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Designing a Benchmark Indicator for Managerial Competences in Construction at the Graduate Level

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Abstract: The roles of construction project managers have evolved throughout the years. Current-day construction managers are faced with several challenges that require the acquisition of competencies in administration and management. Most employers in the construction industry seek professionals with a sound background in managerial skills. Nevertheless, most university curricula in architecture and civil engineering concentrate on conventional construction programs, leaving little room for appropriate courses in management. Accordingly, this paper proposes a tool for analyzing and comparing graduate programs related to management and administration in the construction sector. To achieve this, the study takes into consideration (1) a holistic model intended to map managerial competencies in construction, and (2) specific required subjects, revealed through market demands. This investigation compares the model versus university syllabuses, and subsequently proposes a benchmark indicator that measures the deviation of each program from the overall average. This study takes a significant step forward in determining whether the main topics reviewed cover specifications stated by the model and market demands for the professional construction manager. Further research is recommended to enhance the proposed methodology and seek the best way to cover current needs of professionals and employers in the construction industry. **DOI:** 10.1061/(ASCE)EI.1943-5541.0000075.
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Introduction

The growing complexity of the construction industry forces professional engineers to evolve and adapt. The level of education for a manager has become much higher in the construction industry (Christodoulou 2004). In the past, managers were either craft persons without a college education or graduates of an engineering program and trained on the job (Arditi and Polat 2010). However, as the magnitude and complexity of construction projects have increased, so has the demand for more specialized expertise (Gann 2000).

According to several writers (Edum-Fotwe and McCaffer 2000; Christodoulou 2004; Galloway 2007; Milosevic et al. 2007; Arditi and Polat 2010), managers currently working in the construction industry are faced with numerous issues regarding management and administrative activities, and they require extensive expertise to perform tasks in the areas of marketing, finance, accounting, human resources, contract law, economics, and environmental analyses, among others. Therefore, project managers are not only required to perform technical tasks but also to acquire managerial competencies for the entire construction life cycle (Russell and Yao 1996; Trejo et al. 2002). The performance of organizations that work in the construction industry depends mainly on them (Abbudayyeh et al. 2000; Chinowsky 2002). Moreover, most employers seek a well-managed project leading to growth in productivity and an increase in the quality of the services offered. For employees to fulfill their employers' expectations and properly manage a company, they require professional competencies that include a combination of both technical and managerial skills gained through experiences and studies (Tatum 1987; Milosevic et al. 2007).

The apparent consensus on the need for management education for professionals justifies the pursuit of a program that encompasses the knowledge required for the construction sector (Chinowsky 2002). Some believe that managerial education can be acquired at the workplace or should be introduced and integrated as part of undergraduate programs, while others consider that it should be taught at the graduate level (Christodoulou 2004; Galloway 2007; Arditi and Polat 2010).

Despite the long standing demand for continuous professional development in this area (Oglesby 1982; Arditi 1984; Tatum 1987), little attention is devoted to construction project management in academic courses. Current undergraduate courses in civil engineering and architectural degrees (B.Sc.) predominantly comprise a variety of design-oriented topics, leaving little opportunity for construction management subjects that are vital for successfully accomplishing construction projects (Lowe 1991; Russell and Yao 1996; Long 1997; Edum-Fotwe and McCaffer 2000; Russell et al. 2007; Galloway 2007; Arditi and Polat 2010). In many cases, university programs seeking accreditation are required to follow regulations from an external body such as the Accreditation Board for Engineering and Technology, Inc. (ABET) in the United States, through EC2000 criteria (ABET 2010), or Agencia Nacional de Evaluación de la Calidad y Acreditación (ANECA) in Spain (ANECA 2007) in compliance with the Bologna process (Reinalda

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and Kulesza 2005); both bodies have two main features: development of skills and competencies as core learning outcomes and implementation of quality assurance processes (Moon and Duran 2010). A singular case is the Associated Schools of Construction (ASC) that groups a particular kind of program specifically focused on construction management and that are interdisciplinary in nature (ASC 2010); they are accredited by the American Council for Construction Education (ACCE).

These assertions are also confirmed by several projects financed by the European Union and developed jointly by a network of European professors from several countries (Ireland, Lithuania, Poland, Portugal, Spain, and the United Kingdom). These academicians have been working on the relationship between academic degrees and professional qualifications in construction management; their seminal work is summarized in Teixeira et al. (2006). The last two projects (Teixeira et al. 2006; Pellicer et al. 2008; Minasowicz et al. 2009) linked the aims of extensive survey of the situation, analysis of results, benchmarking among countries, focus on best practices per country, and design and development of minimum contents for teaching manuals. The cooperative research conducted through these projects revealed that minor consideration is given to management and administration in European higher education courses, despite the demand for continuous professional training in this area. According to this research, most of the academic programs are focused on traditional civil engineering or architectural courses that fail to efficiently address the most relevant needs in management and administration knowledge for professionals working in the construction industry.

Summing up, current courses offered by universities do not comply with the managerial requirements of construction industry professionals. According to Russell et al. (2007), "too much focus has been applied to teaching engineers how to calculate and record versus how to think, read, and lead." In view of this scenario, this paper puts forward the research question of whether or not it is possible to measure the gap among graduate programs in the field of construction management. The motive for pursuing this research is to have an unbiased tool and, with it, develop a methodology that will allow for designing or improving a program based on a series of selected requirements or market demands. The path to answer the research question follows these steps: (a) propose a theoretical framework that maps the field of management applied to the construction industry; (b) review and analyze current curricula offered by a number of relevant universities worldwide in the area of management for the construction sector; and (c) devise a benchmark indicator to compare, design, or restructure programs in construction management and administration to meet present and future demands. Thus, the purpose of this paper is to define an objective indicator for analyzing and comparing programs in the field of construction management; the focus is on university graduate programs (M.Sc. degree), considering that these programs are more flexible and easy to adapt to market needs.

Model

The first objective of the study is to design a model that covers the typical phases of both the life cycle and the organizational breakdown in management and administration for the construction industry. The perspectives of either life cycle or organizational breakdown are mentioned in isolation in the literature; however, the combination of these two dimensions can lead to a new approach toward managerial competencies in construction at the graduate level. This model is based on the following analyzed inputs: (a) previous experience of the writers in several European projects throughout the last decade (Teixeira et al. 2006; Pellicer et al. 2008; Minasowicz et al. 2009); (b) a technical report prepared by the Spanish Association of Civil Engineers (CICCP 2008); and (c) the design of a new master's degree with a specialty of 30 credits in construction management (Pellicer et al. 2009) to be implemented in 2013 at the Universidad Politécnica de Valencia to comply with the new academic scenario according to the Bologna process (Reinalda and Kulesza 2005; Moon and Duran 2010). The accumulated experience and knowledge of the writers was vital to completing a proposal of the model that was initially introduced in its incomplete form in Pellicer et al. (2009) and that is developed further in this paper. The proposed model is named MAC^2, standing for Management and Administration in Construction as a two-dimensional matrix; it is depicted in Fig. 1.

Because a holistic approach is pursued to design the model, the whole life cycle of the infrastructure is taken as a reference (Wideman 2004). This life cycle displays four typical phases (Stuckenbruck 1981): feasibility, design, construction, and operation. This model does not consider the divestment or disposal phase

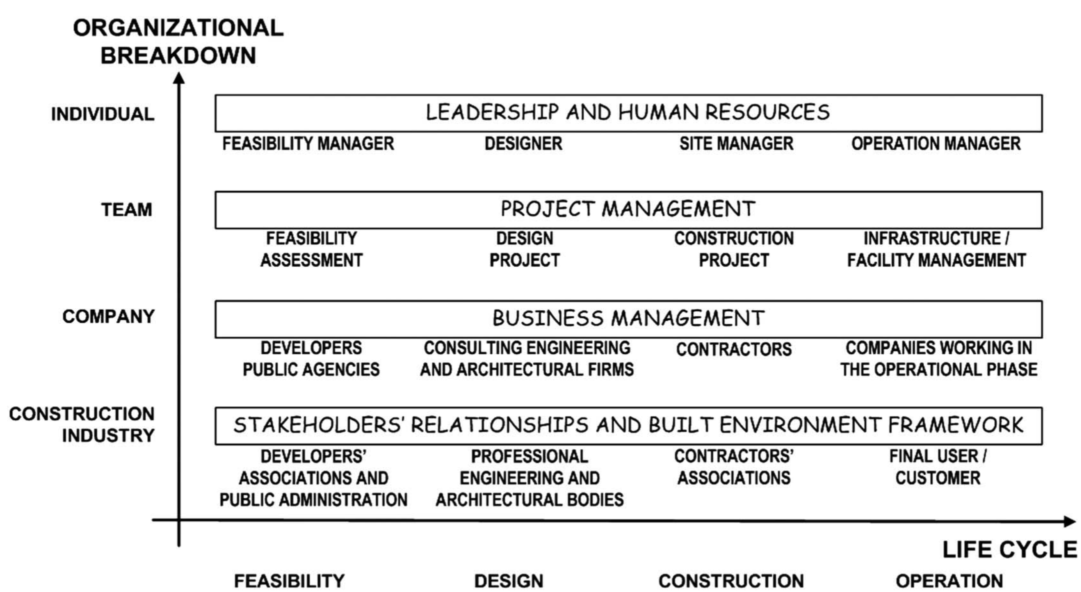

Fig. 1. MAC^2 model of management and administration in construction (developed from Pellicer et al. 2009)

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because of its uncommonness and its similarity in many aspects to the construction phase. The life cycle of the infrastructure is assigned as one of the dimensions of the model and is linked in time.

The other dimension of the model is organizational level. Russell and Yao (1996) and later Milosevic et al. (2007) proposed two main categories at this level: project, and business management. In this paper, four facets are considered in increasing order of degree of disintegration: construction industry, company, team, and individual. The aforementioned report prepared by the Spanish Association of Civil Engineers (CICCP 2008) confirms that the main skills required by civil engineers are those related to these four categories.

From an individual point of view, leadership (Farr et al. 1997; Bowman and Farr 2000; Riley et al. 2008) and human resources management (Edum-Fotwe and McCaffer 2000) are essential. This level considers the project manager as the main player that can be particularized as the designer (design phase) or the site manager (construction phase). Human resource issues are key, considering the importance of personnel in construction organizations. Leadership, as a combination of knowledge and skills, influences and motivates employees to carry out tasks. This level includes topics such as negotiation processes, conflict management, and team building.

Project management is established at the team level (Cleland and King 1968; Russell and Yao 1996). Companies in the construction industry work and manage by projects (Gann and Salter 2000; Winch 2006). Thus, construction professionals will join one or several project teams to develop their job. For that reason, it is essential to ensure expertise in issues related to project management (Arditi and Polat 2010), which can be divided into six main parts (Romero and Pellicer 2008): time management, cost management, resources management, quality management, environmental management, and safety and health management. From the perspective of the life cycle, projects can undertake different designations: feasibility assessment (feasibility phase), project design (design phase), project construction (construction phase), and infrastructure or facility management (operation phase).

The company level focuses on business management (Russell and Yao 1996; Milosevic et al. 2007). With the experience gained throughout the years, engineers and architects may rise to intermediate positions as managers, in whom the required managerial skills exceed those at the project management level. Business management in the construction industry embraces topics related to operational and strategic planning, financial management, total quality management, control, and marketing, among others. In addition, several types of firms come up through the process, such as public agencies and developers (feasibility phase), consulting engineering and architectural companies (feasibility and design phases), contractors and specialty subcontractors (construction phase), and maintenance contractors, service operators, and concessionaires (operation phase). Consulting engineering and architectural firms and contractors are the two most important firms with respect to the number of technicians involved (mainly civil engineers, quantity surveyors, and architects).

Finally, construction engineering education has to focus on the entire life cycle of a facility. This level displays the different types of procurement from every point of view, as well as contract conditions (Arditi and Polat 2010). Approaches such as strategic partnering, lean project delivery (LPD), or private finance initiatives (PFI) should also be considered because they are becoming essential topics in the construction industry.

Method and Data

The final objective of this research is to offer a methodology that allows for the design or restructuring of a M.Sc. program based on a series of selected requirements. This way, the graduate program can encompass the knowledge required for management throughout the entire construction cycle. These requirements that need to be fulfilled are proposed in the MAC^2 model, displayed in Fig. 1. The program must also comply with and respond to a series of deficient aspects detected in engineering programs related to the construction industry.

Nevertheless, this paper is focused only on the first phase of the overall research. The aim of this paper is to define a benchmark indicator for analyzing and comparing programs. This goal is achieved through the following series of steps that will be explained in more detail in subsequent sections:

1. Determine the study sample. In this case, it is necessary to revise current curricula offered in distinguished universities and to select specific programs as units of the sample;
2. Analyze the study sample with each dimension of the MAC^2 model to reveal the areas in which each program concentrates its courses;
3. Devise an indicator to compare programs; and
4. Compare each program using the deviation indicator, which is applied to determine the program that distributes its courses more like the average, identifying clusters among the study samples.

As stated, the initial step is to revise current curricula offered by universities to determine the sample of programs to analyze further and match with the MAC^2 model. Thus, an in-depth analysis of several graduate degree programs at leading universities was pursued. Many M.Sc. programs related to construction management were taken into consideration. The exploratory analysis was developed exclusively through the internet. Because higher education institutions and programs can differ, a first approach was done using a set of well-known universities in the category of engineering and technology that offer an ongoing graduate program on management in construction. Additionally, to narrow the analysis, the methodology imposed additional requirements to select the programs; for example, each university must not only have access to its program through the internet, but its information must be understandable and offer a detailed description of the syllabus and its courses. Programs that did not have enough information on its syllabus and courses were discarded. Nevertheless, the chosen set of programs does not affect the design of the methodology. The proposed method used for comparison between programs would not change for another set of programs with other selection criteria.

Table 1 shows the list of universities selected for the present analysis. For each university, a code and name of the graduate program (M.Sc. degree) were assigned. The geographical distribution of the universities was, 6, 6, 5, 3, 2, and 1 from Europe, Australia, the United States, Asia, Latin America, and Africa, respectively.

Design of a Benchmark Indicator

The categories chosen to evaluate each program correspond to those represented in the MAC^2 model and include organizational levels and construction life cycle, each evaluated separately. The first categories analyzed correspond to the four aforementioned organizational levels of leadership and human resources, project management, business management, and stakeholders' relationships and a developed environmental framework. The process of evaluation was to place each course, depending on its content, into

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Table 1. M.Sc. Degree Programs

Code	University	Program
Auc	The American University in Cairo	Construction Engineering
Cuohk	City University of Hong Kong	Construction Management
Delft	Delft University of Technology	Construction Management and Engineering
Hkust	The Hong Kong University of Science and Technology	Civil Infrastructural Eng. and Management
Lboro	Loughborough University	Construction Project Management
Ntu	Nanyang Technological University	International Construction Management
Puc	Pontificia Universidad Católica de Chile	Management in Construction
Qut 1	Queensland University of Technology	Project Management
Qut 2	Queensland University of Technology	Engineering Management
Slfd 1	University of Salford	Construction Management
Slfd 2	University of Salford	Project Management in Construction
Tkk	Helsinki University of Technology	Construction Economics and Management
Umich	University of Michigan	Construction Engineering and Management
Umlb 1	The University of Melbourne	Engineering Project Management
Umlb 2	The University of Melbourne	Engineering Management
Unal	Universidad Nacional de Colombia	Construction
Uncst	The University of Newcastle (Australia)	Engineering Management
Unm	The University of New Mexico	Construction Management
Upv	Universidad Politécnica de Valencia	Planning and Management in Civil Eng.
Usc	University of Southern California	Construction Engineering and Management
Usyd	The University of Sydney	Project Management
Uwscm	University of Wisconsin in Madison	Engineering in Professional Practice
Wustl	Washington University in St. Louis	Construction Management

each level. Each course was categorized in accordance with its relationship with any of the organizational levels. Any course could be directly involved with either one, two, three, or all of the levels. Therefore, the percentage of credits for each course was distributed according to the number of levels included in that specific course. Table 2 illustrates the importance of each organizational level according to its graduate program. Combining all 23 M.Sc. degree programs evaluated, the average percentage of courses related to each of these categories is: 45% to project management, 32% to business management, 13% to leadership and human resources, and 11% specific to stakeholders' relationships and a developed environmental framework.

The next step was to analyze each program using the same process but from a facility life cycle perspective. The phases of the facility life cycle evaluated were: feasibility, design, construction, and operational. Table 2 also illustrates, in percentages, the outcomes of each program distribution regarding every phase. The results reveal that most of the programs concentrate 38% of their courses on the construction phase, followed by the design phase at 28%, and, finally, 18% and 16% for the operational and feasibility phases, respectively.

Therefore, according to Table 2, no program covers every aspect reflected in MAC^2 in a balanced way. The reason is because every level can have different weighting evaluation factors since each particular program varies depending upon local circumstances. A benchmark indicator allows comparing each of the programs using another one as a reference.

The mean squared error (MSE) is applied to determine the program that distributes its courses closer to a reference set; it could be a hypothetical program or an existing one. In this paper, the average program is used as the reference. MSE is defined as the sum of the squares of the differences between the average ($\bar{x}$) and the percentages (x) devoted to each level or phase of each program, as shown in Eq. (1). This mean squared error is called the deviation indicator from this point forward.

$$\mathrm{MSE} = \sum_{i=1}^{23} (\bar{x} - x_i)^2 \tag{1}$$

From an organizational level analysis, the average value of MSE is 204. Ten out of the 23 programs analyzed (43%) exceed the average value of the MSE, as displayed in Fig. 2. The programs more similar to this average are those of the American University in Cairo, Delft University of Technology, and Universidad Politécnica de Valencia; the programs furthest from the average distribution are at the University of Newcastle, Helsinki University of Technology, and Pontificia Universidad Católica de Chile. We note that the program at the Universidad Politécnica de Valencia that appears in Tables 1 and 2, and in Figs. 2 and 3 corresponds to the current program.

The average value of the deviation indicator concerning the facility life cycle phases is 131. As displayed in Fig. 2, 10 out of 23 programs exceed the value of the indicator. The master's degree programs studied at universities such as the University of Wisconsin in Madison, University of Salford, and Delft University of Technology were closest to the average results, whereas Universidad Nacional de Colombia, The American University in Cairo, and Loughborough University were furthest from the average distribution. As demonstrated, the deviation indicator for the life cycle (131) is less significant than that of the organizational level (204), which means that there is less disparity between programs from a life cycle perspective.

The previous results reveal that the evaluated M.Sc. programs focus their content mainly on project management and the construction phase. As demonstrated by the deviation indicators, there is a more equal relationship in each program's contents regarding

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Table 2. Importance of Facility Life Cycle and Organizational Levels per Program

	Organizational levels				Life cycles			
Code	Leadership and human resources	Project management	Business management	Developed environmental framework	Feasibility	Design	Construction	Operation
Auc	9%	57%	26%	7%	9%	22%	53%	16%
Cuohk	13%	33%	46%	8%	16%	26%	39%	20%
Delft	22%	37%	26%	15%	20%	29%	29%	22%
Hkust	8%	52%	29%	10%	6%	29%	48%	17%
Lboro	6%	48%	23%	23%	9%	41%	41%	9%
Ntu	5%	52%	31%	12%	15%	23%	51%	11%
Puc	7%	33%	49%	11%	20%	27%	34%	18%
Qut 1	28%	41%	22%	9%	16%	30%	30%	24%
Qut 2	16%	32%	32%	20%	16%	28%	34%	22%
Slfd 1	22%	38%	28%	12%	20%	29%	29%	22%
Slfd 2	18%	40%	24%	18%	13%	28%	39%	21%
Tkk	2%	44%	48%	6%	19%	24%	29%	28%
Umich	12%	49%	27%	12%	17%	26%	37%	20%
Umlb 1	9%	59%	22%	9%	6%	27%	46%	21%
Umlb 2	10%	44%	38%	8%	17%	23%	42%	19%
Unal	4%	51%	34%	10%	7%	36%	51%	7%
Uncst	31%	31%	31%	6%	22%	28%	28%	22%
Unm	13%	44%	33%	10%	13%	32%	42%	13%
Upv	5%	56%	27%	12%	27%	23%	31%	19%
Usc	20%	48%	26%	6%	17%	26%	43%	15%
Usyd	14%	50%	29%	7%	18%	30%	30%	23%
Uwscm	13%	42%	40%	4%	19%	29%	29%	23%
Wustl	7%	47%	37%	10%	16%	31%	41%	13%
AVERAGE	13%	45%	32%	11%	16%	28%	38%	18%

facility life cycle than concerning organizational levels. The values resulting from categorizing each course and, therefore, each program are just indications of how each course is distributed according to each dimension of the MAC^2 model, and in no way does the average result determine the level of excellence of a specific program.

The next step is to plot both indexes as variables in a scatter chart. This way, each university program is represented in a two-dimensional space of the chart regarding its deviation from life

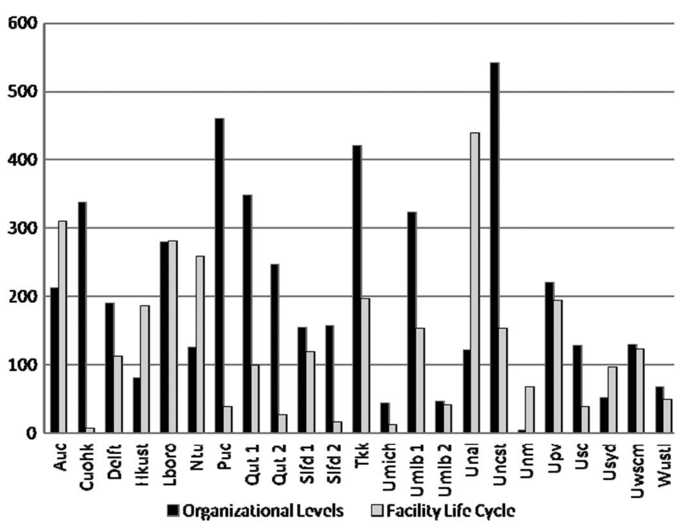

Fig. 2. Deviation indicator per program and dimension

cycle or organizational level. An important step is to select a distance measurement or a benchmark indicator for this analysis because this determines the similarity between two elements. In this case, the Euclidean distance is chosen, in which the vector measures the distance from each program to the origin (average).

Fig. 3 displays the scatter chart for both deviation indicators (life cycle and organizational level), placing each university in the Euclidean space. It also shows the programs ordered by distance to the average, where The University of Newcastle is the farthest and Delft University of Technology is the nearest.

Fig. 3 also maps the programs using both dimensions and displays how universities can be grouped according to the content of their programs. As illustrated, each quadrant represents similar characteristics. Therefore, programs with a balanced curriculum, represented in Fig. 3 as quadrant "A," form a cluster of universities with similar graduate programs and include the University of Salford, Delft University of Technology, University of Sidney, University of Melbourne, and University of Michigan, among others. Certain programs in universities such as Helsinki University of Technology, Loughborough University, and The University of Newcastle, among others, focus their courses in more specific areas and, consequently, form a specific quadrant "C" located further in the matrix. The other two quadrants represent universities that are balanced in either one of the facets of the matrix, for example, organizational levels, quadrant "B" (Pontificia Universidad Católica de Chile or Queensland University of Technology one) or facility life cycle, quadrant "D" (Universidad Nacional de Colombia or Nanyang Technological University).

The benchmark indicator (BI) allows comparisons between programs and can detect certain clusters. The BI does not determine

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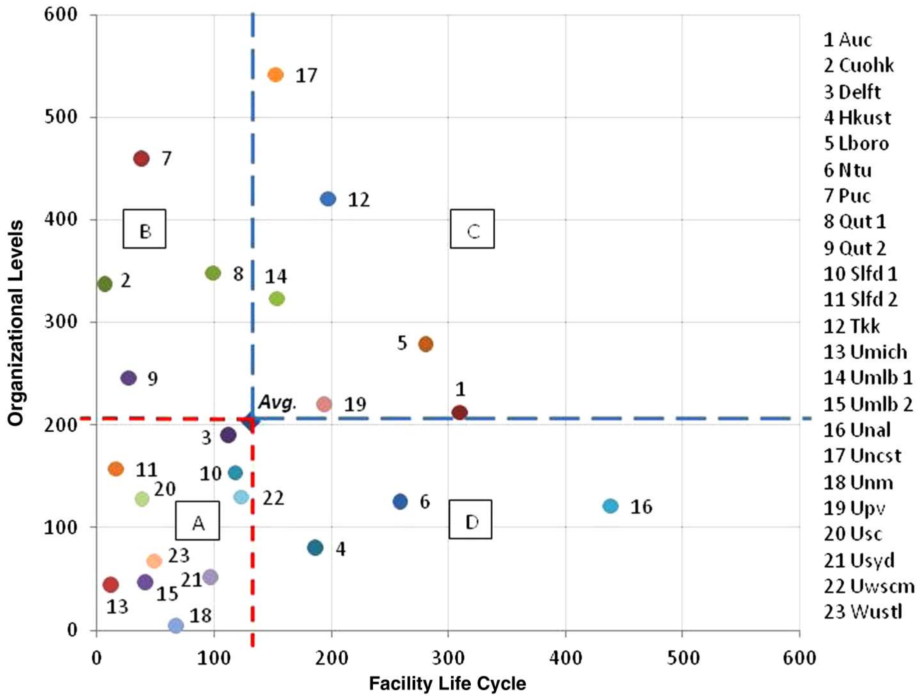

Fig. 3. Deviation of programs from the average

which program is superior; this indicator allows a comparison between each program and the average. Another program could have been adopted as a reference using the previously explained method.

Conclusions and Further Research

Currently, professional engineers are required to have more than the technical education obtained from their traditional degree programs. Employers demanding that their companies are properly managed demand this requirement, thereby achieving increased levels of productivity and quality. Issues such as leadership, management, communication, team work, and critical thinking are a few of the skills now required for an effective professional engineer in a managerial position.

Using the entire construction process as a reference, this paper proposes a holistic model for management and administration in the construction industry based on the previous experience of the writers. The model displays two dimensions: life cycle and organizational level. The former is linked to time through the four typical phases of the facility life cycle: feasibility, design, construction, and operation. The latter considers four levels of organization that could be found in the construction industry, ordered from lower to higher degree of disaggregation: life cycle, company, project (or team), and individual.

This model intends to offer a framework for mapping the requirements that should be covered in graduate university programs oriented to improving the knowledge of management and administration in the construction industry. The analysis of the current programs offered by a set of prestigious universities shows that some of them are not balanced according to the average of the 23 selected programs. As an initial premise, these programs represent the current corpus of knowledge demanded by employers; further research is needed to challenge this premise.

The MAC^2 model was used to consider the needs from the organizational level to the facility life cycle perspective, both proposed to be covered by master's degree programs regarding management in construction. The objective is to verify the adequacy of various examined graduate programs related to this area with a double comparative level. A thorough study of the courses offered in programs at top universities was completed and therefore allowed the determination of deviation indicators on both dimensions of the model: life cycle of construction and organizational level. This allows future master's degree programs or a restructured existing one to strive and focus its program using the average results of these recognized prestigious programs as a benchmark reference. Nonetheless, the distribution of programs does not determine the superior program; it is only an indicator of how each program approaches the average. When a specific program is used as a benchmark reference, a proper review of the curriculum under analysis is possible.

Furthermore, analysis of each program's deviation from the average leads to the design of a benchmark indicator. The BI aims to measure the divergence of each program from the average by taking into account the two dimensions of the model. This benchmark indicator also allows for comparison among programs, allowing for the research question to be answered positively and the purpose of the paper to be accomplished.

The proposed model serves as a bridge to study its relationship with the offered graduate courses and market needs. Accordingly, obtaining objective guidelines for designing or modifying a master's degree program related to construction management is possible based on the needs of the market; such guidelines can cover all aspects of the organizational level as well as the entire life cycle of an infrastructure.

This is the first phase in designing a methodology that allows for creating or restructuring a master's program for professional managers in the construction industry. To comply with this goal, the following future works are recommended:

1. Determine the extent to which current curricula offered by various universities cover the entire proposed model. To accomplish this, a relationship between the courses of the selected

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programs with the MAC^2 model must be settled upon. Results could demonstrate how specialized a course is regarding the proposed model;

2. Relate market demands with both offered courses and the MAC^2 model. At first, the aspects that professional civil engineers lack will be matched with the representative topics from each program, resulting in determining the topics that have the best possibility of covering these needed aspects. A list of parameters could serve to evaluate and compare each program; and
3. Propose a theoretical program that best fills each facet of the proposed model and that covers market demands.

At this time, our research team is developing a new master's program at the Universidad Politécnica de Valencia for civil engineers that seek to work as professional managers in the construction industry to comply with the new academic scenario according to the Bologna process. One way to achieve this goal is to survey construction stakeholders to determine local conditions and market demands. Then, a relative weighting evaluation factor for each aspect involved in the model would be particularized. Thus, the benchmark indicator proposed in this paper can serve to evaluate and compare the distance between each tentative program and the theoretical program derived based on market needs. Similarly, any university could review any program attending to specific construction market demands.

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