# A Strategic Approach to Industrial Engineering Curriculum in Brazilian Private Schools

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***Abstract*** **- The design of an engineering curriculum in Brazil must comply with the National Guidelines for Undergraduate Engineering Curriculum. This document specifies the desired profile of graduates and defines competencies and general skills. In addition, it specifies the basic and vocational contents as well the average credits and workload distribution by content. The specific content is defined by the accredited school. This practice is relatively new in Brazil. Not long ago, the federal government used to impose rigid and detailed curriculum guidelines. Although the new practices provide high flexibility to design a curriculum, the fact is that industrial engineering curricula in Brazil are still somewhat similar. The difference lies in the rigor with which these contents are assigned to students in different institutions. This paper begins with an analysis of the industrial engineering curriculum in some important private schools. The next step is, by applying the concepts of competitive strategy, to propose a path to follow in the design of a production engineering curriculum. We believe that with this approach a new pattern of competition would appear among these institutions, which would begin to offer greater variety and customized curricula to their target public, the ultimate purpose of the Federal Government.**

*Index Terms:* engineering curriculum, competitive strategy

## 1 Introduction

Until March 2002, the curricula of undergraduate Brazilian engineering Courses had to comply with Resolution #48 (of April 27, 1976) [4], established by the now extinct Federal Education Council. That resolution stated the minimum requirements for the content and duration of those courses. Law #9394 (of December 20, 1996) [2] and the "new" National Curricular Guidelines for Brazilian Undergraduate Engineering Courses [3], entered into force on March 11, 2002, replaced the previous legislation and greatly increased the autonomy and flexibility for the elaboration of curricular structures. Those guidelines establish the following:

- characterization of the graduate's profile
- definition of 13 competencies and skills for engineering graduates, as stated below:
  a. applying mathematical, scientific, technological and instrumental knowledge to engineering;
  b. designing and conducting experiments, and interpreting the results;
  c. conceiving, designing and analyzing systems, products and processes;
  d. planning, supervising, elaborating and coordinating engineering projects and services;
  e. identifying, formulating and solving engineering problems;
  f. developing and/or utilizing new tools and techniques;
  g. supervising system operation and maintenance;
  h. critically evaluating operation systems and maintenance;
  i. communicating effectively in written, oral and graphic forms;
  j. working in multidisciplinary teams;
  k. understanding and applying professional responsibility and ethics;
  l. evaluating the engineering activities impact on a social and environmental context;
  m. evaluating economic viability in engineering projects;
  n. ongoing concern in professional development.
- encourages the reduction of class time and increases complementary activities such as scientific initiation, multidisciplinary projects, visits, team work, assistant work, prototype work and involvement in junior companies.
- requires supervised internship with a minimum of 160 hours and makes it mandatory to complete a Final Undergraduate Engineering Project as a demonstration the synthesis and integration of knowledge.
- requires control of the learning process.

The Curricular Guidelines also orient and restrict some of the content to be taught in class. These contents are divided into 3 large groups: Basic, Vocational and Specific content. Vocational and Specific Content are proposed exclusively by the Undergraduate Engineering Education Institution.

In the following pages, these contents will be detailed and specified for industrial engineering, as they are an important issue for this analysis.

Basic Content, required for all engineers, totals 15 and must be accompanied by experiments in physics, chemistry and information technology laboratories, as below:

a. Scientific and Technological Methodology
b. Communication and Expression;
c. Information Technology
d. Graphical Expression
e. Mathematics
f. Physics
g. Transport Phenomena
h. Solids Mechanics
i. Applied Electricity
j. Chemistry
k. Materials Science and Technology
l. Management
m. Economics
n. Environmental Science
o. Humanities, Social Sciences and Citizenship

Vocational Content totals 53 subdivisions. Only the 14 subdivisions pertinent to industrial engineering, within the scope of the present analysis, will be listed here:

a. Algorithms and Data Structure
b. Product Engineering
c. Ergonomics and Safety
d. Strategy and Organization
e. Production Management
f. Environmental Management
g. Economic Management
h. Technological Management
i. System modeling, analysis and simulation
j. Operational research
k. Manufacturing processes
l. Quality
m. Information systems
n. Transportation and logistics

The guidelines also define the approximate workload distributions for each group of contents: Basic, Vocational and Specific as 30%, 15% and 55% respectively.

Table I summarizes the proposed workload of subjects which Brazilian industrial engineering courses must follow in their curricular structures. It is clear that the complementary activities, the supervised internship and the final undergraduate project workloads are not included in this list and must obey the minimum imposed by the curricular guidelines.

TABLE I
CONTENT WORKLOAD OF CURRICULAR GUIDELINES

| Class of Content | Approximate Load | Content in Industrial Engineering |
|---|---|---|
| Basic | 30% | 15 |
| Vocational | 15% | 14 |
| Specific | 55% | |

Is important to note that the previous legislation was much more restrictive, both in content and in workload distribution. It established the minimum curricula that had to be followed by each kind of engineering course, making it difficult for different institutions to mold and train different profiles of engineers.

It is precisely the use of the greater freedom (autonomy and flexibility) proposed by the recent National Curricular Guidelines that will be analyzed in this article.

## 2 COMPETITIVE STRATEGY IN EDUCATIONAL INSTITUTIONS

This item reports some of the concepts of competitive and functional strategies in an educational institution reality and is supported by definitions founded in [1]. Suppose that an institution selects a certain customer segment and defines the set of needs that it aims to satisfy through its products and services (target market). The institution’s competitive strategy is what it should do particularly well to meet the needs of these consumers. It is based upon the characteristics that this specific consumer prioritizes, as sets of service variety, quality, cost and time of delivery.

The competitive strategy of the company should also determine its functional strategies – what each function must do particularly well to reach the target needs. The functional strategies guide how the company should adjust the competitive strategy. For industrial engineering educational institutions, it can be considered that three major functions are involved in the undergraduate process: Design of Service Delivery System, Marketing and Sales and, finally, Service Operation.

If the functional strategies are not aligned with the competitive strategy, the institution should deal with conflicts between isolated functional objectives and effectively meeting consumer needs, and conflicts between different visions of what the priorities and the real needs of these consumers are. This strategic alignment between the functional strategies and the competitive strategy of the institution is crucial. In other words, the three major functional strategies listed above must be aligned with the competitive strategy of the institution.

This article deals with the design of the educational service, particularly with curriculum structuredevelopment, which will serve as a base for the service operation. The bottom line is that educational service development must be aligned with a clear and specified competitive strategy chosen by the institution, particularly in the establishment of curricular guidelines that are part of its competitive strategy.

Furthermore, a curriculum structure of a given industrial engineering course also induces its competitive strategy or at least the curriculum structure is a strong determinant of the needs the institution intends to satisfy and the segment of consumers it aims to reach.

From the strategy concepts stated above, if the industrial engineering educational institutions in a given region attempts to follow exactly what is in the curricular guidelines and further structure, curriculums with large uniformity of content and workload, the graduating industrial engineering students will present very similar skills and competencies. The differences between them will be due to the rigor of the teaching-learning process and students’ own individual characteristics. Although these institutions supply a great mass of undergraduate professionals that meet the needs considered by the common strategy adopted, whether aware of it or not, they might not be meeting other needs that are not clearly identified.

## 3 DATA SURVEY

A survey was conducted on the curricular guidelines of the industrial engineering courses in the city of São Paulo, Brazil. The city of São Paulo is one of the largest cities in the world with approximately 11,000,000 inhabitants and belongs to the most important state economy in Brazil. There are nine institutions that offer industrial engineering courses. In this article, seven of these courses are dealt with, as two of them did not supply the necessary details of their curricular structures. For ethical reasons, the names of the institutions will be omitted.

Table II shows the institution codes used in this study, the industrial engineering course name, the category as public or private institution and its regime as annual or semestral.

TABLE II
INSTITUTIONS AND COURSES

| Institution | Course Name | Publ/Priv | Regime |
|---|---|---|---|
| 1 | Industrial Engineering | **Public** | Sem |
| 2 | Industrial Engineering | **Private** | Sem |
| 3 | Industrial Engineering | **Private** | Sem |
| 4 | Industrial Engineering | **Private** | Annual |
| 5 | Industrial Engineering | **Private** | Sem |
| 6 | Ind Engineering-Mechanics | **Private** | Sem |
| 7 | Ind Engineering-Chemistry | **Private** | Annual |

The subjects contained in the curricular guidelines were obtained by [5] and/or directly from the institutions researched. They were classified as belonging to the three major content areas listed in the introduction: Basic, Vocational and Specifics. This last class was sub-classified into seven other classes for a better characterization of the specific contents offered and to allow a better evaluation of the competitive strategy followed by the institution through its course.

This sub-classification was defined based on our experience in the education in industrial engineering and the papers published by ABEPRO, the main industrial engineering association in Brazil. Next the classes and the symbols as considered in this study are as follows:

**EF or Economy and Finance** includes Engineering Economy, Cost Accounting, Financial Engineering and Administration and Project Investments.
**GE or General** includes Marketing Assessment, Strategic Planning, and Operations Strategies, Entrepreneurship, Marketing Strategies, Enterprise Network, Innovation Management, Technology Management and other integrative subjects or one not belonging to any previous classes.
**OL or Operations and Logistics** includes Production Systems Management, Production Planning and Control, Logistics and Supply Chain Management, Plant and Facility Project, Maintenance Management, Production Simulation and Productive Process Management.
**OR or Operational Research** includes Mathematical Programming, Multicriteria Decisions, Stochastic Process, Simulation, Decision Theory, Game Theory and Demand Analysis.
**QP or Quality and Product** includes Statistical Quality Control, Normalization, Quality Certification, Metrology, Equipment Reliability, Service Quality, Market Research, Product Planning, Product Project Methodology, Product Engineering and Marketing.
**IT or Information Technology** includes Automation, Industrial Robotics, Process Control, Information Technology Management, Data Base Modeling, Computer-Aided Design and Information Management System.
**LO or Labor and Organization** includes Labor Organization, Labor Psychology, Occupational Biomechanics, Work Safety, Risk Prevention, Product Ergonomics, Process Ergonomics, Ergonomics, Industrial Organizations, Natural Resource Management, Energy and Waste Management.

The classifications made are not exact, since the vocational and specific contents might contain subjects with common names and certain subjects might be difficult to precisely classify. In the subsequent analysis, it will be considered that the GE class does not characterize a clear content. Tables III and IV summarize the contents and codes considered:

TABLE III
CODES AND CONTENTS

| Code | Contents |
|---|---|
| BC | Basic |
| VC | Vocational |
| SC | Specific |

TABLE IV
SUB CLASSIFICATION OF THE SPECIFIC CONTENTS

| Subclasses of Specific Contents | |
|---|---|
| Code | Subclass |
| EF | Economy and Finance |
| GE | General |
| OL | Operations and Logistics |
| OR | Operational Research |
| QP | Quality and Product |
| IT | Information Technology |
| LO | Labor and Organization |

Tables V, VI and VII and VIII contain the results of the compilation done by the curricular guidelines supplied according to the classes considered in this study:

TABLE V
HOURS OF THE STRUCTURES BY CLASSES OF CONTENTS

| Institution | BC | VC | SC | PartHs | Others | TotHs |
|---|---|---|---|---|---|---|
| **1** | 1755 | 240 | 1410 | 3405 | 660 | 4065 |
| **2** | 1480 | 160 | 2280 | 3920 | 560 | 4480 |
| **3** | 1650 | 360 | 2520 | 4530 | 255 | 4785 |
| **4** | 2400 | 640 | 1200 | 4240 | 384 | 4624 |
| **5** | 1980 | 60 | 1920 | 3960 | 840 | 4800 |
| **6** | 2180 | 320 | 1200 | 3700 | 400 | 4100 |
| **7** | 2065 | 210 | 1680 | 3955 | 195 | 4150 |

TABLE VI

HOURS OF THE STRUCTURES BY SUBCLASSES OF SPECIFIC CONTENTS

| Institution | EF | GE | OL | OR | QP | IT | LO |
|---|---|---|---|---|---|---|---|
| 1 | 180 | 150 | 300 | 180 | 180 | 180 | 240 |
| 2 | 200 | 720 | 480 | 240 | 240 | 240 | 160 |
| 3 | 420 | 510 | 360 | 330 | 240 | 270 | 390 |
| 4 | 160 | 80 | 320 | 160 | 80 | 80 | 320 |
| 5 | 240 | 400 | 460 | 180 | 220 | 200 | 220 |
| 6 | 80 | | 240 | 160 | 80 | 480 | 160 |
| 7 | 140 | 490 | 210 | 140 | 70 | 140 | 490 |

TABLE VII

PERCENT OF HOURS OF THE STRUCTURES BY CLASSES OF CONTENTS

| Institution | BC | VC | SC | Other |
|---|---|---|---|---|
| 1 | 0.52 | 0.07 | 0.41 | 0.19 |
| 2 | 0.38 | 0.04 | 0.58 | 0.14 |
| 3 | 0.36 | 0.08 | 0.56 | 0.06 |
| 4 | 0.57 | 0.15 | 0.28 | 0.09 |
| 5 | 0.50 | 0.02 | 0.48 | 0.21 |
| 6 | 0.59 | 0.09 | 0.32 | 0.11 |
| 7 | 0.52 | 0.05 | 0.42 | 0.05 |
| CurrGuid | 0.30 | 0.15 | 0.55 | |

TABLE VIII

PERCENT OF HOURS OF SUBCLASSES

| | % of (BC+VC+SC) | | | | | | |
|---|---|---|---|---|---|---|---|
| Institution | EF | OL | OR | QP | IT | LO | Max |
| 1 | 0.05 | 0.09 | 0.05 | 0.05 | 0.05 | 0.07 | 0.09 |
| 2 | 0.05 | 0.12 | 0.06 | 0.06 | 0.06 | 0.04 | 0.12 |
| 3 | 0.09 | 0.08 | 0.07 | 0.05 | 0.06 | 0.09 | 0.09 |
| 4 | 0.04 | 0.08 | 0.04 | 0.02 | 0.02 | 0.08 | 0.08 |
| 5 | 0.06 | 0.12 | 0.05 | 0.06 | 0.05 | 0.06 | 0.12 |
| 6 | 0.02 | 0.06 | 0.04 | 0.02 | 0.13 | 0.04 | 0.13 |
| 7 | 0.04 | 0.05 | 0.04 | 0.02 | 0.04 | 0.12 | 0.12 |
| Max-Min | 0.07 | 0.07 | 0.04 | 0.04 | 0.11 | 0.08 | |

## 4 RESULTS

Table VII shows that the percentage of basic, vocational and specific institution contents do not obey the values defined by the curricular guidelines except in institutions 2 and 3.

With the same exceptions, it is noted that the basic contents of the institutions are much higher than those proposed and very similar. This shows that the institutions still follow a pattern that reinforces basic knowledge, which is characteristic of the previous legislation that provides the minimum curricula. It's interesting to observe that this standard is followed by institution 1, the only public and the most traditional of the sample. Although it might be justified in a public institution, it does not look healthy for the private group.

Table VIII does not show the GE subclass, as stated before. In this subclass, it can be noted that the percentages of the subclasses in the total contents are very low. The maximum values of the subclasses vary from 8% to 13%. This is not enough to characterize emphasis on a specific content by the institutions.

In the same table, it can be noted that the differences between the maximum and minimum values for each contents vary from 4% to 11%. This suggests that there is no significant difference between specific contents in the institutions analyzed.

## 5 CONCLUSIONS

The analysis suggests there is neither curricular specialization in the institutions nor significant difference in the specific contents between the institutions. Consequently, there are no different competitive strategies among them and their industrial engineers have very similar competencies and skills. The consequence of this is previously discussed.

As a solution to this problem, the specific contents could be differentiated through specializations that would certainly meet the consumers' need. As an example, some possible specializations are mentioned:

a. Specialization by broad economic sector of activity – Operations or Services
b. Specialization by type of activity – Agriculture, Chemistry, Textile, Transportation or Banking
c. Functional specialization – Marketing and Sales or Operations or Distribution
d. Specialization in support functions – Accounting or Finances or Human Resources or Information Technology

It is suggested that, initially, the person in charge of the Industrial Engineering course of a specific institution should define a competitive strategy along the following lines:

1 Identifying the important consumer segments of Industrial Engineering.
2 Identifying the needs of those segments.
3 Choosing which segments the course intends to serve.
4 Defining what its engineers should do well to meet the set of needs of the chosen segments; in other words, defining the competitive strategy.

At the end of these stages, the profile of the institution graduate students will be clear.

The next step should be to match the pedagogic project (pedagogic proposal) to the selected competitive strategy and take the following actions ***in agreement with the adopted competitive strategy*** by:

1. Prioritizing knowledge areas.
2. Redefining the curricular structure with specific contents.
3. Training and renovating the teaching staff.
4. Offering optional subjects.
5. Forming partnerships with companies for undergraduate projects.
6. Focusing on research themes.
7. Interacting with institutions that have similar competitive strategies.

This does not mean abandoning any knowledge area since the industrial engineer is not allowed to graduate with limited training and the graduation of a limited specialist is not wanted. But it can mean that the institutions might take the opportunity and make use of the freedom allowed in the curricular guidelines for 55% of specific contents to prepare a better engineer with an education geared toward the market and future employment.

## REFERENCES


[1] Chopra, S. and Meindl P. Supply Chain Management: Strategy, Planning and Operation, Upper Saddle River, N.J., Prentice-Hall, (2007).
[2] Lei de Diretrizes e Bases da Educação, Lei no 9.394 de 20/12/1996.
[3] Resolução CNE/CES 11, de 11 de março de 2002, Institui Diretrizes Curriculares Nacionais do Curso de Graduação em Engenharia.
[4] Resolução do CFE Nº 48 de 27 de abril de 1976, Fixa os mínimos de conteúdo e de duração do curso de. graduação em Engenharia
[5] INEP Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira em http://www.inep.gov.br