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Case Article

ABCtronics: Manufacturing, Quality Control, and Client Interfaces

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Teaching statistics in an undergraduate or a graduate business administration course, business analytics course, or engineering program remains a challenging task for the instructors. Often students fail to comprehend the real-life application of statistical concepts with the help of disconnected textbook examples. This failure inspires scholars to develop case studies on statistical theories in real-life industry backgrounds or realistic industrial settings. Recognizing the students' difficulty to understand the diverse statistical concepts in a realistic setting, we design a case study in an industrial background to facilitate students' learning. It is constructed by drawing inspiration from real-life business scenarios in the context of the integrated chip manufacturing industry. It helps to bridge the gap between theoretical understanding and practical application. The case starts with introducing various probability distributions and gradually incorporates intricate concepts of statistics like sampling distribution, hypothesis testing, and regression models in realistic scenarios. Each assignment question enables the teacher to engage in the in-depth discussion regarding the applications of different statistical concepts about business problems of integrated chip manufacturing. Also, it involves the application of the software tools for solving statistical problems. This case article demonstrates different usages of the case, ranging from a common thread for classroom discussion throughout the course to a class reading for providing a holistic approach to understanding and applying different statistical concepts in real-life scenarios by the end of the course.

Keywords: probability distributions; sampling distribution; confidence interval; hypothesis testing; linear regression; case study

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1. Introduction

The curriculum across disciplines such as business administration, business analytics, and engineering programs puts emphasis on the application of real-life examples to equip students with better understanding and decision-making skills. It is important to incorporate an appropriate approach that facilitates students to understand concepts in different scenarios. In this context, case-based pedagogy has shown its relevance to facilitate students' understanding in a more effective manner (Suresh 2002). Our investigation indicates that there is a prevalence of case studies in statistics courses (Parr and Smith 1998, Groebner et al. 2013). Previously, textbooks (Levin and Rubin 1997,

Hildebrand and Lyman 1998) had been used to introduce different concepts and describe them with examples derived from daily life activities. Because of the lack of the direct link to the industrial problems, students often failed to comprehend the real-life applications of statistical concepts (Suanpang et al. 2004). The lack of a significant number of articles that discuss statistical concepts in a real-life business setting has opened up a plethora of opportunities to the scholars to develop the articles that discuss the statistical concepts in industrial backgrounds. Several scholarly contributions on diverse statistical concepts such as data analysis (Perer and Shneiderman 2008, Conant 2015), probability distributions (Cochran 2010, Dunn

2013), hypothesis testing (Evans and Olson 2007, Nava-Whitehead and Gow 2008), regression analysis (Kvam and Sokol 2004, Zhu and Lakhani 2015), and so on, signify this fact. Also, a number of research articles address the issues like employment of software tools (Teixeira et al. 2009, Begen and Xia 2013) in statistical problems and real-life applications of statistical theories (Shanks 2007, Anderson et al. 2011).

Our exploration of the existing literature on case studies related to different statistical theories reveals the presence of a significant number of casebooks (Klimberg et al. 1994, Bryant and Smith 1995, Chatterjee et al. 1995, Carlson 1997). The investigation into these casebooks indicates that a single scholarly work is limited to demonstrating only a few concepts. Though these case studies successfully describe specific topics, a single case study comprising the applications of various statistical concepts will be more efficient to provide a broader picture. The common thread facilitates students to grasp different concepts in a better way. Scholarly works by Berenson et al. (2011) and Anderson et al. (2011) pay attention to this issue. They discuss several topics with a continuing example. For instance, Anderson et al. (2011) employ a Citibank example to demonstrate the concepts related to the discrete probability distributions and then they incorporate the case of Procter and Gamble to discuss data analysis, continuous probability distributions, and regression models. Our investigation into the existing research articles reveals another interesting insight. Many scholars depict a realistic industry setting motivated by the real-life example in their case study and demonstrate the concepts of statistics. For an example, Stevenson and Cheng (2014) discuss the application of hypothesis testing in the pickle processing industry where they delineate the industry issue of raw material wastage as a decision-making problem of a fictitious plant manager.

Motivated by these examples, we develop a case study to facilitate students' learning of diverse statistical concepts. It is constructed by drawing inspiration from real-life scenarios in the context of the integrated chip manufacturing industry. This case study presents a much broader spectrum of statistical concepts compared to the continuing examples presented in the existing works ranging from the fundamental topics like random variables, probability, and probability distributions to the advanced topics like sampling distribution, confidence interval, hypothesis testing, and regression modeling. The case study facilitates the students' theoretical understanding and practical applications of the statistical concepts. Also, recognizing the software application in today's business scenario, we implement the application of software tools for solving statistical problems. The case study does

not involve any real-life data. All the data are generated through an extensive simulation study.

The organization of this article is as follows. Section 2 presents the case characteristics, case synopsis, and a brief description of the case documents. Section 3 demonstrates pedagogical objectives along with the intended areas of application of the case study. Section 4 describes the results obtained from class experience as well as discusses the insights obtained from it. The article ends with some concluding remarks.

2. Case Overview

In this section, we first describe the case characteristics and how we design the case. Next, we demonstrate all documents associated with the case study and their applications. Finally, we provide a brief description of the case study.

2.1. Case Characteristics

According to the literature of case study methods (Cliff and Curtin 2000), this case study can be considered as a directed case. The objective of this case is to facilitate students' learning of various statistical concepts such as probability distributions, sampling distribution, confidence interval, hypothesis testing, and linear regression in a realistic background. To enhance students' understanding of the application of the above mentioned concepts, we design all the problems in the background of the integrated circuit (IC) chip industry. For the sake of realistic depiction of the industry characteristics, we have done an extensive literature review of scholarly articles, expert opinions, and newspaper articles. The fictitious company "ABCtronics" is constructed by taking motivation from the organizations in practice. The case study does not involve any real-life data. All the data used for analysis are generated through a simulation study.

2.2. Case Documents

The following documents are associated with this case study:

- (i) Case study
- (ii) Case article (this document)
- (iii) Teaching note along with supplementary Excel file (available as restricted instructor materials at <https://www.informs.org/Pubs/ITE/Access-Restricted-Materials>)
- (iv) Student assignment given in the form of Excel spreadsheet (available as restricted instructor materials)
- (v) Reading material (available as supplementary material at <http://dx.doi.org/10.1287/ited.2016.0158ca>)

This case study is prepared for the students and classroom use. It presents a brief background of the IC chip industry and different problems like production issues, operational issues, marketing issues, etc., faced by an IC chip manufacturing company named as ABCtronics. The case article describes the motivation behind this work along with relevant existing scholarly works, case synopsis, pedagogical objectives, possible classroom usage, and class experience. The teaching note comprises assignment questions and detailed analysis of the case to help an instructor to decide the direction of the class discussion. The assignment questions are developed on the basis of the main issues discussed in the meeting presented in the case study. The supplementary Excel file attached with the teaching note shows the Excel applications of statistical concepts to solve the assignment questions.

To improve students' theoretical learning with the practical application, the student assignments are provided in the form of Excel spreadsheets. We have used Microsoft Excel 2010 for our analysis. It involves Microsoft Excel applications to solve the assignment problems. Reading material is prepared using various statistical textbooks and online resources. It consists of a summarized description of all statistical concepts covered in the class, related formulas, and real-life examples of these theories. Reading material helps students to quickly become aware of the theories involved in the case study. Also, it has a stand-alone usage as a user-friendly study material comprising different statistical concepts.

2.3. Case Synopsis

A number of interrelated managerial problems about production, quality control, and customer satisfaction level of a semiconductor chip manufacturing company named ABCtronics are presented in the case. The case provides the relevant data on the plant performance, a detailed description of its operating procedures, quality control policies, and issues that it is currently facing at a client site.

Instead of presenting a linear outlook on each of the issues, the case study outlines the perspective of different stakeholders of the same organization and the students are motivated to think about how the same problem is being viewed by them. Through all of these managerial issues, diverse topics of statistics are covered. The series of case questions are so designed that it starts with a relatively easy statistical concept of probability distribution and progressively adds complex concepts like hypothesis testing and regression to familiarize the students with a substantial portion of the statistics course. The design of the case study is consistent with the conventional wisdom of pedagogy that teaching new concepts becomes more useful when the same is linked to previously learned concepts and is positioned in a familiar context.

3. Pedagogical Objectives and Teaching Suggestions

In this section, at first we demonstrate the teaching objective of this case study. Further, we describe the course curriculum where it can be included and present the possible applications of the case study in those courses.

3.1. Teaching Objectives

As mentioned before, the primary purpose of this case study is to facilitate students' learning about real-life applications of different statistical concepts, tools, and techniques. The description of objectives in detail is provided below:

- (i) It helps students to acquire knowledge about the applications of probability concepts along with different probability distributions in solving the problems related to manufacturing industries.
- (ii) It facilitates students' understanding of developing the appropriate hypotheses, conducting proper tests, and determining the minimum sample size before conducting any survey.
- (iii) It provides an exposure of the demand forecasting through the use of regression techniques.
- (iv) The Excel assignment supplements students' theoretical learning with practical applications.

3.2. Teaching Suggestions

As mentioned above, the case is designed such that it enables an instructor to discuss a number of topics. This case can be included in the following curriculums:

- (i) Basic statistics courses of business administration and engineering at the undergraduate level.
- (ii) Specialization courses of statistics at the graduate level.
- (iii) Graduate business statistics courses for the management of business administration (MBA) programs.
- (iv) Statistics courses of the short duration management programs designed for the executives from manufacturing industries.
- (v) Undergraduate and graduate business analytics courses.

The probable applications of this case study are listed below:

- (i) In the specialization courses at the graduate level, it can be used in introductory classes so that students can brush up the theories learned in the undergraduate courses. On the other hand, it can be provided to the students as an assignment work within a few weeks of the commencement of course work.
- (ii) In a graduate level business statistics course, the case has a twofold advantage. An instructor can explain practical applications of different concepts through it in class. In that scenario, the case study

Table 1 Student Feedback Form

Academic Background.....

Statements	1 (Strongly disagree)	2 (Disagree)	3 (Neither agree nor disagree)	4 (Agree)	5 (Strongly agree)
S1:					
S2:					
S3:					
S4:					

Notes. S1: ABCtronics case has increased my interest in business statistics. S2: ABCtronics case has increased my insight in the use of statistical tools and techniques for solving real-life business problems. S3: I think that ABCtronics case is value adding to typical textbook exercises, as the case helps in understanding how various statistical concepts can be employed in practice. S4: The case gradually increases its level of complexity and introduces different concepts and thus enables me to understand the statistical tools and methods in a better way.

plays a role of a common thread of discussion. Also, it can be included in the evaluation as an end-term project work.

(iii) In undergraduate statistics courses and short duration management programs, the case can be used for class discussion to provide the basic introduction to random variables, probability distribution, sampling distribution, confidence intervals, hypothesis testing, and linear regression models. The instructor can maintain a back and forth approach to lecture-based study and case-based discussion. For example, he can refer to the case study after discussing a few concepts and show the applications of those concepts in real-life scenarios instead of using disparate small cases. Thus, it can serve the purpose of an anchor in a statistics course.

4. Classroom Experience

For the sake of testing the effectiveness, the case study has gone through a two-level classroom experience. At first, we organized an informal statistics class at the Indian Institute of Management Calcutta (IIM C). First-year and second-year graduate students requested to join the class. At the next level, this case was used in an MBA course of the Carey Business School at the Johns Hopkins University (JHU).

The students of both the schools had substantial knowledge of the above mentioned concepts related to probability distributions, confidence interval, hypothesis testing, and linear regression because of their prior and ongoing coursework experience. A total of 30 students of IIM C appeared for the informal class. In the case of the Carey Business School, there were 70 students in the class, divided into two sections. We demonstrated the case study in the class and asked students to submit the solution of the assignment questions along with the feedback forms. Following the approach of Beliën et al. (2013), we developed the feedback form presented in Table 1. These feedback forms were employed to capture the students' responses to various qualitative components like enhancement of the student interest, value addition from the tools' and techniques' learning perspective, continuity of the story, etc. A total 19 students

Table 2 Student Break Up

	IIM C	JHU	Total
Humanities	0	5	5
Business Administration	1	22	23
Commerce	1	0	1
Economics	4	3	7
Engineering	12	13	25
Hotel Management	0	1	1
Healthcare and Medical	0	10	10
Science	0	4	4
Mathematics	1	2	3
Statistics	0	3	3
Total	19	63	82

of IIM C submitted the solutions and feedback. This informal class at IIM C is a pilot study before introducing the case to the real class environment. In the Carey Business School, the case was given to the students as an assignment near the end of the course. In a similar fashion, they were requested to submit the feedback forms. We received all 70 responses. Because of incompleteness, we ignored seven feedback forms. We considered the remaining valid 63 students' feedback for the case evaluation, 32 for one section and 31 for another.

Table 2 describes a detailed break up of student composition regarding the academic background of the students who participated in the tutorial in IIM C and the two sections in JHU and submitted the complete feedback form.

Regarding the student composition, from Table 2 it is evident that the two sections at JHU have comprised students of diverse backgrounds. On the other hand, the pilot study group at IIM C is dominated by engineers. Overall, we have been able to use our case in the classes consisting of students from different academic qualifications. Table 3 represents average scores obtained from the students of IIM C and JHU in the various components of the feedback form regarding the statistics case study.

Average feedback scores in different components along with the overall average score reflect that the case study can meet the students' expectation.

Table 3 Description of Average Feedback Scores

	S1 (Average score)	S2 (Average score)	S3 (Average score)	S4 (Average score)	Overall average score
IIM Calcutta	4.42	4.47	4.47	4.26	4.41
JHU-Section 1	4.00	4.03	4.00	4.03	4.02
JHU-Section 2	3.87	4.10	4.06	3.68	3.93
JHU	3.94	4.06	4.03	3.86	3.97
Total	4.05	4.16	4.13	3.95	4.07

Table 4 Description of Average Feedback Scores from the Students of Diverse Background

Student background	Average score
Humanities	3.60
Science	3.50
Business Administration	4.01
Economics and Commerce	4.37
Engineering	4.24
Medical and Healthcare	3.73
Mathematics and Statistics	4.58

From the scores, it is evident that students recognize the knowledge acquisition regarding the statistical techniques and the value addition compared to the conventional textbook approach. Also, participants appreciate its usefulness to increase students' interest in statistics and its smoothness regarding the flow of the story. Students have enjoyed the reading of the case because of the resemblance of ABCtronics with the real business organization. Overall, the case paves a way to learn statistics in a more efficient and entertaining manner. It helps to equip students with practical applications of statistical theories to tackle real-life problems. A couple of student's voluntary comments written on the blank space of their feedback form justify our above-mentioned claims:

"I found this case study to be very relevant [because] it was founded in the real business technology. I can envision the probabilities being calculated and their real value in [a] business setting."

"I enjoyed reading this case study. I have never realized that ABCtronics is not a real organization."

We have extended our analysis to learn about the acceptance of the case study among audiences from the diverse background. Table 4 shows average feedback scores obtained from different academic backgrounds. It is evident that the case study is highly recognized by the students from mathematics and statistics, economics and commerce, business administration, and engineering. Also, it has maintained its appeal to the students of humanities, science, and healthcare backgrounds.

5. Conclusion

This article begins with the motivation and the importance of the case study. Then, it provides a brief

description of the documents associated with the case study along with case synopsis. Next it demonstrates the pedagogical objectives, probable course curriculums where it can be included, and the ways of implementation. Finally, it presents the results and insights obtained from classroom use.

The example of a real business organization can enhance the appeal of the case. But the reluctance of the companies to release their confidential data hinders us to implement that. From a future research opportunities' perspective, if academicians develop case studies for other core courses of operations management like operations research, inventory control, and so on, it can enrich the existing curriculum of corresponding courses.

Supplemental Material

Supplemental material to this paper is available at <http://dx.doi.org/10.1287/ited.2016.0158ca>.

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