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Developing of Specifications and Academic Curriculum in Construction Engineering, A case study in University of Dammam, KSA*

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Developing an engineering curriculum in order to meet the local and regional market needs is of great importance. Seeking professional and academic accreditation from world-wide organizations, such as National Commission of Academic Accreditation and Assessment in Kingdom of Saudi Arabia and Accreditation Board for Engineering and Technology should be considered. This paper discusses different stages of developing the specifications and curriculum of Construction Engineering Program in the College of Engineering, University of Dammam. Feedback from the main stakeholders in the local area as well as the academic reviewers from well-known international universities is presented and discussed. Comparison between the proposed curriculum with similar accredited programs worldwide is also presented.

Keywords: curriculum; construction engineering; accreditation

1. Introduction

Engineering is one of the most rapidly changing areas of technology in today's society. Therefore, constantly developing and updating engineering programs is critical to their survival and growth. Improvement of quality in the face of rapid changes requires an effective system of management and monitoring. Problems relating to higher education and the evolutionary changes in the way graduates work, are causing colleges across the world to assess and develop their curricula. The collective goal is to have timely flexible programs of ever-improving Quality [1].

Because engineering is a global profession, engineering education has been charged to prepare engineers accordingly. However, it is widely recognized that engineering knowledge and the acquisition of technical skills are necessary but insufficient in the preparation of future engineers. Of equal importance are personal and interpersonal skills and attitudes. A graduate must be critically aware of the impact of engineering activity on society and the environment [2].

Society expects a lot from engineers. They are expected to have a strong scientific background; competent technical skills; a sharp awareness of the social concerns linked with their profession roles; a deep appreciation for safety and security; an ethical sense and appropriate behaviour; an openness to other cultures; a willingness to be both geographically and professionally mobile; adequate project management and teamwork skills as well as many other attributes [3].

Institutions of higher education are becoming increasingly involved in conducting assessments and development within their academic programs and administrative support organizations. They have been called upon by a strong and influential externally driven motivation to publicly demonstrate how academic programs continuously develop and improve [4]. Institutions are facing internal and external pressures to increase quality and provide pioneer program even while funding resources are dwindling.

The construction industry has its own unique aspects that differentiate it from other industries. Geographical dispersion of operations, fixed site location, complex and expensive processes are among the major characteristics of the industry. The fact that every project is one of a kind, demand is not continuous, and that different resources are required during a project life cycle, creates great challenges in the allocation of human and physical resources. These factors create management problems that are specific to the construction industry.

Construction industry is one of the largest and most important industries in the world today. With modern technological advancements, construction is rapidly becoming one of the most difficult and complex businesses to manage. Contemporary construction practice demands that the construction

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professional not only understands construction concepts, but also has a strong background in engineering and management techniques. Emphasis is placed on new technologies, developments, and techniques in both domestic and international construction fields. Therefore, the discipline contains interrelated processes that should be offered to graduates. As clients progressively demanded more different and complex buildings and facilities, the need for new construction methods and management techniques, coupled with advancement in technology, fostered the development of the general contractor. The design and construction function was subdivided into many engineering specialties and trade activities respectively. Managing the multitude of parties and workers involved in modern projects together with the adversary relationships among the architect, engineer, general contractor and owner, is not an easy task.

Construction engineering (CE) is no simpler today and both beginner and experienced engineers find it difficult to come to terms with this subject. Today's construction industry has become more complex than ever before with the emergence of new business demands and challenges.

CE is still a relatively new discipline in the civil engineering realm. For example, in the USA, it started with the development of pioneering master's programs approximately 45 years ago, followed by PhD programs 5 years later [5]. Today CE is an established academic and research area that builds upon a long series of publications of scholarly work and debate. CE is the art of bringing the project on time and within budget despite all the variables and specialties within a project as well as the high fragmentation within the construction industry [6]. The construction industry is the largest non-oil economic sector in the Kingdom of Saudi Arabia. The construction sector employs 14% of the total workforce in Kingdom. Saudi Arabia leads the construction industry in the Gulf where the value of projects has touched $1.9 trillion by May 2008, which represents a 35 percent increase from the same period in 2007. The Gulf's biggest nation now accounts for 25 percent of all construction projects in the Gulf Cooperation Council (GCC) countries [7]. The building boom is also being spurred by planned government investments to expand the country's electricity network and water supplies. The construction element attached to power supply development is estimated at nearly $700 million. In total, current infrastructure and public sector building programs are valued at some $35 billion. Plans include building 600 new factories, schools, doubling desalination capacity, increasing electrical generation and distribution. Some 600,000 new homes were planned to be built from 2006 to 2009 with many more planned [8]. In 2009, the Saudi Construction Industry has seen an increase of 26% in spending compared with 2002 [8]

Business Monitor International (BMI) is forecasting nearly seven percent growth in the kingdom's construction sector in 2011, fuelled by billions of dollars of projects. According to BMI's Key Projects Database, $80 billion worth of infrastructure projects is currently under way in the county. Based on the number of ongoing projects, BMI analysts said they are optimistic for the medium term outlook for Saudi Arabia, with average real growth of 4.13 percent forecast per year between 2010 and 2014 [10]. This is couched in strong fundamentals for continued demand for construction projects, from housing to transport. The Saudi Electricity Company is planning to invest$80billions in the construction sector to 2018 [10].

The construction industry accounts for around one-tenth of the world's gross domestic product, seven percent of employment, half of all resource usage and up to 40 percent of energy consumption. This industry has a profound impact on our daily lives: the buildings we live and work in, the roads and bridges we drive on, the utility distributions systems we use, the railways, airports and harbours we travel and trade from are all products of this vital industry [9].

In Saudi Arabia, there are 24 governmental universities, 8 Private one and 22 colleges or institutes [11]. Most of these educational institutions offer different engineering disciplines and programs. In spite of that there is no construction engineering program in these Saudi universities, institutes and colleges. Therefore, College of Engineering, University of Dammam (UoD), is proposing to establish a new B.Sc. program in Construction Engineering emphasizing on the construction of highways as well as different types structures, such as residential and industrial buildings, dams, tunnels, halls, stadiums and bridges. The program will provide courses focusing on analysis, design, construction and construction management of these structures.

Construction engineers need different abilities to do their job. They must have the ability to reason, convey instructions to others, comprehend multi variables, anticipate problems, comprehend verbal, written and graphic instructions, organize data sets, speak clearly, visualize in 4D time-space and understand Virtual Design and Construction methods. A typical construction engineering curriculum is a mixture of engineering mechanics, engineering design, construction management and general science and mathematics [16].

2. Specifications of construction program

2.1 Department vision

The department vision is to be an internationally-recognized as a region-leading centre for life-long learning and research in practical and cutting-edge construction engineering, and to be a key player in developing the local construction industry through new generation of knowledge, innovative research and expertise that improve the way of life.

2.2 Department Mission

The mission of the department is to provide a comprehensive and state-of-the-art engineering knowledge to enable students to integrate various design, economic, construction and management aspects so as to work as construction engineers with business, industry and consulting firms in both public and private sectors.

2.3 Objectives

CE has been designed to offer high quality program that prepares graduates with a sound education in CE, and develops their skills, and professional preparedness with a sense of ethical values and social responsibilities. To maintain a sustained program of continuing education and life-long learning with focus on contemporary issues, our alumni are expected to be:

- Practical construction engineers and/or construction managers who are pursing or have attained professional registration,
- Aware of the environmental and economic influences of construction engineering solutions,
- Effective communicators who work in multi-disciplinary engineering teams,
- Engineering professionals who try to find leadership roles in community organizations.

2.4 The Program learning outcomes

The courses of CE curriculum will provide instruction and guidance that help students to get the following learning outcomes:

- A broad foundation in mathematics, physics, chemistry, geology, information technology IT, statistics and probability and engineering principles.
- A base of engineering and design knowledge and applications appropriate to construction of buildings, tunnels, offshore and industrial structures, transportation and bridges.
- A base of knowledge in construction process, designs, methods, materials, systems, and equipments.
- An understanding of construction management topics such as, contracts and law, cost analysis and control, planning and scheduling, project finance, and risk management
- An understanding of the professional and ethical responsibilities, leadership, decision making and optimization methods, engineering economics, and safety.
- Understanding of the role of construction engineer and impact of construction engineering in global context.
- Effective oral, written, and graphical communication abilities to effectively communicate with engineers and non-engineers.
- Ability to use current technology to meet the above objectives.

The program will require a mandatory summer training program that enables the student to experience the real work environment. It also provides an opportunity to participate in group work. The student will spend four weeks working in workshops and Engineering surveying camp in the summer after the sophomore year. After the junior year the student is required to spend eight weeks in a construction company and/or a construction site. Upon completion of yearly training program, every student will be required to write a brief report on his work experience and present it orally. By completing the summer training program, the student will be able to have the following outcomes; on-job training, group work experience, ability to gain knowledge and acquire skills in practical work environment, enhancing written and oral communication and developing psychomotor skills

The curriculum contains a mandatory graduation project which is a capstone senior-level course that must be completed under the supervision of a faculty member. The student and/or group of students is/are required to undertake a graduating project that may have components of analysis, synthesis, design, evaluation, alternative solutions and cost analysis and time control. A comprehensive dissertation on the project work is required from the student and/or group of students, who must present his/their work in front of an examining committee.

The assessment of knowledge obtained by the students and their numerical and communication skills will be done through a combination of written exams, homework, and quizzes. Also projects, training reports, presentations, lab tests and term papers will be considered. The cognitive skills of the students will be assessed through design projects as well as the senior-level capstone design project, which will have at least 40% weight on the use of appropriate choices and investigated methodology in seeking solution through student presentation and discussion with the examiners [13].

2.5 Key performance indicators

Key Performance Indicators (KPIs) or Key Success Indicators (KSIs), help an organization define and measure progress toward organizational goals. Once an organization has analyzed its mission, identified all its stakeholders, and defined its goals, it needs a way to measure progress toward those goals. KPIs are quantifiable measurements, agreed to beforehand, that reflect the critical success factors of an organization. They will differ depending on the organization. A school may focus its Key Performance Indicators on graduation rates of its students. A KPI for a social service organization might be number of clients assisted during the year. Whatever KPIs are selected, they must reflect the organization's goals, they must be key to its success, and they must be quantifiable (measurable).

KPIs usually are long-term considerations. The definition of what they are and how they are measured do not change often. The goals for a particular KPI may change as the organization's goals change, or as it gets closer to achieving a goal [12].

As provided by the UoD Quality Unit, the following 9 KPIs were selected and will be used in the college of Engineering to measure progress towards the Construction Engineering Department goals. [13]:

1. Quality management
2. Learning and teaching
3. Student administration and support staff
4. Learning resources
5. Facilities and equipment
6. Financial planning and management
7. Employment process for faculty and staff
8. Research
9. Community relationship
10. The process of assessing these 9 KPIs will be done by the UoD Quality Unit.

3. Curriculum development

3.1 Market response

In April 2009, a delegation from the college of Engineering visited the national oil company of Saudi Arabia, ARAMCO in Dhahran which is the largest oil company in the Middle East and Gulf Area. The college team met with representative from different departments and units. The objective of the visit was to discuss the curriculum of CE in the light of the needs of ARAMCO in order to prepare students to potential job opportunities in the future. The meeting attendants discussed the courses contents and specifications and different specialties in the programs. The company representatives emphasized the need to add a course about the safety and protection in construction, and a course to cover the design and construction of industrial buildings. They expressed their satisfaction with the width, depth and trends in the Construction Engineering curriculum. They showed interest in designing cooperative program for 6–9 months to train students of CE Program in ARAMCO one year before graduation.

The same delegation visited Saudi Basic Industries Corporation, SABIC, and the Royal Commission in Jubail in June 2009 in order to discuss with them the contents and specifications of CE curriculum and investigate the needs to modify existing courses or create new courses to meet their needs. The college delegates met with representatives from SABIC from concerned departments. The representatives of SABIC and Royal Commission were satisfied with the curriculum of CE Program. The following suggestions and recommendations were raised during these meetings:

- Make an agreement between the college of Engineering and both of SABIC and the Royal Commission in Jubail to have a cooperative program for 6–7 months for students of Construction and Environmental programs.
- Provide courses in CE curriculum with emphasis on the industrial engineering. Such courses can cover advances in technology, methods of construction and structural design of industrial buildings.

The recommendations of both ARAMCO & SABIC representatives are reflected in elective courses which a student is responsible to take during his senior year. Extending the cooperative program to six months is difficult to achieve because it will lengthen the program to more than five years, which is not practical.

3.2 Accreditation By ABET

Almost every university program must be accredited by a competent and reputed body at national or international level. The Accreditation Board for Engineering and Technology (ABET) is the recognized U.S. accreditor of college and university programs in applied science, computing, engineering, and technology. ABET was established in 1932 and is now a federation of 28 professional and technical societies representing the fields of applied science, computing, engineering, and technology [14]. ABET is responsible for assuring educational quality. It is a voluntary, non-governmental process of peer review designed to determine if certain defined standards and criteria are being met. Accreditation verifies that an institution or program has met the criteria.

ABET accreditation tells students, their parents, and employers that the program has met minimum

Table 1. Reviewers Comments and Corresponding Actions

Comment	Action
Shortage in the area of basic math and sciences	• Math courses increased to 5 courses (18 Credits) • Basic Science increased by one Physics course (4Cr.) and one Geology course (2 Cr.) • Percentage of basic math and sciences modified to be in the range of ABET requirement (32 Credits).
Rearrangement of math courses to satisfy the prerequisite of other courses	• The new arrangement is Calculus I, Calculus II, Differential Equations and Numerical Methods, Linear Algebra, and finally Probability and Statistics.
Rescheduling physics I and calculus I to be taught before statics	• Physics I and Calculus have been scheduled to 1st semester. • Statics has been scheduled to 2nd semester.
Adding one or two elective courses to match with need of the gulf industrial structures	• Two courses were added: – Design of Fixed Offshore Structures – Industrial Structures
Rescheduling safety course to be mandatory	• Construction Safety course has been moved to 1st semester of Senior

standards of quality education and it has been judged by professionals to provide an adequate preparation for the program graduate. The whole point of the accreditation process is to enable the program establish both the direction and the means for improvement, and further inculcate confidence in the students, parents and employer alike. In a major shift influenced by pressures from industry

Table 2. Program Comparison against Other Accredited Programs

Category	**UoD**	**1**	**2**	**3**	**4**	**5**
# of Credits	**168**	**130**	**135**	**162**	**128**	**123.5**
# of Years	**5**	**4**	**4**	**5**	**4**	**4**
Technical Electives	4 courses- total 12 Cr. All of these courses are related to civil engineering and construction management	4 courses- total 10 Cr. All of these courses are related to civil engineering and engineering management	4 courses- total 12 Cr. All of these courses are related to civil engineering and engineering management	5 courses- total 15 Cr. 4 courses related to different minors.	One elective course of 3 Cr. Whether thermodynamics, principles of electrical engineering or other approved technical elective	2 courses- total 5 Cr., (3 Cr. math or statistic elective, 2 Cr. engineering electives)
General Electives	None	None	6 courses of total 18 Cr. 15 out of the 18 Cr. are classified as Humanities and the rest are social sciences.	0-6 Cr. according to student selection	None	18 Cr. of social and humanities courses
Humanities	A combination of humanities, communications and social behaviours according to Islam.	Only humanities are classified under this category	Both of humanities and social sciences are classified under this category	Both of humanities and social sciences are classified under this category	Cultural and historical, and social foundations	A combination of humanities, communications and social
% Humanities	15	18.5	13.3	17.9	18.8	21.4
% Basic Sciences	22	22.3	22.5	32.1	25.8	30
% Engineering	63	59.2	64.2	54.9	55.4	48.6

1. North Dakota St. Univ. (USA) college of engineering and architecture, department of construction management and engineering.
2. Purdue University (USA), College of Engineering, Division of construction engineering and management.
3. American Univ. Cairo (EGYPT).
4. University of Central Florida, Civil engineering- construction engineering concentration.
5. Iowa State University, construction engineering- building emphasis.

and global competition, ABET introduced the Engineering Criteria 2000 (EC2000) [15], which addressed the effectiveness of engineering education programs by focusing on assessment and evaluation process that assures the achievement of educational objectives and outcomes.

The construction program in UoD has been scheduled to be routinely evaluated and redefined based on qualitative and quantitative assessments of its performance according to the rules of National Commission for Academic Accreditation and Assessment (NCAAA) in the kingdom of Saudi Arabia. We will be seeking accreditation from ABET.

3.3 Steps and development

The program passed through several stages of development ever since only three college faculty members initiated the curriculum in late 2008. It took a lot of meetings and discussions to come up with a proposed program. At this stage an in-depth review was received from a professor of Civil Engineering from an Australian university.

The program was later refined when more faculty members joined the college in early summer of 2009. Consequently it was sent again in its pre-final form in October 2009 to four more international reviewers; three from USA and one from the Middle East. The comments received from the reviewers have been utilized to revise the program. Reviewers recommended increasing the total credit hours of basic science courses to be 32 hours, according to ABET requirements. Also, they suggested adjusting the sequence of related courses, such as statics, physics and calculus, and adding prerequisite courses for some specific courses. Based on feed-

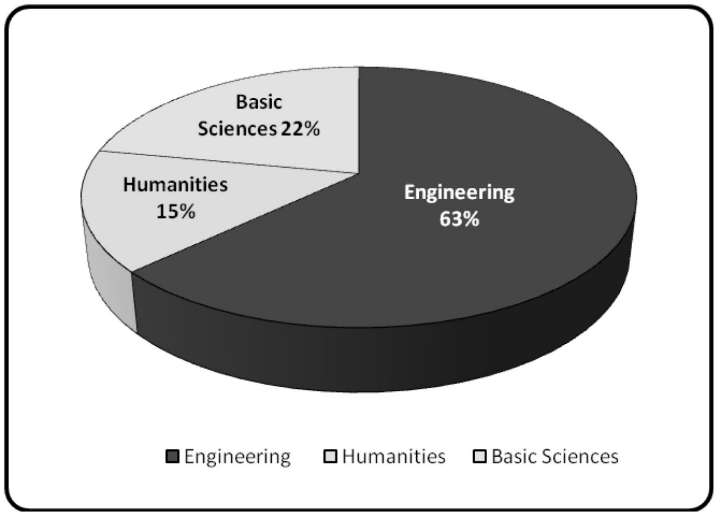

Fig. 1. Elements of Construction Engineering Program by percentage.

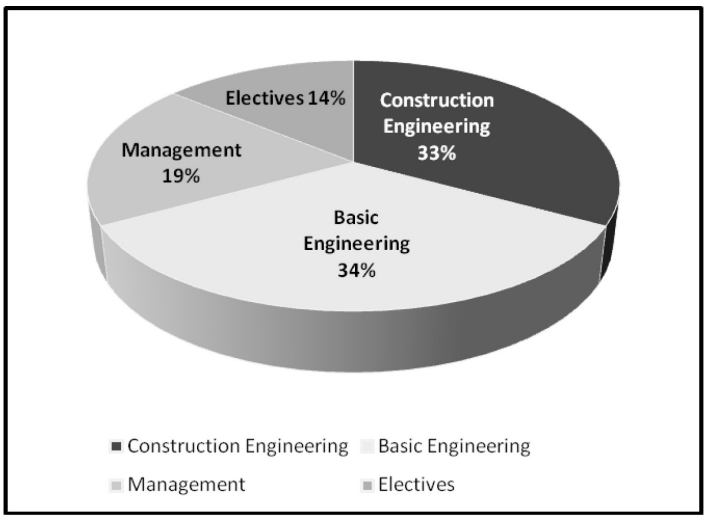

Fig. 2. Elements of Engineering Topics by percentage.

Table 3. Construction Engineering Curriculum

Year	1st Semester		2nd Semester	
	Course Title	**Credit**	**Course Title**	**Credit**
1st Year (Preparatory Year)				
	English Language I	6	English Language II	6
	Mathematics I	2	Mathematics II	2
	Physics	3	Arch & Eng Drawing Skills II	2
	Arch & Eng Drawing Skills I	2	Education & Communication Skills	2
	Computer Skills	2	Scientific Research Skills	2
			Physical Education	1
	Total Credits Hours:	**15**	**Total Hours:**	**15**
2nd Year (Freshman Year)				
	Introduction to Islamic Culture	2	Faith and Ethics in Islam	2
	Library Skills	1	Calculus II	4
	English Composition	3	Physics II	4
	General Chemistry	3	Computer Programming	2
	Calculus I	4	Engineering Drawings	3
	Physics I	4	Statics	3
	Introduction to Engineering	1		
	Total Credits Hours	**18**	**Total Credits Hours**	**18**
3rd Year (Sophomore Year)				
	Economic System in Islam	2	Social & Political System in Islam	2
	Oral Communication and Public Speaking	1	Linear Algebra	3
	Diff. Eq. and Numerical Methods	3	Geology	2
	Dynamics	2	Thermodynamics	3
	Fluid Mechanics	3	Building Construction	2
	Engineering Surveying	3	Concrete Material	2
	Strength of Materials	3	Analysis of Determinate Structures	3
	Total Credits Hours:	**17**	**Total Hours:**	**17**
	1st Summer Training—One Month—0 Credit Hours – Repot Submission Is A Must			
4th Year (Junior Year)				
	Technical Writing	2	Research Methodology	1
	Probability and Statistics	3	Engineering Economics	2
	Analysis of Indeterminate Structures	2	Electro-Mechanical Systems	3
	Fundamentals of Soil Mechanics	3	Planning, Scheduling & Control	3
	Cost Estimating	2	Transportation Engineering	3
	Design of RC Structures	3	Foundation Design	3
	Formwork Design & Const. Meth	2	Construction Contracts and Law	2
	Total Credits Hours:	**17**	**Total Credits Hours:**	**17**
	2nd Summer Field Training—Two Months—0 Credit Hours – Repot Submission Is A Must			
5th Year (Senior Year)				
	Professional Practice and Ethics	2	Global Business Culture	2
	Cash Flow Forecast & Finance Management	2	Senior Design Project II	4
	Senior Design Project I	2	Elective II *	3
	Construction Safety & Protection	2	Elective III *	3
	Design of Steel Structures	3	Elective IV *	3
	Elective I *	3		
	Sanitary Engineering	3		
	Total Credits Hours:	**17**	**Total Credits Hours:**	**15**

back with the main stakeholders in the region, adding one or two courses focusing on the design and construction of industrial structures was recommended. Such structures are widely spreading in the eastern province of the kingdom because of the flourishing of oil and petrochemicals industry. Table 1 shows the major comments which were received and the actions taken.

The program in its latest form is compared against other similar accredited programs in Egypt and USA in several categories as specified by ABET. Results that are shown in Table 2 indicate similar trends between CE curriculum in UoD and five other international programs. It can be seen from table 2 that the curriculum of UOD is very close to the compared universities in humanities, basic sciences and engineering courses, respectively. It should be noted that the number of years at UOD is 5 years similar to the American university in Cairo. That is why the number of hours is greater

than the other universities listed in the table. In additional to that, the offered technical electives at UOD are matching with most of the compared programs

After the final program was set, the resulting percentages of the program contents (Basic Sciences 22%, Engineering 63%, and Humanities 15%), excluding Preparatory year, were calculated to ease the comparison with similar CE programs. These percentages are graphically presented in Fig. 1. Basic sciences include math, physics, geology, and chemistry. Humanities include Islamic courses, economics, and communication skills. The percentages of the topics/elements of the engineering sector are shown in Fig. 2, which include basic engineering, construction engineering and management, and electives.

4. Approved program

CE program consists of five years. The number of credits required for the degree of Bachelor of Science in CE is 168 hours. One credit is translated into 50 minutes of lecturing and 100 minutes of practical/laboratory. The program is currently running with 28 students in the third year and 30 students in the second year and expecting 30 out of 60 students in the first year. Table 3 shows the curriculum of CE program in its final approved form

5. Conclusions

In order to meet local and regional market needs, a new CE program has been developed in UoD after determining its vision, mission and specifications. Feedback from industry and from international academic reviewers were considered in designing our CE program curriculum in order to narrow the ongoing gap between the academic and industrial perspective. The curriculum has been designed to meet the objectives and requirements of NCAAA, and to seek the accreditation from ABET. Moreover, main stakeholders' visions as well as the requirements of new skills and capabilities required for construction engineers are also considered. This is critical for curriculum and for our student's employability. Feedback from international academic reviewers of similar programs in different well-known universities in the region and worldwide provides good evidence on that the curriculum was well established. It is tempting to say that CE program at UoD will provide qualified construction engineers for working environment.

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