied Research in Construction Management) were excluded in this study due to the properties of the two courses. Table 3 summarizes the result of descriptive statistics from the survey.

As stated above, MDS analysis was performed to visually explore the relationship among all graduate courses and detect some implied dimension hidden in the minds of the students. This analysis is certainly based on the assumption that the higher the correlation coefficient is between two evaluated courses, the higher similarity is between the two.

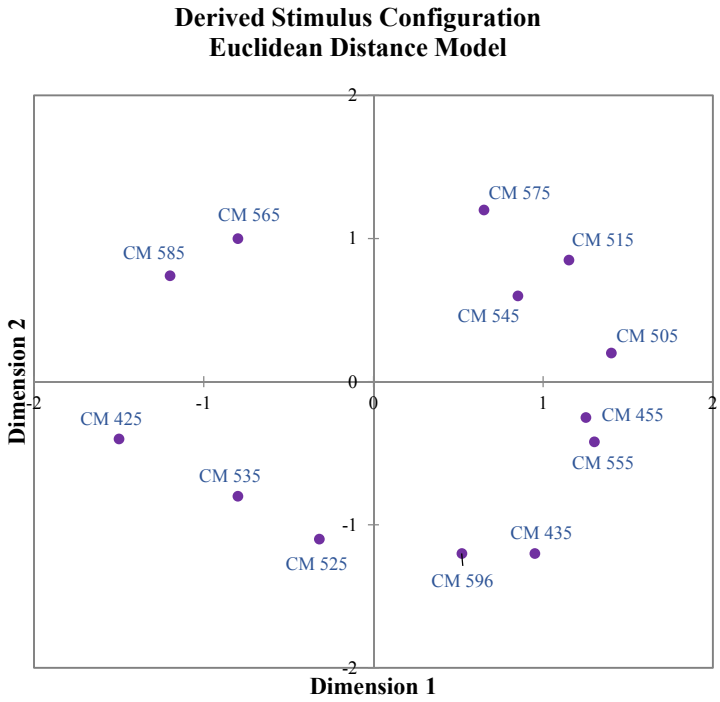

Figure 1. Two-Dimensional MDS Representation

As illustrated in Figure 1, the graduate courses are arranged in such a way that their distances correspond to the correlations in a two-dimensional configuration plot. For example, CM 455 (Project Management) and CM 555 (Project Controls) are close to each other because the two courses are highly correlated. The two-dimensional MDS representation shows how closely the courses are positioned one another in terms of the similarity. Interestingly, the distance between the points of CM 455 and CM 555 is the shortest. However, students' perceptions on the relevance of the two courses presented in Table 3 are quite different, considering their similarity.

Based on the clustering results on Figure 1, it appears that the students made subtle judgements. For instance, CM 585 (Advanced Construction Law) is seen as closer to CM 565 (Construction Labor Relations) than to CM 515 (Construction Law) even though CM 585 and CM 515 are very closer in terms of their course subjects. In addition, CM 525 (Construction Equipment Operation

and Management) and CM 596 (Safety Administration) are not close in the two-dimensional space although the two courses have the same average score as presented in Table 3. These indicate that there are clearly some other aspects of the students' perceptions influencing the course ratings.

The initial MDS scores were rotated multiple times to achieve the optimum solution for similarities and dissimilarities (distances) between all pairs of the elements (courses) and to produce the two dimensional spread. Close examination of clusters and elements (courses) in the clusters led us to the following meaningful dimensions: the x-axis (dimension 1) and the y-axis (dimension 2) represent "specialized (left) vs. general (right) knowledge" and "management (top) vs. project-specific (bottom) skills", respectively. Clearly, these dimensions are 'hidden and implied' in students' evaluation of the courses; and multidimensional scaling is designed to detect these implied dimensions. Unfortunately, this statistical technique is incapable of interpreting the results. Hence, researchers' close examination of the clusters are required to interpret the results and understand the 'hidden and implied' dimensions.

As noted, by inspecting the configuration plot, it became evident that variation in the direction of the x-axis corresponds to a tendency to be specialized or general knowledge. In addition, variation on the y-axis separates management and project-specific skills. Therefore, it is assumed the students were taking account of these factors consciously or unconsciously when making their judgement for this survey. The results of this MDS analysis are useful to understand what the students' expectations are and reform the graduate curriculum. Surprisingly, all of the core courses create a cluster. This is likely because all of the courses deal with general and management concepts.

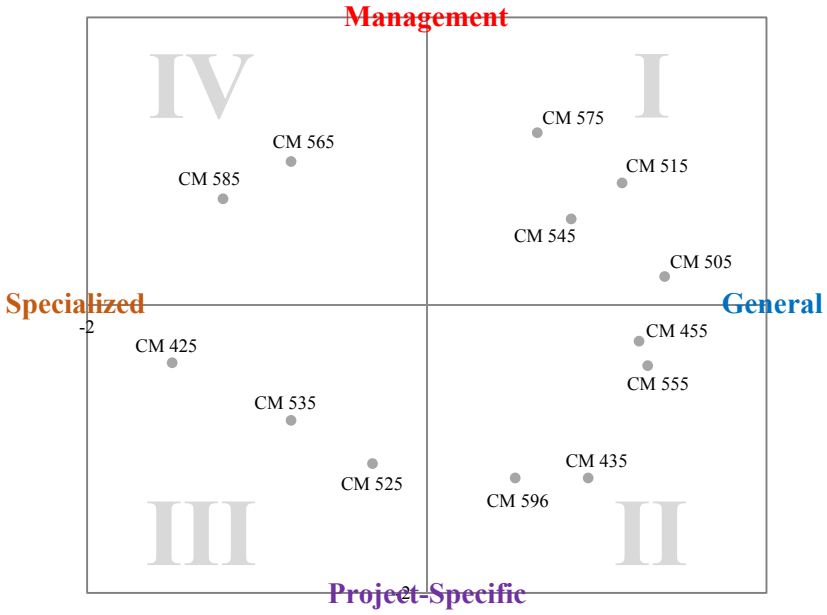

Figure 2. MDS Analysis Results

As shown in Figure 2, the quadrant I courses lay the groundwork for running a construction organization, including such topics as understanding financial techniques, legal principles, project delivery methods, and risk analysis common to the construction industry. The quadrant II courses build upon the foundation laid in the first quadrant, examining the various approaches to the process of monitoring and controlling projects as well as managing a construction site. In quadrant III courses, the emphasis is on the detailed tools and techniques for building construction. The quadrant IV courses emphasize upon acquiring the skills and the approaches needed for collective representation and dispute resolution. In addition to the courses in Figure 2, the capstone course (CM 595 Applied Research in Construction Management) as well as the 'Research Methods' course encompasses and applies all prior course works, and requires the production of a complete professional-quality project analysis, utilizing actual industry data and resources.

The students' ratings on the satisfaction levels of the overall graduate coursework and program were gathered on 5-point scales (1= strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, or 5 = strongly agree). The raw response ratings were analyzed to identify if there was any correlation between the two variables. As the result of this study, $r(46) = 0.48$, p-value < 0.005. This means that there is a significant positive relationship between these two variables. In other words, for those who responded to this survey, higher curriculum satisfaction scores correlated with higher overall program satisfaction score.

At the end of this survey, the students were asked to suggest new course topics. The majority of the students who responded to this question suggested the following course topics:

- Sustainability/Green Construction Techniques
- Building Information Modeling (BIM)
- Lean Construction Techniques
- International Project Management
- Advanced Cost Estimating & Analysis
- Advanced Construction Scheduling
- Advanced Materials & Methods
- Human Resources in Construction
- Environmental Issues with Building Construction
- Historic Building Preservation & Restoration

When adding a new course within the CM graduate curriculum, the MDS analysis results (refer to Figure 2) and the new course topics suggested by the students can be useful. For instance, based on the MDS analysis results, the new course needs to be placed in the fourth quadrant to keep the balance with other existing courses. Then, the new course topic can be selected using the criteria of "specialized" and "management". Therefore, the most appropriate topic would be "Environmental Issues with Building Construction" to meet the student's expectations.

IMPLICATIONS

This study shows that MDS can be utilized as a method for analyzing gradate curriculum for CM professional education and identifying where the curriculum is focused and should be focused. The results of the MDS analysis can be used to understand the CM graduate student's expectations from their higher education. This information would be useful in guiding the development and implementation of new graduate courses in CM education. Therefore, the CM graduate curriculum and program can be further aligned with industry requirements.

This study should become a stepping stone to using MDS as an analysis tool for curriculum development. Thus, the MDS method may evolve into a type of curriculum analysis technique, a way of quickly gathering information about student opinions which can be used as a feedback mechanism to revise the curriculum for CM professional education. Furthermore, MDS can be also used to assess the impact of the possible curriculum changes from students' suggestions of new courses and topics.

The clear conclusion of this MDS analysis is that student perception of the CM graduate courses involves more than is conveyed by the subject matter. It may be worth adding two cautionary remarks about this study. The similarities were obtained by the assessments of the forty-eight students. Implicitly, it was assumed that all the students used the same interpretable variables when making subjective assessments of the courses and the same relative weight when rating each of them. This may not be issues in this study. However, it would be useful to have a method of discovering whether this is true or not. The second remark is that the identification of interpretable dimensions for a two-dimensional configuration plot may be not the best way of discerning interesting patterns. It could be better to analyze the clusters of points which have practical significance.

CONCLUSION

To align the CM curriculum and program with industry requirements, construction programs must have a strong alliance with industry. Moreover, the administrator and the faculty must cooperate to develop a graduate construction education program of high quality and establish a structure to facilitate planning and evaluation for continuous improvement of the master's degree program. Undoubtedly, a graduate curriculum appropriately aligned with industry requirements is an important factor to ascertain the effectiveness of graduate construction education. To accomplish the goals and objectives of the graduate program, the graduate curriculum should be regularly evaluated to reflect demand and change in the industry in training and educating future construction leaders. Even though there is a strong subjective element in using MDS analysis, this method has been used to make more explicit the similarities, differences, and limitations in many other domains. This paper merely presents how to use the statistical approach to analyze graduate curriculum for CM professional education.

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