Abstract. In typical operations research courses, optimization problems, such as transportation and assignment problems, are frequently discussed and taught as stand-alone problems. An integrated approach may prove to be necessary in order to enable students to have a holistic understanding of a complex problem (e.g., a project). In this paper, a global supply network design problem is presented where the case company can source from multiple “suppliers” using multiple modes of transport (including the use of containers with different capacities), allowing lateral supply between warehouses, etc. As more factors are considered, the problem becomes much more complex than any isolated problem in a typical course. The case was tested in an undergraduate course in Australia, and students found this case challenging but at the same time rewarding once solved.

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1. Introduction

In logistics and supply chain management curricula, network design has been one of the cornerstones to understand and support the operations in supply chain management. Designing a proper global supply network requires consideration of many factors, such as transportation planning, custom duty charges, exchange rates, and inventory planning (because of the longer lead time), for example. With these many factors, real-life cases are usually too complex to be used for classroom teaching.

On the other side, activities such as case studies and problem-solving exercises engage students in active learning, which in turn improves student learning effectiveness (Prince 2004). Therefore, finding the right balance between real-world complexity and assessment/project practicality would be key.

Many companies source from overseas suppliers. Although sourcing from overseas usually come with cheaper price, there are some disadvantages of longer lead time, higher chance of delays, slower response to market changes, and fluctuations in exchange rates (Holweg et al. 2011). Market uncertainty and volatility in business, which have been more conspicuous since the 2008 global financial crisis, create more challenges—and hence higher risks—for companies and demand them to be more agile and flexible (Christopher and Holweg 2011, 2017).

One mitigation strategy to supply chain risks is to source locally (Tomlin 2006). Whether a company decides to completely shift from overseas sourcing to local sourcing, or use both overseas and local sourcing at the same time, its supply network topology will most likely be changed, and a scrutiny of the new supply network would be essential to enable the right decision to be made.

Motivated by these observations, we develop a case project where a company is shifting from global sourcing to incorporating local suppliers. The case considers realistic operational constraints but, at the same time, limits its size to a manageable number of nodes to make it less overwhelming. Students are required to design the supply network for the case company using linear programming and integer programming in an Excel spreadsheet. They will need to develop proper understanding of network flows, command network model building in Excel spreadsheets, and conduct analyses from the optimization results for this case project. At the end of the project, students will present their findings and write a
project report based on their project journey. The case project is suitable to be used as a course project to facilitate project-based learning (Bell 2010).

The organization of the rest of this article is as follows. Section 2 presents the case challenges and the documents associated with this case. Section 3 discusses the pedagogical objectives and offers some teaching suggestions. Section 4 presents the classroom experience of teaching this case project over the past few years. We conclude the article in Section 5.

2. Case Overview

In this section, we describe some of the case challenges and then present the associated documents for the case. This case relies on a number of interrelated network design problems. Consequently, a clear understanding of the different network flows would be pivotal to solving the problem. Although the data provided in the case are fictitious, they do reflect some practical operational costs in the case setting.

2.1. Case Challenges

In this case, both 20’ and 40’ containers are used for sea transportation. On top of that, less-than-container load (LCL) must be used when there are not enough units to fill a full container. Such a requirement makes the typical piecewise linear sea transportation cost function (displayed in Figure 1) not applicable. In Figure 1, the unit transport costs for 20’ containers and 40’ containers are $c_1$ and $c_2$, respectively, and the capacities for a 20’ container and a 40’ container are $a_2$ and $a_4$, respectively. Although 40’ containers have twice the capacity of 20’ containers (i.e., $a_4 = 2a_2$), the relationship $c_2 < 2c_1$ always holds. When partially empty containers are allowed, we see $a_1$ and $a_3$ as the break-even volumes for full 20’ and 40’ containers, respectively. However, in this case, the LCL rate will apply whenever the number of LCL units is fewer than $a_2$.

The availability of different types of containers introduces the first challenge that students have to deal with. Contrary to the unit transport costs that are commonly used for transport problems, students will need to work out a way to calculate the total transport cost when 20’ containers, 40’ containers, and LCL units are used. This, in a way, is similar to multimode transport, albeit only sea transport is involved.

The second challenge students need to deal with is the (implicit) colocation of facilities. In the case, ports collocate with demand cities, domestic production collocates with one of the demand cities, and lateral supply requires every demand city to be prepared to ship units out and be ready to receive from other cities. These colocations of facility will need students to have a clear idea of each facility’s respective role and model them accordingly in the Excel spreadsheet.

Associated with the colocation problem comes the third challenge, which requires the balancing of the inflows and outflows for each facility node. Multiple inflows and outflows for most of the nodes, coupled with the colocation of facilities, make the distinguishing between these flows trickier. Students are advised to clearly draw the inflows and outflows on a picture in order to properly “capture” them in the Excel spreadsheet.

2.2. Case Documents

The following documents are associated with this case study:
1. Case study
2. Case article (this document)
3. Case teaching note (restricted instructor mode)
4. Excel spreadsheet with the case solution (restricted instructor mode)

3. Pedagogical Objectives and Teaching Suggestions

3.1. Teaching Objectives

This case study builds on students’ understanding of key principles relating to network optimization and modeling such optimization problems in Excel spreadsheets. The case focuses on the following learning goals:
- Modeling different modes of transport, including different types of containers in sea transport, for supply network design
- Constructing network optimization models and modeling the network flows properly
- Utilizing linear programming and integer programming to solve optimization problems
- Building optimization problems into an Excel spreadsheet and solving them using the “Solver” add-in
  - Interpreting optimization results and professionally communicating the results with peers and nonexperts in the domain
  - Experiencing a flavor of consultancy through the project

This case study complements instructions on modeling terminology, linear programming, integer programming,
practical Excel spreadsheet modeling, network design, and transport planning. Students will also appreciate the challenges associated with modeling optimization problems when, in this case study, some of the solutions could be intuitively figured out but need to be represented in a mathematical model that is subsequently built into an Excel spreadsheet for further analysis.

3.2. Teaching Suggestions
This case study could be used as an assignment or as a course project for an operations research course at the undergraduate level. It is suggested that a presentation to be required, which should focus on delivering and justifying the optimization results and challenge students to explain the optimization approach in easy-to-understand ways for people who do not use optimization tools. A project report is also suggested to follow the presentation. Such a report should discuss the project from a business perspective and use the modeling and optimization results to support the recommended solutions. Students are encouraged to use different scenarios to demonstrate that the proposed solutions make sense from a business perspective. In this way, students can feel like they are delivering a consultancy project to their clients.

The case could also be used for a postgraduate course with the following possible extensions:

1. How sensitive is the solution to some of the parameters, such as unit cost at different places, transport cost, and lead time? What can be concluded from your findings?
2. How sensitive is the solution to the demand fluctuations?
3. How about another mode of transport, with a cheaper transport cost but longer lead time, for domestic transport? How will this change the solution?
4. How would you organize the monthly schedule of shipping and production at each location, in order to satisfy demand on time?

4. Classroom Experience
This case has been delivered as a course project over the past few years for cohorts of logistics and supply chain management students. The students were given about 15 hours of instruction on linear programming, integer programming, and modeling in an Excel spreadsheet, which was supplemented by computer labs and self-paced online learning materials and quizzes. The deliverables are a presentation of the case project, which is “targeted” at a management team without any technical optimization background. On top of that, students need to produce a project report to discuss in more detail the project journey, describe technical difficulties, and conduct some analysis for the solution reported.

Overall, students found the case to be challenging but rewarding at the same time. They believed the case project built up their confidence in conducting numerical analysis and prepared them for workplaces. The following student course evaluation comments (as they appeared on the form) confirm these claims:

“Learning useful Excel skill[s] with example[s] of real business [has encouraged] me to learn and give[n] me confidence of [my] future career.”

“This course had great links to real world concepts of logistics and how the use of modelling is needed to apply this knowledge.”

“This course has been extremely challenging; however it was obvious as to why we were learning such important things, as problems were always compared to real life issues and situations developing our knowledge for the future.”

Furthermore, some students reported that they were successfully invited for job interviews and received job offers based (partially) on this case project, which is extremely rewarding for the course teaching team to hear.

5. Conclusion
The primary benefits of this case study are threefold: learning to work with linear/integer programming and network design, learning to solve an optimization problem in an Excel spreadsheet, and learning to effectively communicate technical information and optimization results.

Furthermore, this case study gives students a chance to “experience” consultancy work and demands them to use effective communication skills to talk to various stakeholders, experts and nonexperts included. Besides, the employability aspect of the case project reported by some students is really encouraging.

The setting of the case study mimics a real business environment, which subsequently enables students to relate to real-world business decision-making process. Nevertheless, the case would be more appealing if we could obtain actual business data over a period of time and ask students to examine how their solutions perform in the real business world.

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References


