Statistical Analysis on the Time-Variance of Accreditation Units (2001-2017)

FINAL

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Executive Summary

The objective of this report is to analyze and assess statistically significant trends in the time variance of accreditation units (AU) allocated by engineering programs in Canada. Through this analysis, the aim is to provide a clearer picture of the efforts required by postsecondary institutions to adapt to changing academic requirement criteria, as established by Engineers Canada, over time.

Due to the wide variety of engineering programs across provinces, the data was grouped into 92 strata, each consisting of a province and a program category. The categories used in the report are the same as those used the Enrolment and Degrees Awarded Report, which consistently catalogues each engineering program under a parent field. To get a representative sample of the 279 accredited programs in Canada (as of 2017), with a confidence level of 95% and a margin of error of +- 5%, a total of 163 programs needed to be sampled, corresponding to 58% of accredited programs in the same year. Since several strata only contained a single program, a total of 184 programs (66%) were sampled to ensure that categories populated by a single engineering program were also represented (Cochran, 1963).

For each stratum, the study compares AUs in each category and as a combined group across the last three accreditation cycles (i.e. the 6-year cycle between accreditation visits). These cycles were numbered from the most recent (cycle number one) to the furthest back (cycle number three). Because some programs have not yet been accredited for three cycles, the total number of programs varies by cycle. Also, because these cycles are staggered (e.g. programs could technically fall into the same cycle but occur up to five years apart), some exceptions were made in the data to reduce bias.

For sampled institutions, the most prominent changes appear to have occurred from cycle number one to cycle number three, where AUs, complementary studies, and engineering sciences were found to have increased by an average of 54 AUs, 33 AUs, and 16 AUs respectively. On the other hand, natural sciences have shown an average decrease of close to 10 AUs in the same interval. Although the biggest change in AUs happened from cycle number one to cycle number two, none of the categories of AUs have shown a statistically significant increase in the same interval. However, natural sciences and engineering design have shown a statistically significant difference from the previous cycle (cycle number two) to the latest cycle (cycle number three), whereby both have decreased by an average of 9 and 21 units respectively.

Taken as a whole across programs nationally, the study revealed that the overall increase of AUs amounted to the equivalent of adding one course over a four-year degree (or approximately 50 AUs).

Background

The Canadian Engineering Accreditation Board (CEAB) uses academic units (AUs) as one way to measure curriculum content of engineering educations programs seeking accreditation. Under the CEAB Accreditation Criteria and Procedure guide, section 3.4.1.1, AUs are defined as:

"an hourly basis for an activity which is granted academic credit and for which the associated number of hours corresponds to the actual contact time between the student and the faculty members, or designated alternates, responsible for delivering the program."

This report was initiated to address concerns raised by engineering education stakeholders that AU demands had grown significantly over time by conducting a detailed analysis of AU counts over a number of accreditation cycles.

Objective

The objective of this report is to analyze and assess statistically significant trends in the time variance of academic units (AU) allocated by engineering programs in Canada. Through this analysis, the intention is to identify trends related to the efforts required by postsecondary institutions to adapt to changing academic requirement criteria, as established by Engineers Canada via the Canadian Engineering Accreditation Board, over time.

Data

This report explores AU requirement trends in several key areas: mathematics (M), natural sciences (NS), engineering science (ES), engineering design (ED), complementary studies (CS), and total AUs.

Engineers Canada collects data, including the AU allocations, from each accredited engineering education program during the accreditation visit process. This report was created from information collected and retained by Engineers Canada from 2001 to 2017. This time frame encompasses three 6-year accreditation cycles for currently accredited programs.

Sampling

Since the data can be categorized by institution, program, province, or any combination of these, it is of interest to obtain a widely representative sample that allows for certain filters to be applied (e.g. trends in AUs by province, or a comparison of average AUs between two different programs). Therefore, to allow for future opportunities to filter data by location or discipline, as well as to ensure that each subgroup within the population is properly represented, this analysis was conducted using stratified random sampling (Sharma, 2017).

Initially, the research team considered separating the data into subgroups (strata), with each stratum consisting of an engineering program and a province (e.g. aerospace engineering programs in Ontario). However, the sheer variety of engineering programs requires that similar disciplines be categorized together so that the total number of strata is reduced (for the breakdown, see Appendix A). The categories used are the same as those used the Enrolment and Degrees Awarded Report, which consistently catalogues each engineering program under a parent field (Engineers Canada, 2017). Ultimately, then, the data analyzed consists of 92 strata, each consisting of a grouped province and discipline (e.g. biosystems programs in Ontario; electrical programs in Alberta, etc.).

While this report takes into consideration the population as a whole, stratified random sampling was used to improve the representation of subgroups. As a benefit, the underlying methodology of stratified random sampling potentially enables specific inquiries in the future (e.g. inquiries pertaining to certain provinces or discipline fields).

To get a representative sample of the 279 accredited programs (2017) with a confidence level of 95% and a margin of error of +- 5%, a total of 163 programs needed to be sampled, corresponding to 58% of accredited programs in the same year. Since several strata only contained a single program, a total of 184 programs (66%) were sampled to ensure that categories populated by a single engineering program were also represented (Cochran, 1963).

To assess changes in AUs over time, the study sampled the last three accreditation cycles for each of the 184 individual programs, except when the program had not yet completed three. This approach led to differing sample sizes from one cycle to the next. When analyzing the differences between two cycles of accreditation, only programs that were present in both cycles are considered. Additionally, the study's focus on changes over time required that a number be assigned to each cycle relative to the present. The latest visit was labelled cycle number three, the previous visit cycle number two, and the one before that, when available, cycle number one.

Within this framework, several exceptions were made to reduce bias, because institutions can receive accreditation visits up to six years apart and still technically fall within the same accreditation cycle. Thus, when a program's latest accreditation visit happened before 2010, it was associated with cycle number two. Similarly, when the latest or previous accreditation visit happened before 2006, it was associated with cycle number one.

Analysis

Analysis compared two cycles at a time by finding the differences in AUs for each of the sampled programs shared by them. Three statistical tests were then performed on the array of differences, such that the likelihood of a statistically significant change could be assessed (i.e. how likely it is that such differences would be observed if there was no would be observed if there was no true difference). Below is a brief description of the purpose of each of the three tests used in this analysis:

Paired t-test

The paired t-test or dependent sample t-test is used to verify whether the average difference between two sets of observations is zero. In a paired t-test, as opposed to an unpaired t-test, each set of observations is performed on the same subjects, resulting in a pair of observations (e.g. two cycles of accreditation for individual programs). This test is commonly used to determine whether certain events or factors have an impact on the measured variable (Goulden, 1956). Since this analysis is concerned with variations in AUs over time, the t-test was deemed an adequate investigation tool.

The paired t-test is accompanied by a set of assumptions that must be respected to prevent any biases or incorrect conclusions. These assumptions are the following:

- The dependent variable must be continuous.
- The observations are independent of one another.
- The dependent variable should not contain any outliers.
- The dependent variable should be approximately normally distributed (a test will be performed to determine whether this assumption is respected or not in each of the analyses). Despite this, there exists strong evidence that this assumption may be violated without introducing significant error to the analysis if large samples are being considered (>30).

Normality test

As mentioned under the fourth condition of the paired t-test, a test for normality should be employed to correctly assess the relevance of that assumption. The Kolmogorov-Smirnov test was chosen, as it compares if two samples have similar distributions (Daniel, 1990). The sampled data was compared to a normal distribution, with the criteria for normality being a probability result of over 95%. Hence, the assumption of normality is discarded whenever there is a less than 95% chance that the distribution is normal according to this test. In the eventual occurrence that the assumption of normality is violated, the t-test will still be considered for analysis of data due to its robustness to normality for large sample sizes. Ultimately, the normality test should be used as a tool to assess the validity of the fourth assumption and should not be a determining factor in assessing the power of the paired t-test.

Wilcoxon signed ranked test

Although the paired t-test is known to be very robust to non-normality when large sample sizes (>30) are involved, an alternate test which does not assume normality will also be employed. This alternate test is the Wilcoxon-signed ranked test, which is commonly used as a substitute to the paired t-test and presents a smaller chance of committing a type I error, although it is accompanied by a small loss of power (Imam, Usman, & Chiawa, 2014). The Wilcoxon-signed ranked test is used to determine whether two dependent samples were selected from populations having the same distribution. Like the t-test, the Wilcoxon-signed ranked test also has several assumptions that need to be obeyed (Wilcoxon, 1945).

1) The difference data must be continuous (as is the case with AUs).
2) Data are paired and come from the same population (see the sampling section of this report).
3) Each pair is chosen randomly and independently (see the sampling section of this report).

No further testing is necessary to ensure all the above-mentioned criteria are complied with.

Results

For a difference to be statistically significant, it needs to fall below a certain probability threshold. This threshold represents the probability that the given result would be observed if there was in fact no difference between two cycles. Most statistical analyses choose this threshold to be of 5%, meaning they will consider a difference to be statistically significant if the probability of observing it when no real change exists is less than 5%. This 5% threshold will also be used in this analysis.

Hence, any tests that yielded a probability value of less than 5% were deemed to present a statistically significant difference. However, it should be noted that having a statistically significant difference is not the same as having a relevant difference for a researcher's purposes. Thus, a 95% confidence interval around the calculated average difference is also displayed in the result tables.

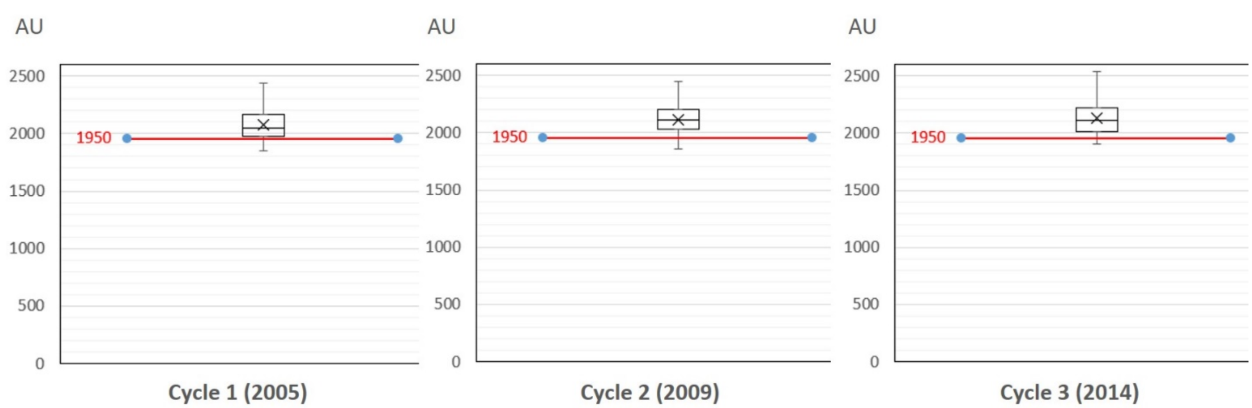


Figure 1 – Comparison of AUs over cycles 1, 2, and 3

Figure 2 represents what percentage of each cycle's programs had a total of 1950+ AUs. The numbers inside each bar represent the number of programs with more than 1950 AUs out of the total number of programs sampled, while the year beside each cycle's number represents the average year of all programs sampled in the cycle.

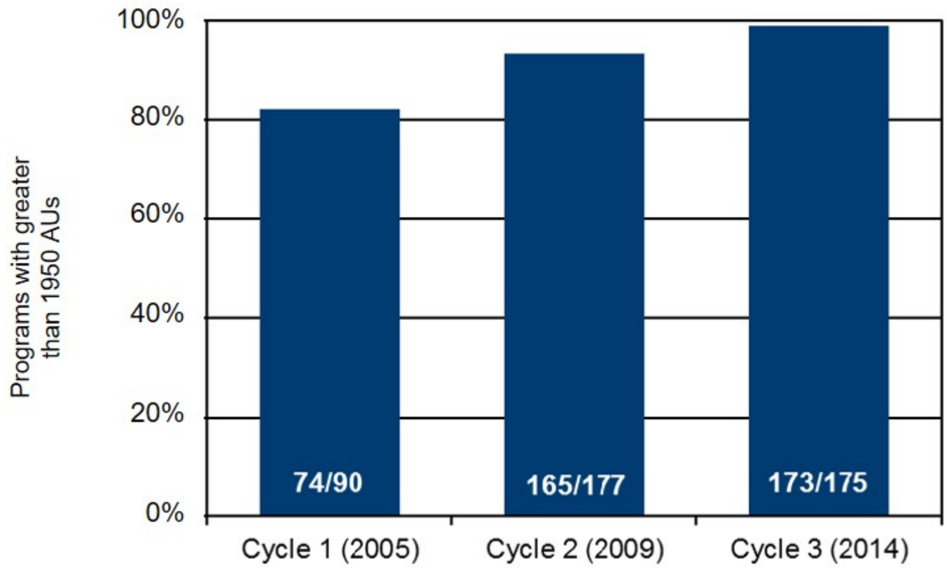


Figure 2 – Comparison of Programs with greater than 1950 AUs in each cycle.

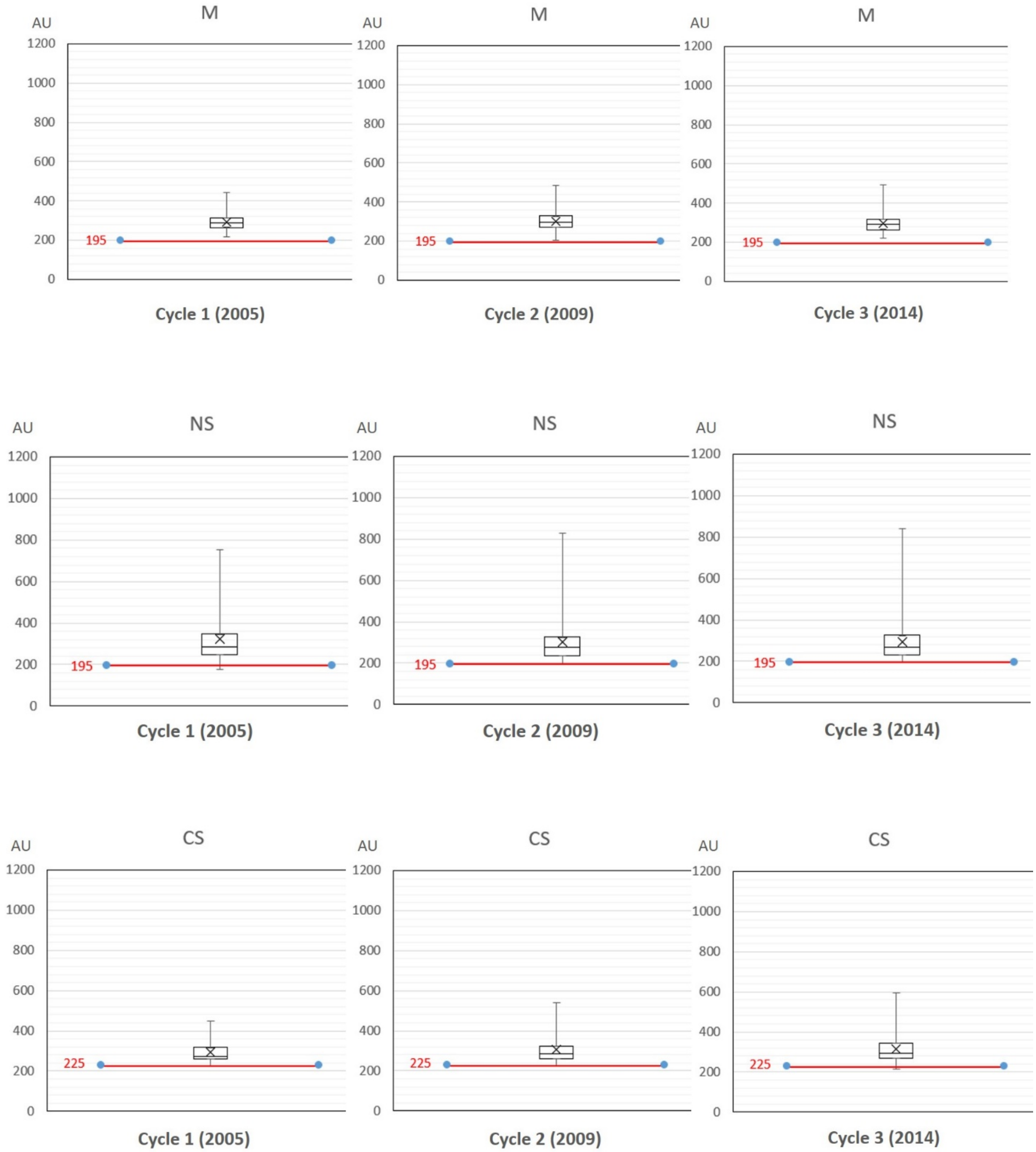
Table 1 below summarizes information used to produce box-and whisker plots, as well as to better understand the distribution of AUs depicted in Figure 1.

Table 1 – Statistical summary of data

CURRICULUM CONTENT CATEGORY	Cycle 1 (2005)	Cycle 2 (2009)	Cycle 3 (2014)
Mathematics			
CEAB requirement	195	195	195
Mean	294.1	301	295.2
Median	287	294.5	288.5
Minimum	216	203.7	223
Lower Quartile	264.1	278.3	262.4
Upper Quartile	312	327.6	315.3
Maximum	442.9	484.2	493
Natural Science			
CEAB requirement	195	195	195
Mean	312.8	304.1	295.7
Median	284	274.7	265
Minimum	178	196.4	195
Lower Quartile	247.3	234.6	230.6
Upper Quartile	345	321.5	310.8
Maximum	754	827.3	840

CURRICULUM CONTENT CATEGORY	Cycle 1 (2005)	Cycle 2 (2009)	Cycle 3 (2014)
Complementary Studies			
CEAB requirement	225	225	225
Mean	292.8	305.3	313.7
Median	274	285.6	293
Minimum	225.5	223.1	212.9
Lower Quartile	259	258.3	265.1
Upper Quartile	313.9	322.2	337
Maximum	448.6	540	596.3
Engineering Science			
CEAB requirement	225	225	225
Mean	712	732.7	749.4
Median	694.4	734.5	729.9
Minimum	402.3	363.7	411.9
Lower Quartile	622	640.1	655.5
Upper Quartile	802.9	823	826
Maximum	980	1130.8	1190
Engineering Design			
CEAB requirement	225	225	225
Mean	370.3	380.1	363.7
Median	344	373	342.4
Minimum	223.3	228.2	226.9
Lower Quartile	302.9	320	302
Upper Quartile	435	423.6	396
Maximum	643.6	607.7	623.1
Total			
CEAB requirement	1800 +	1800 +	1950
Mean	2073	2116	2125
Median	2046	2109	2097
Minimum	1845.8	1856.5	1908
Lower Quartile	1977	2027	2014
Upper Quartile	2173	2202	2213
Maximum	2438.1	2449.4	2533.5

Box-and-whisker plots of each cycle's AU ranges can be found below for a better illustration of the shape and variability of the distributions.



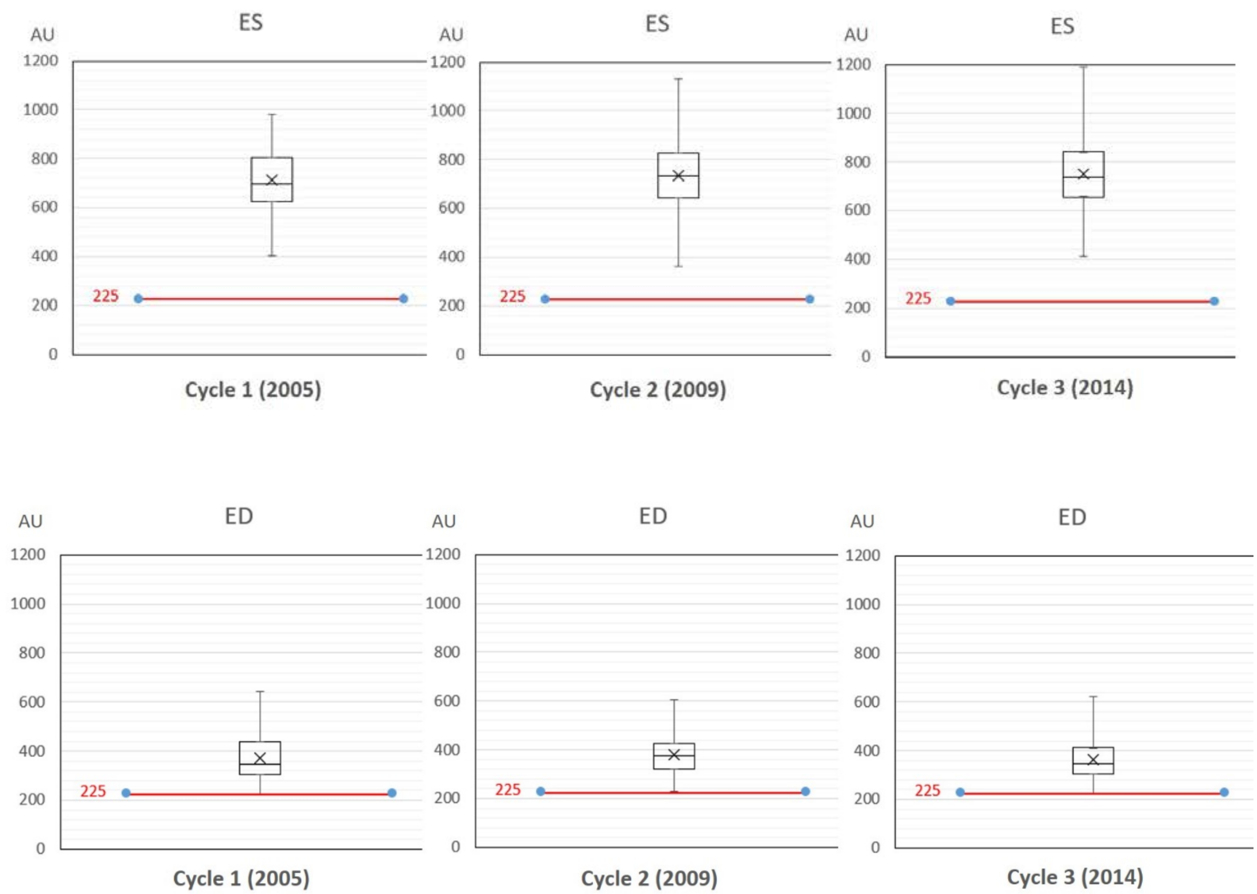


Figure 3 – Variability of AUs distribution

Tables 2, 3, and 4 below display the results of the three statistical tests when applied to comparisons between each combination of two cycles. Numbers in bold highlight probability values below the previously established 5% threshold, indicating statistically significant differences.

Table 2 – Changes from cycle 2 (2009) to cycle 3 (2014)

Category	Average Difference	95% Confidence Interval	t-Test Probability	Wilcoxon Test Probability	Normality Test Probability
Math (M)	-5.1	(-10.8, 0.6)	8.6%	34.0%	98.2%
Natural Sciences (NS)	-8.5	(-15.3, -1.6)	**2.1%**	32.5%	97.7%
Complementary Studies (CS)	4.6	(-4.8, 13.9)	24.9%	33.4%	96.4%
Engineering Sciences (ES)	12.6	(-2.7, 27.9)	10.7%	26.9%	99.3%
Engineering Design (ED)	-20.6	(-31.1, -10.1)	**0.0%**	**0.7%**	97.5%
Accreditation Units (AU)	9.4	(-8.0, 26.8)	22.6%	47.4%	97.6%

Table 3 – Changes from cycle 1 (2005) to cycle 2 (2009)

Category	Average Difference	95% Confidence Interval	t-Test Probability	Wilcoxon Test Probability	Normality Test Probability
Math (M)	-0.8	(-9.3, 7.7)	39.1%	7.8%	96.9%
Natural Sciences (NS)	-5.2	(-16.0, 5.6)	25.3%	40.9%	**94.4%**
Complementary Studies (CS)	13.5	(-0.5, 27.5)	6.4%	21.8%	**91.6%**
Engineering Sciences (ES)	7.8	(-11.7, 27.2)	28.9%	34.0%	98.0%
Engineering Design (ED)	11.7	(-2.5, 25.9)	10.4%	**0.1%**	98.3%
Accreditation Units (AU)	42.6	(20.1, 65.0)	**0.1%**	**1.7%**	99.2%

Table 1 – Changes from cycle 1 (2005) to cycle 3 (2014)

Category	**Average Difference**	**95% Confidence Interval**	**t-Test Probability**	**Wilcoxon Test Probability**	**Normality Test Probability**
Math (M)	-1.2	(-10.3, 8.0)	38.5%	16.1%	99.3%
Natural Sciences (NS)	-9.8	(-21.9, 2.4)	11.1%	**1.1%**	**93.6%**
Complementary Studies (CS)	16.2	(4.0, 28.5)	**1.3%**	45.0%	99.4%
Engineering Sciences (ES)	32.8	(8.2, 57.4)	**1.3%**	8.9%	99.3%
Engineering Design (ED)	-5.8	(-24.0, 12.4)	32.6%	34.5%	99.3%
Accreditation Units (AU)	53.6	(20.4, 86.7)	**0.3%**	24.3%	95.6%

Observation

Examination of the data revealed that, simply stated, the overall increase of AU over the study period has amounted to, for a specific number of institutions, the equivalent of adding one course over a four-year degree (in the range of 50 AUs). The most prominent differences appear to have occurred from two cycles ago (cycle 1) to the latest cycle (cycle 3) where overall AUs, complementary studies, and engineering sciences were found to have increased by an average of 54 units, 33 units, and 16 units respectively. On the other hand, natural sciences have shown an average decrease of close to 10 units in the same interval. Although the biggest change in overall AUs happened from two cycles ago (cycle 1) to the previous cycle (cycle 2), none of the individual categories of AUs have shown a statistically significant increase in the same interval. However, natural sciences and engineering design have shown a statistically significant difference from the previous cycle (cycle 2) to the latest cycle (cycle 3), whereby both have decreased by an average of 9 and 21 units respectively.

Overall minimum program requirements have evolved. Prior to 2008, the stipulation was that "The entire program must include a minimum of 1,800 AU. It is expected that accredited programs will continue to have additional AUs to demonstrate innovation and to achieve the special goals that a particular engineering school may have for an education in engineering." What does need to be emphasized however, is that from 2008 to the present, the total AU requirement is 1950. This is the program's objective and it only needs to be reached for compliance with criteria to be met. No excess is required.

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Appendix

Appendix A – Discipline categories as used for stratified random sampling

Discipline: Biosystems

- Agricultural and Bioresource Engineering
- Bioengineering
- Biological Engineering
- Biomedical and Mechanical
- Biomedical Engineering
- Biomedical Mechanical Engineering
- Biosystems Engineering
- Chemical and Biological Engineering
- Forest Engineering
- Génie agroenvironnemental
- Génie alimentaire
- Génie biomédical

Discipline: Chemical

- Chemical & Petroleum Engineering
- Chemical and Biochemical Engineering
- Chemical Engineering
- Chemical Engineering and Bioengineering
- Génie biotechnologique
- Génie chimique
- Nanotechnology Engineering

Discipline: Civil

- Architectural Conservation and Sustainability
- Building Engineering
- Civil & Environmental Engineering
- Civil and Environmental Engineering
- Civil Engineering
- Génie civil
- Génie de la construction
- Infrastructure Protection & International Security
- Safety and Risk Engineering

Discipline: Computer

- Computational Science and Engineering
- Computer Engineering
- Computer Networks
- Computer Science
- Computer Systems Engineering
- Electronic Systems Engineering
- Engineering Systems and Computing
- Génie informatique
- Human Computer Interaction

Discipline: Electrical

- Biomedical and Electrical
- Communications Engineering
- Electrical & Biomedical Engineering
- Electrical and Computer Engineering
- Electrical Engineering
- Electrical/Computer Engineering
- Electronic Business Technologies
- Energy Systems Engineering
- Génie des opérations et de la logistique
- Génie des technologies de l'information
- Génie électrique
- Génie électromécanique
- Génie énergétique
- Information systems security
- Quality Systems Engineering
- Sustainable Energy Engineering

Discipline: Engineering Physics

- Engineering Chemistry
- Engineering Mathematics
- Engineering Physics
- Engineering Science
- Génie physique
- Mathematics and Engineering
- Mathématiques
- Mathématiques ingénieur

Discipline: Environmental

- Sciences de la Terre et de l'atmosphère
- Clean Energy Engineering
- Environmental Engineering
- Environmental Systems Engineering
- Génie des eaux
- Maîtrise en génie de l'environnement
- Maîtrise en Sciences de la Terre
- Sustainable & Renewable Energy
- Water Resources Engineering

Discipline: Geological

- Génie géologique
- Geological Engineering

Discipline: Industrial or Manufacturing

- Advanced Design and Manufacturing Institute
- Génie de la production automatisée
- Génie industriel
- Industrial Engineering
- Industrial Systems Engineering
- Manufacturing Engineering
- Mechanical Manufacturing Engineering

Discipline: Materials or Metallurgical

- Génie des matériaux et de la métallurgie
- Génie métallurgique
- Materials Engineering
- Materials Science
- Materials Science & Engineering
- Metallurgical Engineering and Materials Science
- Mining/Materials Engineering

Discipline: Mechanical

- Automotive Engineering
- Energy Engineering
- Génie mécanique
- Mechanical & Manufacturing Engineering
- Mechanical & Materials Engineering
- Mechanical & Mechatronics Engineering
- Mechanical Engineering
- Mechanical Systems Engineering
- Mechanical/Industrial Engineering
- Mechatronic Systems Engineering
- Mechatronics Engineering
- Space Engineering

Discipline: Mining or Mineral

- Génie des mines
- Génie des mines et de la minéralurgie
- Génie minéral
- Mineral and Mining Exploration Engineering
- Mineral Engineering
- Mineral Resources Engineering
- Mining Engineering
- Natural Resources Engineering

Discipline: Software

- Génie logiciel
- Information Technology
- Software Engineering
- Software Engineering & Virtual Systems Design
- Software Systems Engineering

Discipline: Other

- Aeronautical Engineering
- Aerospace Engineering
- Centre for Business, Entrepreneurship & Technology
- Core Program
- Doctorat en ingénierie

- Doctorat en ressources minérales
- Engineering and Public Policy
- Engineering Design
- Engineering Entrepreneurship & Innovation
- Engineering Management
- General Engineering
- Génie
- Génie aérospatial
- Génie des systèmes électromécaniques
- Génie du bois
- Génie géomatique
- Génie nucléaire
- Génie unifié
- Geomatics Engineering
- Green Process Engineering
- Information and Systems Engineering
- Ingénierie
- Integrated Engineering
- Internetworking
- Maîtrise en ingénierie
- Maîtrise en ingénierie (gestion)
- Management Engineering
- Management Sciences
- Master of Engineering Degree
- Nuclear Engineering
- Ocean and Naval Architectural Engineering
- Oil and Gas Engineering
- Petroleum Engineering
- Petroleum Systems Engineering
- Process Engineering
- Process Systems Engineering
- Sciences appliquées
- Systems Design Engineering
- Systems Science
- TIM (Systems)
- UNENE