

**Simple spreadsheet modeling by
first-year business undergraduate students:
Difficulties in the transition from
real world problem statement to mathematical model**

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ICME-11 TSG 21 on modelling

Framework of Galbraith & Stillman (2006): Critical activities in the transition from *real world problem statement* to *mathematical model* (difficult part of the modeling cycle) are:

- **Identifying dependent and independent variables for inclusion in algebraic model,**
- **Realizing that independent variable must be uniquely defined,**
- **Representing elements mathematically so formulae can be applied,**
- **Making relevant assumptions,**
- Choosing technology/mathematical tables to enable calculation,
- **Choosing technology to automate application of formulae to multiple cases,**
- Choosing technology to produce graphical representation of model,
- Choosing to use technology to verify algebraic equation,
- Perceiving a graph can be used on function graphers but not data plotters to verify an algebraic equation.

Research description and **main outcomes**

Learning task – Choose business of your choice and give recommendations to have it profitable or more profitable.

Help offered – The teacher explained a solution regarding a taxi business within a local area and the Excel Goal Seek command was used to find out the number of passengers that, on average, makes this business profitable.

Level of difficulty – Only simple deterministic and non-optimization spreadsheet solutions with some “what-if” analyses were required.

Project duration, student cooperation, and rate participation – Project lasted 3-4 week, usually 2 or 3 worked together, and only 20-30% of all students chose to work on it.

Main difficulties were found in selecting, initializing, and relating variables.

Most students were not able to give business recommendations that are both model-grounded and context-grounded.

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One solution

Ticket price (EUR)	30								
No of tables	22	?							
No of guests	132								
No of waiters	4	?							
Payments									
for restorant	1000								
for waiters	100								
for organizers	200								
for decoration	100								
for music	200								
for food	800								
for drink	500								
for security	50								
Fixed costs	1350								
Variable costs	1600								
Total	2950								
Income									
from tickets	3960								
Profit	1010								

The number of waiters depends on the number of guests!
For example, one waiter per 20 guests

Payments for food and drink depend on the number of guests

Data in B22 and B24 are not used!

Note: A business suggestion (based upon 'what if' analyses of a correct model) may require to have the number of guests for which net profit (with tax paid) is at least 30% higher that all costs involved.

Difficulties with selecting variables

- Failure to make distinction between fixed and variable costs (e.g. the number of guests not used)
- Specifying fixed and variable costs in an exhaustive and appropriate way is a key step in developing a good business plan

Difficulties with initializing variables

- Values of payments, costs and income may be unrealistic or even wrong
- Not knowing what values of variables critical to the output should be used for different business scenarios
- Initializing variables is related to selecting variables (directly) and relating variables (indirectly): Consider whether the value of the fixed cost is appropriate in terms of its underlying fixed costs

Difficulties with relating variables

- Variable cost is not expressed in terms of the number of participants
- Different services offered (i.e. cleaning car, washing car, and cleaning & washing car) are not diversified with respect to the number of served customers

Inappropriate business recommendations

- Failure to give business recommendations that are grounded on a good model and context. Not enough to say “to increase sales, give air-conditioning gratis.” **Possible argument:** “As sales are then likely to increase about 10%, profit would also increase as air-conditioning cost is about 8% of standard car version cost ($n \times 1.08 < 1,1n \times 1$).
- Because they had problems to understand business context. modelers expressed concerns about the detailedness and appropriateness of input variables and values assigned to them.

Possible reasons for such outcomes

- Technology can be perceived as a master, servant, partner or extended self (Galbraith, 2002). If modeler views technology as a master, it acts for him/her in a smart way and everything does not need to be specified.
- According to the SOLO Model (Biggs & Collins, 1982), person's understanding of a task progresses from
 - single aspect (uni-structural response) to
 - several, but disjoint, aspects (multi-structural response) to
 - several, integrated aspects (relational response).Giving multi-structural responses may be typical outcomes.
- 'What-if' analyses and scenario solutions not used to find errors in developed spreadsheets (cf. Choosing to use technology to verify algebraic equation). They may reveal that a formula not a constant should be in a cell, but selecting variables and relating them is independent of Excel.

Suggestions for further research on Framework

- *Choosing technology to automate application of formulae to multiple cases* (Activity 6 above) is an activity more relevant to model validation (via 'what-if' analyses or scenario solutions) and the transition from evaluation to report, not to the transition from real world problem statement to mathematical model.
- Extension of Framework should include activities in transition from evaluation to report. Activity of justifying (business recommendation) may include: (1) identifying critical input and output variables, (2) choosing critical values of these input variables, (3) comparing obtained scenario solutions, and (4) finding the values of these variables supporting recommendations to propose.
- Framework should deal with different types of models (deterministic with no optimization, deterministic with optimization, stochastic with no optimization, and stochastic with optimization) and different technologies offered by Microsoft Excel and its add-ins. Selecting, initializing and relating objects will then involve variables, constraints, distributions, and digital tools.