ABET-accredited civil engineering programmes following track system: Part II - implementation of the proposed framework

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ABSTRACT: In Part I of the study, 37 track-based out of 222 ABET-accredited programmes in the United States were surveyed. In addition, a proposed framework for curriculum development based on the track approach within the ABET criteria was presented. This article focuses on the implementation of the proposed framework by presenting three case studies of converting non-track system ABET-accredited programmes into track system and emphasises the benefits of following the proposed framework.

Keywords: Undergraduate education, engineering degree, ABET-accredited, civil engineering curriculum, curriculum development

INTRODUCTION

The proposed framework presented in Part I of this study provides general guidelines for civil engineering curricula following the track system [1]. These guidelines satisfy ABET recommendations and provide an opportunity to include more depth in a specialisation area of student's interest [2]. In addition, courses such as Project Management, Professional Practice, Development and Engineering Ethics could be added to the core engineering courses based on programme needs. Many engineering education leaders and professional organisations suggested these courses to prepare civil engineering graduates better for future challenges [3-9]. This article presents a description of the implementation of the proposed framework through three case studies of non-track ABET-accredited curricula. Benefits of adopting track-system curricula are emphasised and suggested changes are highlighted.

IMPLEMENTATION OF PROPOSED FRAMEWORK

Methodology

The proposed framework suggested that track system curricula with 126-132 total credit hours are most common. Therefore, three curricula were selected within this range of credits to discuss the implementation and provide recommendations on how the proposed framework is to be adopted. The selected curricula were taken from actual ABET-accredited programmes around the world. The following procedure was followed during the implementation discussion:

- General education hours are not changed.
- University requirements are not changed.
- English/Technical writing courses are not changed.
- Total number of credits is not changed.

Case Study I

The first case study presents a civil engineering curriculum, which has credit hours at the lower boundary proposed by Part I of the study [1]. The total credit hours of 125 are distributed as follows: 21 general education hours, 33 hours for

basic mathematics and science, 59 hours are devoted to engineering topics and 12 hours for electives, as shown in Table 1. In this programme, professional training is not required.

Shaded areas in Table 1 include credit hours, which were considered in the change to a track system. Referring to the proposed framework, the following actions are recommended: *Total number of credit hours for core engineering hours and track options is 74 credit hours. Another 53 credit hours could be devoted to core engineering subjects, while 21 are used for each specialty track* [1]. Detailed changes to the curriculum are discussed in the following sections.

Core Engineering

Table 2 summarises the proposed core engineering courses and track options. The majority of the core engineering subjects were maintained from the existing curriculum. However, three subjects were moved to specialty tracks and three subjects were recommended for content/name change. In addition, two additional subjects, Professional Practice and Introduction to Construction Engineering, were added.

Track Options

For illustration purposes, all common tracks that were identified by the study in Part I were included in the case study. Each specialty track has 21 credit hours divided as follows: 15 for main specialty subjects including the capstone design, the other six credit hours provide the breadth needed by the accreditation criteria. Courses previously offered by the curriculum before tracks were placed in their appropriate tracks, as shown in Table 2. Additional courses labelled *new courses* are to be selected from Table 3 [1].

Table 1: Sample curriculum without track system - Case study I.

Engineering Topics (Core)	Hrs	General Education	Hrs	Math & Basic Sciences	Hrs	Other Requirements	Hrs
Intro. to Engineering Design	1	Technical Communication	3	General Chemistry I + Lab.	4	Construction Eng. Elective	3
Intro. to Eng. Analyses	1	Area I Fine Arts	3	General Physics I + Lab. I	5	Environmental Eng. Elective	3
Eng. Graphics	3	Micro-Economics	3	General Physics II + Lab. II	5	Structural Eng. Design Elective	3
Mathematical Software/Program.	2	Ethics	3	Math - Calculus I	4	Eng. Science or Design Elective	3
Statics	3	Cultures and Issues	3	Calculus II	4		
Dynamics	3	Other Cultures	4	Multi-Variable Calculus	4		
Elementary Surveying + Lab.	3	Health & Well Being	2	Differential Equations	4		
Intro. to Civil & Construction Eng.	1			Eng. Science	3		
Civil Eng. Measurement	2						
Construction Materials and Methods + Lab.	3						
Mech. of Materials	3						
Fluid Mechanics	3						
Eng. Statistics	3						
Structural Analysis	3						
Soil Mech. + Lab.	3						
Construction Codes and Specifications	3						
Eng. Economics	3						
Environmental Eng.	3						
Intro. to Struc. Design	3						
Transportation Eng.	3						
Traffic Design w/Lab.	3						
Senior Project I/II	4						
	59		21		33		12

Shaded areas will be considered in the curriculum change

Table 2: Modifications to the sample curriculum (Case study I) adopting the proposed framework.

Core Engineering Education			
Topic	Hrs	Topic	Hrs
Intro. to Eng. Design	1	Mechanics of Materials	3
Intro. to Eng. Analyses	1	Fluid Mechanics	3
Eng. Graphics	3	Engineering Statistics	3
Mathematical Software / Programming	2	Structural Analysis	3
Statics	3	Soil Mechanics + Lab	3
~~Dynamics~~	~~3~~	~~Construction Codes and Specifications~~ Introduction to Construction Eng.	3
Elementary Surveying + Lab	3	Eng. Economics	3
Intro. to Civil ~~& Construction Eng.~~	~~1~~ 2	~~Environmental Eng.~~ Intro-to water and Env	3
Civil Eng. Measurement	2	Intro. to Structural Design	3
Construction Materials and Methods + Lab	3	~~Transportation Eng.~~ Intro to Transportation Eng.	3
Professional Practice	3	~~Traffic Design w/Laboratory~~	~~3~~
New courses added to core courses		53	

Suggested Track Options													
Struc. Eng.		Geotech Eng.		Const. Eng. & Manag.		Transp. Eng.		Env. Eng.		Water Eng.		General Civil	
Fund.of Struc. Dyn**	3	New Course**		Const.Codes and Spec.*	3	Traffic Design w/Lab*		Env. Eng.*	3	New Course**	3	New Course**	3
New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3
New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3
New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3
From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3
From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3
Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3
21													

*Existing courses ** Courses to be selected from Table 3 Courses to provide breadth

Case Study II

The second case study was a civil engineering curriculum composed of a total of 130 credits. Table 3 provides the existing curriculum without change. The total credit hours are distributed as follows: 30 general education hours, 32 hours for basic mathematics and science, 59 hours are devoted to engineering topics and nine hours for electives. Professional training is not required. In addition, this curriculum does not include courses in transportation engineering or construction engineering.

Shaded areas in Table 1 include credit hours which were considered in the change to a track system. Referring to the proposed framework the following actions are recommended: *Total number of credit hours for core engineering hours and track options is 68 credit hours. Another 50 credit hours could be devoted to core engineering subjects, while 18 are used for each specialty track* [1]. Detailed changes to the curriculum are discussed in the following sections.

Core Engineering

The majority of the core engineering subjects were maintained from the existing curriculum. However, four subjects were moved to specialty tracks and two additional subjects, Water Resources Engineering and Transportation Engineering, were added, as shown in Table 4.

Track Options

Because no construction engineering courses were among the original curriculum, therefore, construction engineering is not recommended as a track option. However, other common tracks that were identified by the study were included in the case study.

Each specialty track has 18 credit hours divided as follows: 12 for main specialty subjects including the capstone design, the other six credit hours provide the breadth needed to meet the accreditation criteria. Courses previously offered by the old curriculum before tracks were placed in appropriate tracks in the proposed new curriculum, as shown in Table 4. Additional courses labelled *new courses* are to be selected from Table 3 in Reference [1].

Table 3: Sample curriculum without track system - Case study II.

Engineering Topics (Core)	Hrs	General Education	Hrs	Math & Basic Sciences	Hrs	Other Requirements	Hrs
Challenge of Civil Engineering	1	English Composition I	3	General Chemistry (with Lab)	4	Major Elective	3
Computer Aided Drafting	3	English Composition II	3	Calculus I	4	Major Elective	3
Statics	3	Technical Communication	3	Calculus II	4	Major Elective	3
Dynamics	3	Humanities/Social Sciences	18	Calculus III	4		
Electrical Circuits	3	Visual & Performance Arts	3	Engineering Math	3		
Therodynamics	3			Engineering Statistics	3		
Engineering Economy	3			General Physics I (with Lab)	4		
Computing for Engineers	3			General Physics II	3		
Mechanics of Deformable Solids	3			Geology or Biology	3		
Engineering Materials (with Lab)	3						
Fluid Mechanics (with Lab)	4						
Theory of Structures	3						
Geotechnical Engineering (with Lab)	3						
Hydrology	3						
Environmental Engineering	3						
Foundation Engineering	3						
Reinforced Concrete Design	3						
Water and Waste Water Treatment	3						
Civil Engineering Design & Professional Practice	3						
Capstone Design Project	3						
	59		30		32		9

Shaded areas will be considered in the curriculum change

Case Study III

The third case study concerns a civil engineering curriculum without the track system, which has additional university requirements of free electives and a foreign non-English language. Table 5 provides the existing curriculum without change.

The total credit hours are 140, distributed as follows: 27 general education hours, 35 hours for basic math and science, 63 hours are devoted to engineering topics, and six hours for major electives. In addition, the curriculum includes six credit hours free elective and three hours for foreign non-English language as university requirements. Professional training is required, but it has zero credit.

Table 4: Modifications to the sample curriculum (Case study II) adopting the proposed framework.

Core Engineering Education			
Topic	Hrs	Topic	Hrs
Challenge of Civil Eng.	1	Fluid Mechanics (with Lab)	4
Computer Aided Drafting	3	Theory of Structures	3
Statics	3	Geotechnical Eng. (with Lab)	3
~~Dynamics~~	~~3~~	~~Hydrology~~	3
Electrical Circuits	3	Environmental Eng.	3
Therodynamics	3	~~Foundation Engineering~~	3
Eng.Economy	3	Reinforced Concrete Design	3
Computing for Engineers	3	~~Water and Waste Water Treatment~~	~~3~~
Mechanics of Deformable Solids	3	Civil Engineering Design & Professional Practice	3
Eng.Materials (with Lab)	3	Water Resources Eng.	3
		Transportation Eng.	~~3~~
New courses added to core courses		50	

Suggested Track Options													
Struc. Eng.		Geotech. Eng.		~~Const Eng. & Manag.~~		Transp. Eng.		Env. Eng.		Water Eng.		General Civil	
New Course**	3	Foundation Eng.*			3	New Course**		Water and Waste Water Treatment*	3	Hydrology*	3	New Course**	3
New Course**	3	New Course**	3		3	New Course**	3	New Course**	3	New Course**	3	New Course**	3
New Course**	3	New Course**	3		3	New Course**	3	New Course**	3	New Course**	3	New Course**	3
From other Tracks	3	From other Tracks	3		3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3
From other Tracks	3	From other Tracks	3		3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3
Capstone Design Project I/II	3	Capstone Design Project I/II	3		3	Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3
18													

*Existing courses ** Courses to be selected from Table 3 Courses to provide breadth

Shaded areas in Table 5 include credit hours, which were considered in the change to a track system. Referring to the proposed framework, the following actions are recommended: *1) Math and basic science could be satisfied by 32 credit hours. This will free three credit hours for core engineering hours; and 2) Total number of credit hours for core engineering hours and track options is 72 credit hours [engineering topics (63) + electives (6) + freed from basic mathematics and science (3)]. 51 credit hours could be devoted to core engineering subjects, while 21 are used for each specialty track* [1]. The detailed changes to the curriculum are discussed in the following sections.

Core Engineering

Table 6 summarises the proposed core engineering courses and track options. The majority of the core engineering subjects were maintained from the existing curriculum. However, three subjects are recommended for content/name change and two additional subjects, Professional Practice and Introduction to Construction Eng, are to be added.

Track Options

All common tracks identified by Part I of the study were included in this case study. Each specialty track has 21 credit hours divided as follows: 15 for main specialty subjects including the capstone design, the other six credit hours provide the breadth mandated by the accreditation criteria. Courses previously offered by the curriculum before tracks were placed in appropriate tracks, as shown in Table 6. Additional courses labelled *new courses* were to be selected from Table 3 in Reference [1].

Table 5: Sample curriculum without track system - Case study III.

Engineering Topics (Core)	Hrs	General Education	Hrs	Math & Basic Sciences	Hrs	Other Requirements	Hrs
Introduction to Eng. and Computing	2	Academic Writing & Reading	6	General Chemistry I	4	Major Elective	3
Fundamentals of Graphics	3	Advanced Academic Writing	3	Calculus I	3	Major Elective	3
Statics	3	English for Engineers	3	General Physics I	3	Professional Training in Civil Eng.	0
Elementary Surveying	3	Humanities/Social Sciences	15	General Physics Lab I	1	Free Elective	3
Field Plane Surveying	1			Calculus II	3	Free Elective	3
Construction Materials Lab	1			Intro to Statistical Analysis	2	Foreign non-English Language	3
Construction Material and Quality Control	3			General Physics II	3		
Mechanics of Materials	3			General Physics Lab II	1		
Fluid Mechanics	3			Differential Equations	3		
Urban Transp.Planning	3			Linear Algebra	3		
Theory of Structures	3			Calculus III	3		
Geotechnical Engineering Lab	1			Computational Methods	3		
Geotechnical Eng. Principles	3			Fourth area of Science	3		
Water Resources Engineering	3						
Civil Engineering Cost Analysis	3						
Env. and Water Eng. Lab	1						
Structural Steel Design	3						
Reinforced Concrete Design	3						
Env. Eng.	3						
Fundamentals of Structural Dynamics	3						
Project Estimating, Planning and Control	3						
Highway Design	3						
Capstone Design Project I/II	3						
Geotechnical Eng. Design	3						
	63		27		35		15

Shaded areas will be considered in the curriculum change

DISCUSSION AND CONCLUDING REMARKS

The three case studies highlight the implementation of the proposed framework in the first part of the study. The three cases present curricula within the lower, intermediate and higher proposed credit hours of the curriculum following the track system. The process followed during the implementation maintained the majority of the original courses, but in addition, limited the change/addition in the core engineering courses. Table 7 provides a summary of the implementation results and emphasises the number of new tracks and credit hours that became available in each track. The following parameters need to be considered when making the decision to adopt a track system curriculum:

- Number of students in a programme and their interests.
- Number of academic staff and their specialties.
- Not all suggested tracks could be offered.

It is important to note that the following track system curriculum provided an opportunity to include new courses for in-depth knowledge in all proposed tracks.

Table 6: Modifications to the sample curriculum (Case study III) adopting the proposed framework.

Core Engineering Education			
Topic	Hrs	Topic	Hrs
Introduction to Engineering and Computing	2	~~Urban Transportation Planning~~ Introduction to Transportation Engineering	3
Fundamentals of Graphics	3	~~Water Resources Engineering~~ Intro-to water and Env	3
Statics	3	~~Civil Engineering Cost Analysis~~ Engineering Economics	3
Elementary Surveying	3	Environmental and Water Engineering Lab	1
Field Plane Surveying	1	Geotechnical Engineering Lab	1
Construction Materials Lab	1	Geotechnical Engineering Principles	3
Construction Material and Quality Control	3	Theory of Structures	3
Mechanics of Materials	3	Reinforced Concrete Design	3
Fluid Mechanics	3	Introduction to Construction Eng	3
Computational Methods (Programming)	3		
Professional Practice	3		
New courses added to core courses		51	

Suggested Track Options													
Struc. Eng.		Geotech. Eng.		Const. Eng. &Manag.		Transp. Eng.		Env. Eng.		Water Eng.		General Civil	
Struc. Steel Design*	3	Geotech Eng. Design*	3	Project Estimating, Planning and Control*	3	Highway Design*	3	Env. Eng.*	3	New Course**	3	New Course**	3
Fund. of Struc. Dyn*	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3
New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3
New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3	New Course**	3
From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3
From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3	From other Tracks	3
Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3	Capstone Design Project I/II	3
21													

*Existing courses ** Courses to be selected from Table 3 Courses to provide breadth

Table 7: Summary of the implementation results.

	Case study I	Case study II	Case study III
Total credit hours	125	130	140
Core engineering credits	53	50	51
Number of courses included in the change	6	4	6
Number of new hours courses in core credits	2	2	2
Number of tracks added	7	6	7
Number of hours in each track	21	18	21
Number of new available hours	9 to 12	6 to 9	6 to 9
Number of additional hours needed	0	0	0

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BIOGRAPHIES

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