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A METHOD FOR PLANNING GRADUATE PROGRAMS IN CONSTRUCTION MANAGEMENT

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ABSTRACT

University programs in western countries must be accredited and although several detailed conceptual methods have aimed to design new programs, to date no specific quantitative tools are available. The purpose of this paper is to describe a method to plan, design, or improve graduate degree programs based on selected requirements and market demands. This method involves two metrics, which are later combined into a final index. The first metric is the Completeness Index, which evaluates the extent to which certain programs cover a discipline, in this case construction management, according to a model using two variables: infrastructure life cycle and organizational breakdown. The second metric is the Adequacy Index, which measures how a program addresses the previously identified market demands. The final indicator

(Summary Index) relates both indices in a plot chart. In this study, a sample of 21 construction management programs from prestigious universities and a survey of the Spanish construction industry illustrate the applicability of the method. It can be applied in practice, not only in the construction management field, but also in other fields with an appropriate theoretical model that maps each field of knowledge as well as exploratory data that highlight the demands of each specific market.

KEYWORDS: Construction Management; Graduate Program; Indicators; Market Demands

INTRODUCTION

To be accredited, university programs must comply with regulations of external and recognized institutions, for example the ABET in the United States (ABET 2008) through EC2000 criteria (Prados et al. 2005), or the ANECA in Spain (ANECA 2007). Similar accrediting agencies have been set up in the European Union to recognize universities which comply with the Bologna process (Lucena et al. 2008). These organizations demand that academic programs not only develop skills and competences as core learning outcomes, but they must also implement a quality assurance process (Moon and Duran 2010). The importance of this accreditation is critical, hence the rise in the number of accredited university programs in North America and in Europe over the last decade (Prados et al. 2005, Lucena et al. 2008).

Researchers have proposed and tested detailed methods to design, implement and assess university programs based on some of the criteria previously cited. Olds and Miller (1998) described an assessment matrix to evaluate engineering programs which included: goals and objectives, performance criteria, strategy, appraisal methods, timeline, and feedback. These authors contributed with a conceptual approach of great interest, presenting a comprehensive method for assessing a program; however, they did not provide quantitative metrics but rather qualitative advice. Using this same conceptual approach, McNeill and Bellamy (1999) proposed a very detailed matrix (called articulation matrix) to define a new course. Even though their method was more precise and focused on a single syllabus instead of a whole curriculum, it did not contemplate quantitative indicators. Other authors have followed this path, either for syllabus design (Fillon 2010, Hoskinson 2010), or curriculum design (Atalah and Muchemedzi 2006,

Crawley et al. 2008, Alam et al. 2008); none have provided quantitative metrics in their methods. Especially interesting applications of the conceptual method for design and assessment of university programs were discussed by Wessels and Roos (2009), who adopted the critical success factors method by Johnson and Scholes (1997). Jain et al. (2010) implemented a business process reengineering method (Hammer and Champy 1993). More recently, Yepes et al. (2012) devised a tool to benchmark graduate programs, and applied it to a sample of M.Sc. degrees in construction management.

Nevertheless, two problems have yet to be fully addressed by scholars. First, quantitative tools, which facilitate the design of new programs or improvement existing ones, are scarcely treated by the researchers. Second, even though some contributions consider the needs of the market, complying with the regulations of a certification body (Atalah and Muchemedzi 2006, Woollacott 2009, Salman et al. 2011), they do not explicitly state how this can be systematically accomplished. Thus, the research problem can be articulated as follows: there are no specific quantitative tools for planning, designing, or improving a program taking into consideration the needs of the market. This problem can be addressed proposing a general method to plan, design, or improve a program which integrates established requirements and market demands. In this paper and for illustrative purpose, the method proposed herein is applied to construction management at the graduate level (M.Sc. degrees), based on previous work pursued by the authors (Yepes et al. 2012).

The next section of this paper provides an overview of the proposed method, as well as the necessary steps to plan, design or improve a program. Later, the MAC² model is explained and

serves as a theoretical reference for evaluating completeness in the construction management field. The following section describes an exploratory analysis from two standpoints: a survey of the Spanish construction industry used as a market reference, and a sample of several graduate programs in construction management used to illustrate the application of the method from that point on. Then, the indicators (or metrics), developed for this method, are presented and applied to the sample of graduate programs using the model and the survey as input data. Finally, the last section of the paper offers conclusions, limitations, and further research.

PROPOSED METHOD

The proposed method, developed to plan an academic program, is outlined graphically in Fig. 1.

The method is based on two main ideas:

- (1) Each program is compared to an appropriate theoretical model, which maps the specific field of knowledge; to this end, the completeness of the program can be determined.
- (2) For each program, there are specific requirements influenced by its environment; depending on these requirements, the adequacy of the program to the market demands can be determined.

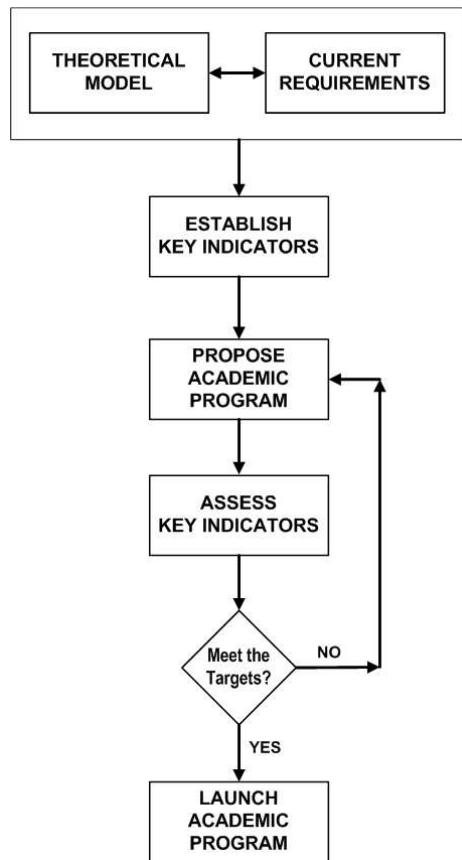


Figure 1: Proposed Method

However, obtaining a theoretical model is not an easy task; it requires an in-depth analysis of the field of knowledge as well as a practical experience and previous research. In the field of construction management, the authors previously proposed and developed a theoretical model (Pellicer et al. 2009, Yepes et al. 2012), which is briefly explained in the next section and will be applied later in the study.

Additionally, the specific requirements for a program may be difficult to obtain. The university sponsoring the program can determine requirements in terms of strategy, such as focusing on aspects that are not covered by their close competitors. Otherwise, the sponsor institution must try to respond to market demands. In this case, exploratory analyses are needed, using a panel of experts, interviews, surveys, and so on; depending on the circumstances, results can be expensive or unreliable.

Considering the two basic ideas stated at the beginning of this section, this method defines two basic indicators: a Completeness Index (CI henceforth) and an Adequacy Index (AI hereafter). CI evaluates the extent to which a program covers the discipline of construction management whereas AI measures how a program covers the requirements identified previously. A final indicator (Summary Index or SI) relates CI to AI in a plot chart; thus, the further a program is from the origin, the better it complies with both indexes. This metric is useful as a benchmark indicator for comparison with other university programs.

Once a theoretical model is available and the requirements are established, value targets can be fixed for each indicator, according to the objectives of the sponsoring institution. To this end, any benchmark analysis available can be used, such as the one shown in this paper. With all the information at hand, a tentative program can be designed, specifying the subjects and their relative weight; no courses and credits should be defined at this point.

The next step is to check if the two basic indicators (CI and AI) meet the targets established previously; the SI indicator may be used as a benchmarking tool to test the proximity to the aim.

If the indicators do not comply, iterations have to be introduced for each, thus modifying the program and re-calculating the indices until the results approach the target close enough.

Finally, once the indicators are validated, the subjects and their weights corresponding to the last iteration can be translated to the final courses and their credits. Fig. 2 summarizes the general step-by-step method.

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| <p>STEP 1: Obtain the requirements of the graduate program according to strategy and market demands.</p> <p>STEP 2: Establish the indicators and fix their intended targets.</p> <p>STEP 3: Propose an academic program specifying subjects and their relative weight.</p> <p>STEP 4: Calculate its completeness (CI) comparing to a theoretical model.</p> <p>STEP 5: Check that the CI complies with its target (if not, return to Step 3).</p> <p>STEP 6: Calculate its adequacy (AI) in terms of the established requirements.</p> <p>STEP 7: Check that the AI complies with its target (if not, return to Step 3).</p> <p>STEP 8: Use the combination of both indexes (SI) as a benchmarking tool if needed.</p> <p>STEP 9: Define the courses and credits for the chosen program according to Step 3.</p> |
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Figure 2: Step-by-Step Method to Set Up a Program

In the following sections, this method is developed further and applied to a sample of existing university programs in the construction management field to provide a benchmark study. Nevertheless, this method may be applied to the specific planning of a new program, or to the

improvement of an existing one; the difference in approach between a particular case study and the sample of chosen universities will be highlighted throughout the text.

THEORETICAL MODEL

The growing complexity of the engineering field, in general, and the construction industry, in particular, means professional engineers must evolve and adapt (Milosevic et al. 2007, Naranjo et al. 2011, Schexnayder 2011). In the construction industry, managerial education has become more demanding, as engineers face many issues regarding management and administrative activities which require extensive expertise to perform tasks (Christodoulou 2004, Galloway 2007, Arditi and Polat 2010). Engineers are required to perform even more complex technical tasks, as well as to acquire managerial competencies (Russell and Yao 1996, Trejo et al. 2003, Jahren and Johnston 2011). Furthermore, most employers seek engineers with professional competencies that include both technical and managerial skills gained through experience and studies (Galloway 2007, Milosevic et al. 2007, Jahren and Johnston 2011).

The perspectives of either lifecycle or organizational breakdown are only mentioned in the literature; however, the combination of these two dimensions can lead to a new approach to managerial competencies in construction. A conceptual model, initially introduced in Pellicer et al. (2009) and fully developed in Yepes et al. (2012), is used here as a basic framework (Fig. 3); these authors conceived the model as a two dimensional matrix, named Management and Administration in Construction (abbreviated herein as MAC²).

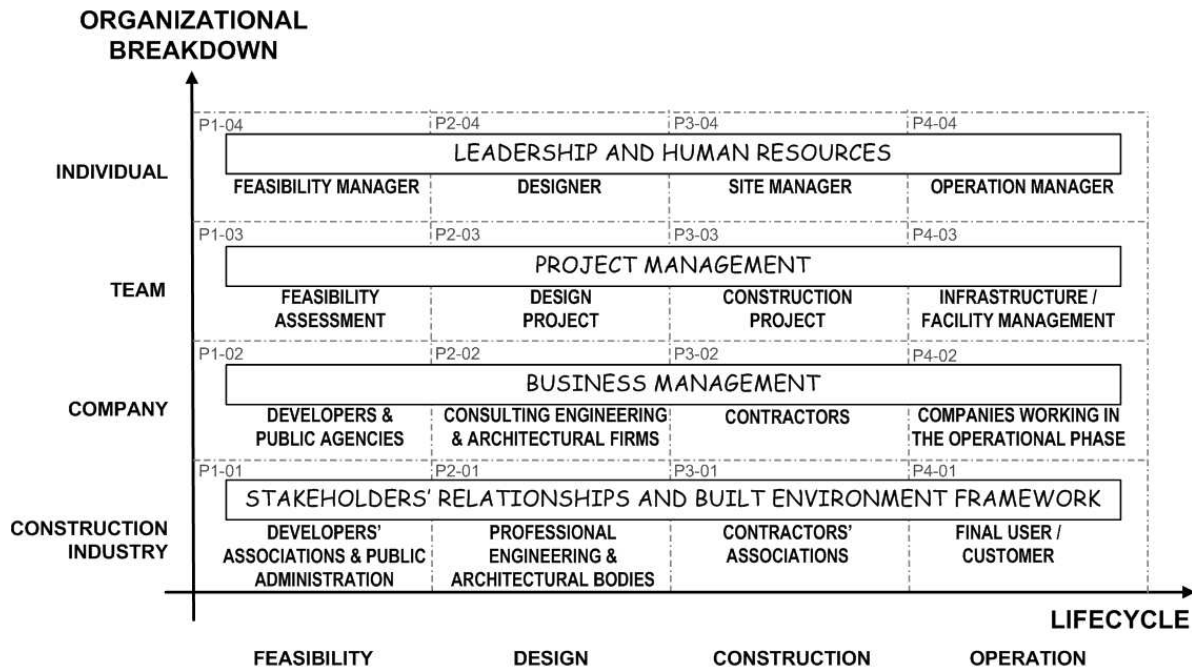


Figure 3: Model MAC² for Management and Administration in Construction (Yepes et al. 2012, ASCE)

One of the dimensions of the MAC² model is the infrastructure lifecycle, which features four typical phases linked with the timeline of infrastructure: feasibility, design, construction, and operation. These phases are those usually considered by previous authors and are referred to as *conceive*, *design*, *implement*, and *operate* by Crawley et al. (2007); this lifecycle approach was used to design a complete curriculum in aeronautical engineering (Crawley et al. 2008).

The other dimension of the model is concerned with the organizational level. Russell and Yao (1996) and Milosevic et al. (2007) described two main facets: project and business management.

Later on, Pellicer et al. (2009) suggested four facets with a further degree of breakdown: construction industry, company, team, and individual.

EXPLORATORY ANALYSIS

Survey of the Spanish Construction Market

Not all cells of the MAC² model have an equal value in regard to market demands. They vary depending on the country, temporal circumstances, sub-sector, and so on, serving as a basis to further relate and value each cell of the model. In order to illustrate this application, in this paper the selected market demands correspond to those of the Spanish construction industry.

The Spanish Association of Civil Engineers (CICCP 2008) developed a survey to determine both the main skills needed by civil engineers as well as the main deficiencies in civil engineering programs. The survey was conducted with 25,543 professional associates. The number of responses received was 2,157; of these, 54% of the respondents were working in construction, 17% in engineering services, and 9% in public agencies. Within this general approach, four survey questions related the importance of management and administration activities in professional development. Furthermore, the questionnaire also asked which skills professional civil engineers considered, in their experience, as deficiencies or lacking in university degree programs. Thirteen topics were highlighted: construction process, technical competences, sustainability, legal aspects, information technology, project management, business management,

quality assessment, safety and health, public-private partnerships (PPP), operation of infrastructure, logistics, and urban planning.

This survey is only one example of how an analysis of this kind can be applied using the proposed method. For each scenario, the sponsoring institution needs to obtain the requirements of its specific market using exploratory techniques: e.g. a panel of experts, interviews or surveys. These requirements can also be set without any investigation, just by focusing on a specific strategy based only on the competitors' proposals.

Sample of University Programs

In order to illustrate the method, various M.Sc. programs were selected to form a sample. An exploratory search to identify academic programs (M.Sc. Degrees) in construction management at leading universities was carried out and 21 were selected (see Table 1). This analysis was pursued using two basic criteria to select the programs. First, each academic program must facilitate not only online access to its curriculum, but the information must also be understandable and include a detailed inventory of the courses, their credits (or relative weights), and their descriptors. An in-depth explanation of this exploratory study can be found in Yepes et al. (2012). It is important to note that the selected set of programs does not affect the method; it would not change with another set of programs using other selection criteria.

Code	University	Program
Auc	American University in Cairo	Construction Engineering
Cuohk	City University of Hong Kong	Construction Management
Delft	Delft University of Technology	Construction Management and Engineering
Hkust	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
Qut1	Queensland University of Technology	Project Management
Qut2	Queensland University of Technology	Engineering Management
Slfd1	University of Salford	Construction Management
Slfd2	University of Salford	Project Management in Construction
Tkk	Helsinki University of Technology	Construction Economics and Management
Umich	University of Michigan	Construction Engineering and Management
Umlb1	University of Melbourne	Engineering Project Management
Umlb2	University of Melbourne	Engineering Management
Unal	Universidad Nacional de Colombia	Construction
Uncest	University of Newcastle (Australia)	Engineering Management

Code	University	Program
Unm	University of New Mexico	Construction Management
Upv	Universidad Politécnica de Valencia	Planning and Management in Civil Engineering
Usc	University of Southern California	Construction Engineering and Management
Usyd	University of Sydney	Project Management
Uwscm	University of Wisconsin in Madison	Engineering in Professional Practice
Wustl	Washington University in St. Louis	Construction Management

Table 1: M.Sc. Degree Programs (Yepes et al. 2012, ASCE)

The curricula of each of the M.Sc. programs, shown in Table 1, were analyzed in such a way that it was possible to group the courses of each program into subject areas. In order to determine the main areas of expertise currently being taught at the graduate level, each course was grouped into common subjects that are used in this paper to reveal their fulfillment with the necessary knowledge for a competent engineer, as well as their matching with the market demands. Over 300 courses were grouped in 27 subjects. Each program was homogenized accordingly, considering a full academic year as a reference; thus, the different value in time for each course was taken into account. As expected, the most common subjects correspond to those of project management, followed by contract management, project scheduling, and business management in construction. The first and second columns in Table 2 list the categories according to the percentage of courses required by each program for each subject area. If the analysis is done for

a single program, no distribution is needed because subjects (or even the courses themselves) can be taken directly at the beginning of the process.

Subjects	%	Subjects	%
Project Management	14.4	Project Design Management	2.6
Contract Management	10.8	Leadership, Communication & Negotiations	2.3
Project Scheduling	10.5	Urban Planning	2.3
Business Management	5.9	Lean Production in Construction	2.0
Financial Management	5.6	Quality Management	2.0
Construction IT & IS	5.2	Construction Economics	1.6
Construction Site Management	3.9	Environmental & Sustainability Mgmt	1.6
Risk Management	3.9	Cost Engineering	1.6
Legal Aspects in Construction	3.9	Real Estate Management	1.3
Team Management	3.6	International Construction & Marketing	1.0
Human Resources Management	3.3	Knowledge & RD Management	1.0
Maintenance Management	2.9	Methods & Equipment for Construction	1.0
Safety & Health Management	2.6	Supply Chain Management	0.7
Project Partnering Strategies	2.6		

Table 2: M.Sc. Degree Subjects

KEY INDICATORS

Completeness Index (CI)

The CI indicator is proposed to evaluate the completeness of the program. To do so, a panel of experts was needed to settle on the relationship between each subject (Table 2) and each cell of the MAC² model (Fig. 3). Five professors in construction, each working at different universities (in Chile, Poland, Portugal, Spain, and the United Kingdom), formed a panel of experts; each has considerable knowledge and understanding of the construction industry, and each has more than 25 years of mixed experience as academicians and construction professionals. Any other technique could be used to determine this relationship between subjects and cells. In our case, a panel of experts was deemed to be the best tool to assess the problem. Furthermore, these panelists were chosen because of their overall knowledge of the research being developed.

A three-level Likert scale was used to determine the relationship between each subject and cell of the MAC² model. The results of this analysis are given in Fig. 4; they determine to what extent a subject is related to each specific part of the model: a strong connection is represented with the most distinctive dark color, a moderate connection with a lighter tone, and a transparent tonality is for representing a weak connection. As noted, the subjects currently taught in M.Sc. programs at the major universities have largely focused on project and business management in both construction and design phases.

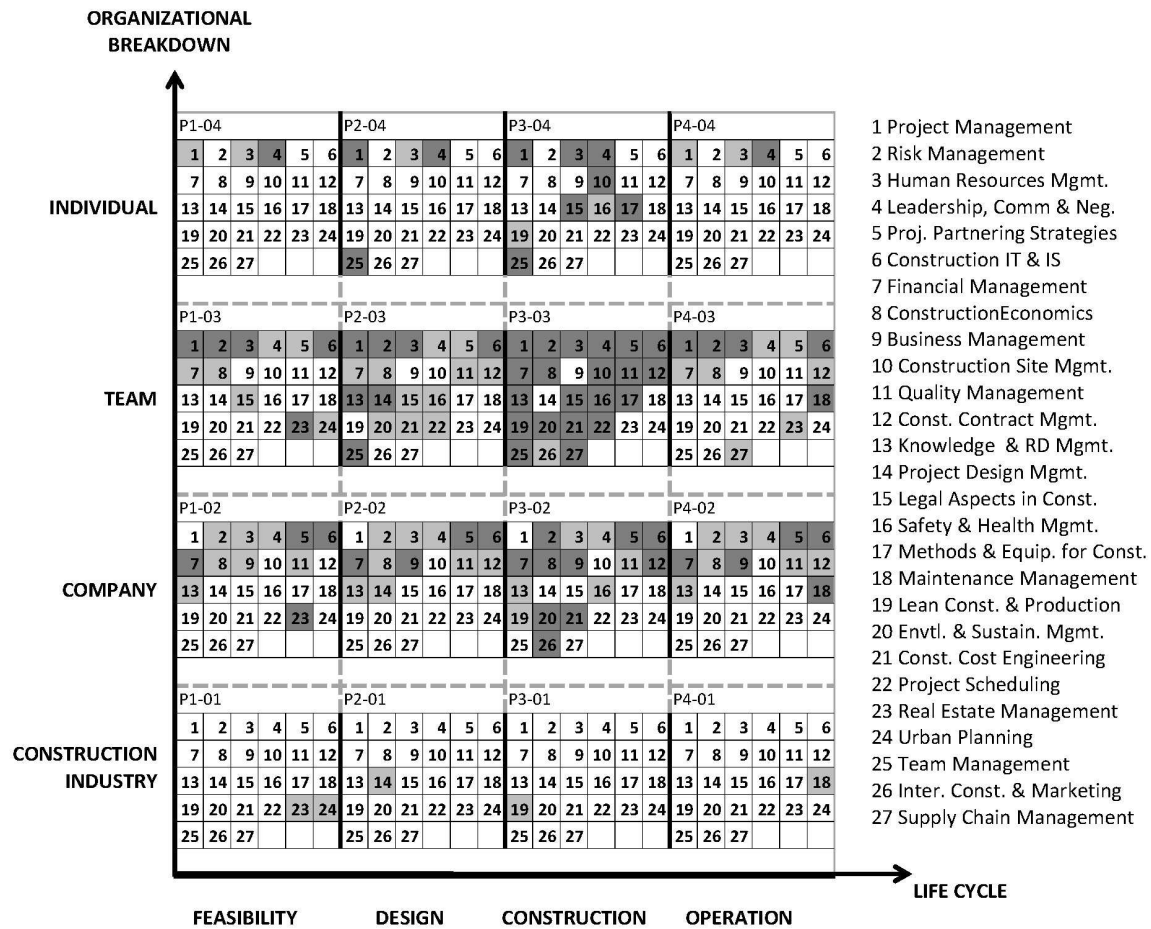


Figure 4: Impact Results between MAC² Model and Subjects

The CI indicator is proposed to evaluate extent to which a program covers individually each and every cell of the MAC² model. This index is considered to determine the number of cells of the model being covered by each program in order to comprise a global perspective of construction management. Therefore, the subjects with a strong link are considered to determine the programs with the highest CI, with the exception of subjects 14, 18, 19, 23, and 24 whose relationship is considered moderate; these subjects are considered since they are the only subjects fulfilling the “construction industry” facet of the model and therefore essential for completing the cells

corresponding to that facet (see Fig. 4). For example, of all of the courses offered by the program “Project Management in Construction” at the University of Salford (Slfd2), 14 of these courses can be considered to have a strong connection with 16 MAC² model cells; this means the equivalent of fulfilling 87.50% of all the cells of the model; if one subject is deemed to cover a given cell, this cell is considered completely fulfilled. Table 3 shows the CI values for each university in the sample.

CI	56.25%	Ntu
	56.25%	U Syd
	62.50%	Umm
	62.50%	Auc
	62.50%	Usc
	62.50%	Cuohk
	62.50%	Umlb 1
	62.50%	Unal
	68.75%	Hkust
	68.75%	Tkk
	68.75%	Umich
	68.75%	Qut 1
	68.75%	Umlb 2
	68.75%	Puc
	68.75%	Upv
	69.84%	Average
	75.00%	Uwscm
	75.00%	Wustl
	75.00%	Unest
	75.00%	Qut 2
	81.25%	Delft
	81.25%	Slfd 1
	87.50%	Lboro
	87.50%	Slfd 2
University		

Table 3: CI per Program

The calculation of the CI indicator can be summarized as follows:

- Take the MAC² model as a reference (see Fig. 3).
- Assess the subjects of the program that cover each of the 16 cells of the MAC² model (see Fig. 4); a panel of experts, a survey, or other exploratory techniques may be used to obtain this matrix.
- Compute the index as the average value of completeness of the 16 cells of the MAC² model to answer the question: what percentage of the cells is covered? (see Table 3).
- If the CI is considered good enough for the target established in Step 2 (Fig. 2), then proceed; if not, return to Step 3 (Fig. 2) and re-design the program.

Adequacy Index (AI)

To design a complete graduate program based on both the MAC² model and the topics considered deficient in construction management programs, it is necessary to contrast the results regarding the required subjects and the needed topics. Having considered the 13 deficient topics (CICCP 2008), the same panel of experts was asked to identify the specific subjects needed to cover each program deficiency (needed topic). The relation was established using a three-level Likert scale which assigned numerical values: weak (1), moderate (2), and strong (3). Thus, each subject was analyzed for each program deficiency, resulting in a two-way matrix (Table 4). This matrix plots the link between each of the 27 subjects and the 13 topics that must be included in future programs; a specific subject that matches each one of the topics would require a strong relation (value 3), resulting in a maximum of 39 points. For Spain, the subjects that best meet these needs are construction site management (29/39; 74%), project management (28/39; 72%), and risk management (26/39; 67%); this indicates how essential these subjects are in fulfilling globally the majority of the deficiencies identified.

SUBJECTS	TOPICS MOST NEEDED													Total	% (out of 39)	HOMOTHETHY
	Construction Process	Technical Competences	Sustainability	Legal Aspects	Information Technolog.	Project Management	Business Management	Quality Assessment	Safety & Health	PPP	Operation of Infrastruct.	Logistics	Urban Planning			
Construction Site Management	3	3	2	3	2	3	2	3	3	1	1	2	1	29	74.4%	100.0%
Project Management	3	2	2	3	3	3	2	3	2	1	2	1	1	28	71.8%	96.6%
Risk Management	3	1	3	3	1	3	3	1	3	2	1	1	1	26	66.7%	89.7%
Legal Aspects in Construction	3	1	3	3	1	1	2	2	2	2	1	1	3	25	64.1%	86.2%
Safety & Health Management	3	2	1	3	1	2	2	1	3	1	2	1	1	23	59.0%	79.3%
Leadership, Comm. and Negotiation	2	2	1	2	1	3	3	1	1	2	2	2	1	23	59.0%	79.3%
Construction Contract Management	3	1	1	3	1	2	1	2	2	2	1	2	1	22	56.4%	75.9%
Methods & Equipment for Construction	3	3	1	1	1	2	1	2	3	1	1	2	1	22	56.4%	75.9%
Project Partnering Strategies	2	1	2	3	1	2	2	1	1	3	2	1	1	22	56.4%	75.9%

SUBJECTS	TOPICS MOST NEEDED														Total	% (out of 39)	HOMOTHETY
	Construction Process	Technical Competences	Sustainability	Legal Aspects	Information Technolog.	Project Management	Business Management	Quality Assessment	Safety & Health	PPP	Operation of Infrastruct.	Logistics	Urban Planning				
Human Resources Management	2	1	1	2	1	3	3	2	2	1	1	2	1	22	56.4%	75.9%	
Business Management in Construction	2	1	1	2	2	2	3	2	1	1	1	2	1	21	53.8%	72.4%	
Maintenance Management	1	1	2	2	1	2	2	1	1	2	3	2	1	21	53.8%	72.4%	
Quality Management	3	2	2	1	1	1	2	3	2	1	1	1	1	21	53.8%	72.4%	
Lean Construction and Production	3	1	1	1	2	3	2	2	1	1	1	2	1	21	53.8%	72.4%	
Project Scheduling	3	2	1	1	2	3	2	1	1	1	1	2	1	21	53.8%	72.4%	
Environmental & Sustainability Mgmt.	2	2	3	3	1	2	1	1	1	1	1	1	2	21	53.8%	72.4%	
Project Design Management	2	3	1	2	2	2	1	2	2	1	1	1	1	21	53.8%	72.4%	
Construction Cost Engineering	2	2	1	1	2	3	2	1	1	2	1	1	1	20	51.3%	69.0%	
Real Estate Management	1	1	1	2	1	2	3	1	1	1	2	1	3	20	51.3%	69.0%	
Supply Chain Management	2	2	1	1	2	2	2	1	1	1	1	3	1	20	51.3%	69.0%	
Team Management	2	2	1	2	1	3	2	1	1	1	1	2	1	20	51.3%	69.0%	
Urban Planning	1	1	2	3	1	2	1	1	1	1	1	1	3	19	48.7%	65.5%	
Financial Management	1	1	1	1	2	2	3	1	1	2	2	1	1	19	48.7%	65.5%	
International Construction & Marketing	1	1	1	1	2	2	3	1	1	2	1	2	1	19	48.7%	65.5%	
Construction IT & IS	2	2	1	1	3	2	2	1	1	1	1	1	1	19	48.7%	65.5%	
Knowledge & RD Management	2	2	1	1	2	2	2	1	1	1	2	1	1	19	48.7%	65.5%	
Construction Economics	2	1	1	2	2	1	2	1	1	1	1	2	1	18	46.2%	62.1%	
	59	44	39	53	42	60	56	40	41	37	36	41	34				

Table 4: Relationship between Subjects and Topics

In this study, a homothety was applied to the values of each subject displayed in Table 4, giving a 100% value to the subject with the highest compliance with the topics needed (see last column in Table 4); in this case is construction site management, as stated previously. It is not necessary to apply this homothety, but it is an indication that there is room for improvement and that current subjects only cover a certain percentage of graduate program needs. An important reminder is that the survey is focused, illustratively, on the Spanish construction industry. The method does not lose generalization if other local topics are considered as demanded by a specific market. Every plan, design or improvement of a program should gather exploratory data targeting its own specific market.

Considering the percentages listed in Table 4, it is possible to calculate how each program covers the needed topics; in this case, it is necessary to distribute the credits of each program among the 27 subjects, resulting in their relative weights. The following step is to multiply both results (for each subject): its contribution to compliance with the topics demanded times its relative weight. The AI indicator is computed as the sum of each of the values per subject. Table 5 provides the final results. The programs at the University of Melbourne Australia along with Queensland University of Technology, City University of Hong Kong, and the Delft University of Technology are those that comply better with these particular market demands. Surprisingly, the only Spanish program in the sample (*Universidad Politécnica de Valencia*) does not fit well with the market demands.

AI	71.1%	Sfhd 1
	73.9%	Niu
	74.6%	Unal
	74.7%	Wustl
	75.1%	Unest
	75.6%	Upv
	75.6%	Hkust
	75.6%	Tkk
	77.1%	Lboro
	77.8%	Umm
	78.4%	Average
	78.6%	U Syd
	78.7%	Umich
	79.3%	Sfhd 2
	79.7%	Usc
	79.9%	Umlb 2
	80.4%	Uwscm
	80.6%	Auc
	80.9%	Puc
	81.3%	Delft
	81.3%	Cuohk
	82.3%	Qut 2
	84.0%	Qut 1
	85.5%	Umlb 1

Table 5: AI per Program

Summarizing, the estimation of the AI indicator can be obtained as follows:

- Compute the topics covered by each subject in % (see Table 4) using a panel of experts, a survey, or other exploratory techniques.
- Apply a homothety to the values of each subject obtained in (a), giving a 100% value to the subject with the largest percentage of compliance with the requirements (see last column in Table 4).

- c) Multiply the contribution to compliance with the subject requirements obtained in (b) times the relative weight of each subject; a number is obtained for each of the subjects.
- d) Compute the index as the sum of figures (Table 5).
- e) If the AI is considered to have an acceptable degree of compliance according to the target established in Step 2 (in Fig. 2), then proceed; if not, go back to Step 3 (in Fig. 2) and re-design the program.

Summary Index (SI)

Combining both sets of results in a comprehensive pooled index allows us to determine which program best fulfills the MAC² model as well as market demands. Consequently, each program is evaluated in terms of the CI, which represents the value of fulfilling every cell of the proposed model, and the AI, which is the value of being able to meet the demands satisfactorily. When combining both indices, as shown in Fig. 5, the programs with the highest results are those in the upper right corner of the graph: University of Salford (Slfd2), Loughborough University (Lboro), and Delft University of Technology (Delft).

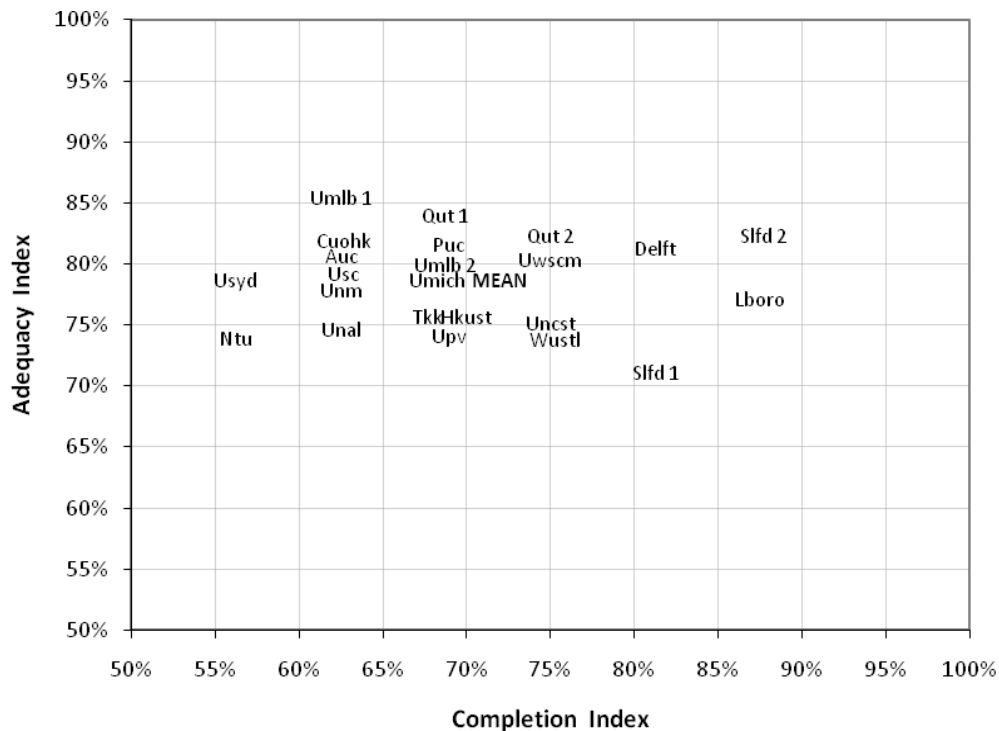


Figure 5: AI and CI Results

Table 6 orders each program according to its distance from the origin, which results in the SI indicator. For example, Nanyang Technological University (Ntu) has a CI of 56.25% and an AI of 73.90% represented in Fig. 4; the distance to the origin is determined by the Pythagorean theorem, obtaining the value of 0.93 in this case (see Table 6). Each university program has its own specifications, structure, and areas of expertise that are in line with their university objectives. Therefore, the rank in Table 6 does not determine the quality of a program nor does it indicate which is better. The results only indicate how each program relates to the theoretical model and the data available. Nevertheless, it is an indicator that may be very useful for benchmarking purposes, not only to check if the proposed program is suitable for its market, but also how it compares with others.

Distance	1.181	Sifd 2
	1.166	Lboro
	1.149	Delft
	1.114	Qut 2
	1.099	Unswcm
	1.085	Qut 1
	1.080	Sifd 1
	1.062	Puc
	1.062	Unest
	1.059	Umlb 1
	1.058	Wustl
	1.054	Umlb 2
	1.050	Average
	1.045	Umich
	1.025	Quohk
	1.022	Tkk
	1.022	Upv
	1.022	Hkust
	1.020	Auc
	1.012	Usc
	0.998	Umn
	0.973	Unal
	0.967	Usyd
	0.929	Ntu
University		

Table 6: Programs Ordered according to their SI

CONCLUSIONS AND FURTHER RESEARCH

This paper presents a novel tool for planning, designing, or improving a graduate program. The proposed method can be applied to any field and any market, having the necessary previous information about the requirements of the programs, based on a theoretical model of the field and the needs of the particular market. This method is based on two metrics (CI and AI), which are later combined into a comprehensive index (SI). First is the CI, which indicates the extent to which certain programs cover the field of knowledge; in this paper the method is applied to construction management using the MAC² model as a reference. The second indicator is the AI, which measures how a program covers the needs of the market, previously identified using surveys or other exploratory techniques. A survey developed by the Spanish Association of Civil Engineers was used for the application described in this paper. The final indicator, SI, relates both indexes in a plot chart. It can be very useful for benchmarking purposes, not only to check if the proposed program fits in its market, but also how is located regarding its competitors. Throughout the process of iterative calculation of the indices, a panel of experts was used for assessing and rating subjects in the model or the topics required. It is important to note that these data could have been obtained by other means without losing of generality of the method.

Accordingly, it is possible to obtain objective guidelines for planning, designing, or modifying a graduate program in construction management, based on the needs of the market, and covering all aspects of the organization as well as the entire lifecycle of an infrastructure. Further, this method allows for comparison among academic programs. The main limitation of the method is that a proper theoretical model mapping the corresponding field of knowledge is essential. Establishing the requirements of the sponsoring institution could also be difficult to achieve if high levels of reliability are sought.

Finally, regarding further research, the method can be applied in practice, not only in the construction management field, but also in other fields. Moreover, every planning, designing, or improvement of a program should have its own exploratory data for its specific market. One interesting possibility is to assess the influence of the type of technique used for detecting market demands, as well as rating subjects to the model or the topics required: e.g., compare results from a massive survey and from a panel of experts; the authors are already working in this line of research. A complementary future line of research of great interest is the utilization of multi-objective optimization, particularly heuristic algorithms such as genetic, simulated annealing, ant colony optimization, and the likes. This would allow for the automation of the iterative process proposed in this paper, using the basic indicators as objective functions; different weights (importance) could be also considered for CI and AI. Obviously, the result of the optimization should be approved by the relevant decision makers.

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