

Marginal Analysis and Data Modeling with Management Applications

Mathematics Applications Shaping Tomorrow (MAST)

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I. Industry Overview

The founder of Wal*Mart opened the first store in 1962. There are now more than 1,250 discount stores in the United States and 1,297 Wal*Mart international stores in Mexico (604), Puerto Rico (54), Canada (213), Argentina (11), Brazil (23), China (26), Korea (15), Germany (92) and United Kingdom (259). Wal*Mart began its international involvement when entering Mexico in 1991. The discount stores typically have approximately 100,000 square feet of space. Wal*Mart Supercenters opened in 1988 and typically have about 200,000 square feet. In addition to general merchandise, the Supercenters carry bakery goods, deli foods, meat and dairy products, and fresh produce. They are open 24 hours a day.

Sam's Club was opened in 1983. It is a members-only warehouse club and offers a broad selection of general merchandise and large-volume items. The typical Sam's Club ranges in size from 110,000 to 130,000 square feet. There are more than 520 Sam's Clubs within the United States.

This module is based upon meetings with store personnel at a typical discount store with about 100,000 square feet of space. Wal*Mart places a strong emphasis on community involvement and through that commitment, four of us from the **MAST** program were able to meet key personnel at the Methuen, MA store. Over a three day period, we met extensively with the director of community relations and the manager of the food department to gain an overall perspective of Wal*Mart operations. Their photo appears below.



Signage is very important within Wal**Mart*. It is used to help the customers access items and to indicate various sale items. Consistency in the signage across stores and in advertising is noticeable wherever the Wal**Mart* name appears. Below is the Methuen store that participated with four of us during our externship, and a typical Wal**Mart* greeter and signage at the front entrance of the stores. This photo was copied from the www.walmartstores.com site.





Some of the best known among Wal-Mart's 1 million U.S. associates are its greeters, who welcome 100 million shoppers a week at nearly 3,000 stores.

Graphs of sales vs. weeks were provided for several items in the food department, for the entire dry goods department, and for promotional end cap items. For one of the items, units sold vs. weeks data was also made available. To respect the confidential nature of the data, adjusted values are included in the material to be included in the handouts section.

II. Student Outcomes

The goal of this module is for students to problem solve retail situations in order to appropriately plan for actions that will increase sales and profit. Students will use the analytic methods discussed in order to deal with simulated retail data. They will be able to:

- Calculate and analyze marginals using the available data,
- Calculate, analyze and discuss apparent outliers,
- Model the data,
- Compute rates of change using the models,
- Compute rates of change using the data,
- Calculate and analyze maximum sales,
- Analyze corporate financial data.
- Students will use graphing calculator and spreadsheet technologies to analyze and model the data.
- In addition, they will experiment with variations in their models based upon outlier removal and perhaps moving average techniques.

Students will apply the following concepts:

- Revenue: the total revenue (sales) from the sale of x units of a product is denoted by R . For a unit price p , the revenue $R=px$.
- Cost: cost C is made up of two components, the fixed cost or overhead and the variable cost which reflect the cost per unit.
- Profit: total profit P is the total revenue minus the total cost, i.e. $P=R-C$.

- Marginal revenue: the derivative of the revenue function, i.e. $\frac{dR}{dx}$. This quantity gives the rate of change of revenue. For small Δx , the marginal revenue gives a good approximation of the actual change in revenue. Without modeling, we can approximate the marginal revenue with available data. The smaller the Δx , the better the approximation.
- Marginal profit: the derivative of the profit function. Above remarks about the marginal revenue similarly apply to the marginal profit.

Re: Larson, Ron and Bruce H. Edwards. *Brief Calculus, An Applied Approach*, 6th edition. Boston: Houghton Mifflin, 2003.

III. Time Frame

This module is designed to be ongoing during the semester.

IV. Facilities, Equipment, and Data

Classroom presentations by the instructor will require access to a PC and accompanying projector, Microsoft Office software, a view screen or white board, and/or a graphing calculator with an LCD and overhead. Corporate financial data for Wal*Mart at www.walmartstores.com is made available and studies are presented for 1993-2003 data. Also adjusted sales data from a local Wal*Mart store for a candy item, a promotional sales item, a boxed food item, and weekly department sales are made available.

V. Standards

Mathematics Management student requirements have been defined by the University of Massachusetts Lowell, College of Management and the Department of Mathematical Sciences. All students in this program are required to master the contents of Management Precalculus 92.121 and Management Calculus 92.122. The focus of this module deals with Management Calculus. A reference site for the course topics is given in section VII. In addition, the following process and content standards are addressed in the module:

- Emphasize modeling the real world and develop problem-solving skills,
- Make use of graphing calculators or spreadsheets to model data sets,
- Promote experimentation and conjecturing,
- Develop and evaluate inferences and predictions that are based on data,
- Formulate questions that can be addressed with data,
- Use the language of mathematics to express mathematical ideas precisely,
- Defend a choice of a least squares model,
- Assess how outliers (points that are significantly distant from the other data points) affect the selection and evaluation of a model.

Links for the standards and underlying principles can be found at the NCTM and AMATYC sites:

<http://standards.nctm.org/document/chapter7>

and

<http://www.imacc.org/standards/introduction.html>

The goal is that students will acquire mathematics through a carefully balanced educational program that emphasizes the content and instructional strategies recommended in the standards along with the viable components of traditional instruction. It is important to stress the importance of mastering the traditional analytic components.

VI. Module Design

The students will apply the concepts of marginal revenue and marginal profit to available and perhaps researched data in order to investigate opportunities for increased sales and profit. In addition to the marginals, some of the analyses may include points of diminishing return on sales, maximization of revenue and profit, minimization of cost, and revenue as a function of units sold. All analytic material will be presented in the traditional manner as previously done. This method has consisted of:

- Classroom presentation of the analytic material by the instructor,
- Integration of technology using graphing calculator capabilities and Excel to supplement class discussions.

Prior to development of this module, quizzes based on homework assignments were given periodically, usually on a weekly basis. A major exam is given every 3-4 weeks. Some of the quizzes were assigned as take-home projects which involved more probing analytic problems that required the use of technology to solve. With these take home projects, the data was well defined for the students.

This module will focus on a more open-ended discussion opportunity for students. They will be required to address previously mentioned student outcomes in order to analyze business performance data. In class, there will be PC presentations by the instructor dealing with the use of Excel to analyze and graph data. Material discussed will be available on-line. Graphing calculator use will be ongoing throughout the semester. Students are expected to use these tools in the development of their individual projects.

VII. Handouts

The open-ended discussion opportunity will be based on the following assignments. They reflect adjusted data and graphs from Wal*Mart for sales in a local store of a candy item, a promotional sales item, a boxed food item, and weekly department sales. Other handouts include corporate financials from www.walmartstores.com , a student survey for assessment of the module's impact, and teaching notes.

1. Weekly sales of a candy item,
Spreadsheet and chart, analysis questions
http://faculty.uml.edu/mstick/92.122/material/Walmart_candy_item.htm
http://faculty.uml.edu/mstick/92.122/material/candy_item.pdf
2. Weekly sales of a promotional item,
Promotional item spreadsheet and chart, analysis questions
http://faculty.uml.edu/mstick/92.122/material/end_cap_item.htm
http://faculty.uml.edu/mstick/92.122/material/end_cap_cookies.pdf
3. Weekly sales within the dry goods department,
Dry goods spreadsheet and chart, analysis questions
http://faculty.uml.edu/mstick/92.122/material/Walmart_dry_goods_weekly_sales.htm
http://faculty.uml.edu/mstick/92.122/material/Walmart_dry_goods.pdf

4. Weekly sales of a boxed food item.
Spreadsheet and chart. analysis questions
http://faculty.uml.edu/mstick/92.122/material/Walmart_boxed_foods_weekly_sales.htm
http://faculty.uml.edu/mstick/92.122/material/Walmart_boxed_foods.pdf
5. A spreadsheet containing actual Wal*Mart corporate cost and sales financial data for 1993-2003 is included for examination and analysis by students,
Financial summary spreadsheet, analysis questions
http://faculty.uml.edu/mstick/92.122/material/financial_summary_data.htm
http://faculty.uml.edu/mstick/92.122/material/financial_summary.pdf
6. Student survey
A pretest and posttest survey to compare student achievement
http://faculty.uml.edu/mstick/92.122/material/pretest_posttest_survey.pdf
7. Teaching notes
*Excel modeling techniques, issues to be considered in the analysis questions for items 1 through 5, a conversation about the use of calculus at Wal*Mart*
http://faculty.uml.edu/mstick/92.122/material/teaching_notes.pdf
http://faculty.uml.edu/mstick/92.122/material/teaching_notes_models.htm

Also included are links to sample spreadsheet worksheets and graphs with detailed process instructions to develop an Excel generated graphical analysis. This material has been previously used for some of the specific topics addressed in the Management Calculus course. Listings for the links are attached.

http://faculty.uml.edu/mstick/92.122/material/marginal_profit.htm
http://faculty.uml.edu/mstick/92.122/material/marginal_profit_document.pdf
http://faculty.uml.edu/mstick/92.122/material/least_squares_regression.htm
http://faculty.uml.edu/mstick/92.122/material/least_squares_regression_document.pdf

The above described worksheet and graphs dealing with the least squares regression has been adapted from material in Larson's text, *Brief Calculus, An Applied Approach*, 6th edition.

Listings for TI-83, TI-86 and TI-89 regression procedures are attached and are available at http://faculty.uml.edu/mstick/links/ti_systems_of_eqs_and_least_squares.pdf.pdf

To enable teachers to more easily replicate the intended outcomes of this module, a listing of the Management Calculus topics appears at http://faculty.uml.edu/mstick/92.122/material/Mgt_Calculus_and_module_topics.pdf

A listing of algebra prerequisites appears at <http://faculty.uml.edu/mstick/92.122/material/requirements.pdf>

The Management Calculus syllabus can be found at <http://faculty.uml.edu/mstick/92.122/syllabus.pdf>.

Listings for these links are also attached.

This module can be used as an ongoing or capstone type of project. Pre-assessment will be in the form of the previously mentioned (**Module Design**) ongoing evaluations which include the traditional exams and quizzes. The student survey pretest and posttest address topics more closely aligned with this module.

VIII. Assessment Techniques

There are various options for assessment that could be considered. When teaching two sections of the Management Calculus course using this module, I counted the pretest as a maximum of two points added to the grade on the first examination. The posttest counted as a maximum of three points added to the final examination. The projects were:

- Project 1 – Candy Sales
- Project 2 – End Cap sales
- Project 3 – Dry Goods Sales
- Project 4 – Boxed Foods Sales
- Project 5 – Corporate Financial Data

Projects 1 and 2 counted as a 15-point take home quiz. Projects 3 and 4 counted as a 20-point take home quiz. The quiz component is perhaps the most important single aspect of the course since it is ongoing throughout the term. Student success in this component usually translates into success in the examinations. Project 5 was worth 35 points (35% of exam 3) and it was a take home portion of the third examination. In my courses, the quizzes totaled 100 points, each of three examinations totaled 100 points, and the common final examination totaled 100 points. Each component was equally weighted so the module accounted for a total of 75 points or 15% (75 out of 500 points) of the final grade. Faculty interested in a capstone project might also consider this as an option. The capstone project might combine projects 1, 3, 5. Comparisons made between overall averages in my Management Calculus classes over the last few years indicate that average and perhaps slightly lower than average students fared best with the opportunity to problem solve with the management data in the MAST module. It was definitely a reinforcement of the fact that people do learn differently.

During the spring 2004 term, I along with two field testers each taught two sections of the Management Calculus course. Each instructor worked with the assessment techniques described above, i.e. the five projects, and the pretest and posttest which address familiarity gained with marginal cost, marginal revenue, and data modeling with management applications. An additional form of assessment could be qualitative surveys administered to the test groups to assess their reactions to the alternative methods used and its impact on their appreciation and understanding of the material. These surveys should include the following open-ended items:

- Comment on the use of Excel and the TI as tools to analyze the project data.
- Comment on the use of the Wal*Mart data as an aid to understand calculus concepts. Specifically address marginal analysis and least squares modeling.
- Make recommendations on any changes you deem appropriate for future implementation of this module within the Management Calculus course.

At UMass Lowell, all sections were exposed to this module, but the degree of implementation and grading depended upon the instructor. Some comments from the field testers were:

- Many of the less mathematically inclined students presented wonderfully detailed assignments and analyses.

- This (MAST module) assignment (its implementation and evaluating deliverables) was a lot of work, but a lot of fun for me. I look forward to doing it again!
- There should be consistency among the sections using this module during a term. It is invaluable for students to know exactly what the deliverable needed to consist of (i.e. typed, Excel charts, models). Deliverables should be individual and specific due dates adhered to.
- Several students commented that because I had made copies each time of the “best” reports and allowed other students to view them, it helped tremendously (for future project assignments).
- Several students felt the module assignments would help them in both other courses and in their careers.

The initial implementation of this MAST module at UMass Lowell was a learning process for the instructors. It was a considerable amount of work but definitely worth the effort and will be repeated. It is expected that those of you at other schools may develop some of your own criteria to test the concepts developed in this module. Please share them.

Review of Items listed in Handouts (topic VII):

I. Student assignments, student survey, teaching notes.

1. Weekly sales of a candy item,
Spreadsheet and chart, analysis questions
2. Weekly sales of a promotional item,
Promotional item spreadsheet and chart, analysis questions
3. Weekly sales of a boxed food item.
Spreadsheet and chart. analysis questions
4. Weekly sales within the dry goods department,
Dry goods spreadsheet and chart, analysis questions
5. A spreadsheet containing actual Wal*Mart corporate cost and sales financial data for 1993-2003 is included for examination and analysis by students,
Financial summary spreadsheet, analysis questions
6. Student survey
A pretest and posttest survey to compare student achievement
7. Teaching notes
*Excel modeling techniques, issues to be considered in the analysis questions for items 1 through 5, a conversation about the use of calculus at Wal*Mart*

II. Sample spreadsheet worksheets and graphs with detailed process instructions to develop an Excel generated graphical analysis.

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TI-83, TI-86 and TI-89 least squares regression procedures at:

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III. Reference material to enable teachers to more easily replicate the intended outcomes of this module.

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store, and fellow college and high school participants in the project for their insights in problem solving issues as they arose.