**MANUSCRIPT TEMPLATE FOR HKSTS CONFERENCE PROCEEDINGS**

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Submission number: __________7____________

# TEACHING INTERMODAL TRANSPORTATION IN A QUANTITATIVE WAY

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**ABSTRACT**
The traditional teaching of Intermodal Transportation focuses on the learning of qualitative analysis. However, it ignores the learning of quantitative methods. Essentially, the intermodal transportation introduces many operations problems when transporting cargo. These problems define the specialty of the intermodal transportation, and the students need more quantitative methods to tackle these problems. This paper summarizes the authors' teaching strategies and philosophy on Intermodal Transportation in a quantitative way. Starting from the design of teaching materials, a general picture of the processes in the intermodal transportation is first presented to students. Then, all the relevant operations problems during those processes are introduced in the categories of traditional Operations Research problems, and each category of operations problems are delivered to students systematically with systematic quantitative methods. However, teaching quantitative methods to students causes troubles to their learning experience. Several troubles and corresponding measures are also discussed.
Keywords: Intermodal Transportation; Teaching Strategy; Quantitative Methods; Qualitative Analysis.

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The traditional teaching of Intermodal Transportation focuses on the learning of qualitative analysis. However, it ignores the learning of quantitative methods. Essentially, the intermodal transportation introduces many operations problems when transporting cargo. These problems define the specialty of the intermodal transportation, and the students need more quantitative methods to tackle these problems. This paper summarizes the authors' teaching strategies and philosophy on Intermodal Transportation in a quantitative way. Starting from the design of teaching materials, a general picture of the processes in the intermodal transportation is first presented to students. Then, all the relevant operations problems during those processes are introduced in the categories of traditional Operations Research problems, and each category of operations problems are delivered to students systematically with systematic quantitative methods. However, teaching quantitative methods to students causes troubles to their learning experience. Several troubles and corresponding measures are also discussed.

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## 1. INTRODUCTION

Intermodal Transportation is a common course in universities, which aims to impart the general background about the transportation of freight by using multiple modes (e.g., trucks, rail, and ship) to undergraduates or postgraduates. This course involves more business features compared with other transportation-related courses, such as Transportation Engineering. Intermodal Transportation has been included into the major courses in the syllabus by some business schools, just like the traditional business courses (Meyer, 1997), e.g., accounting, finance and marketing. Faculty of Business from The Hong Kong Polytechnic University is one of the example to set Intermodal Transportation as the core module. Some civil engineering schools deliver the course to the programs that have a part of a business major, e.g., the School of Civil and Environmental Engineering from Nanyang Technological University. The traditional teaching of Intermodal Transportation among universities focuses on the learning of qualitative analysis. However, it ignores the learning of quantitative methods. Essentially, the intermodal transportation introduces many operations problems when transporting goods. These problems define the specialty of the intermodal transportation, and the students need more quantitative methods to tackle these problems.

This paper summarizes our teaching strategies and philosophy on Intermodal Transportation in a quantitative way, which is based on the teaching experience on the course LGT3003 Intermodalism from the Department of Logistics and Maritime Studies of The Hong Kong Polytechnic University. During the design of teaching materials, a general picture of the processes in the intermodal transportation is first presented to students. Then, we divide all the processes into three categories in terms of operations, i.e., the intermodal routing and network, intermodal terminal scheduling and intermodal operations management. Each category of operations problems is delivered to students systematically with a set of systematic quantitative methods. In this paper, we also summarize some typical troubles from students in response to this new learning experience, for which we show our measures.

## 2. LITERATURE REVIEW

Bektas and Crainic (2007) provided an overview of the intermodal transportation. They started from different perspectives to view the intermodal transportation, i.e., from the carrier perspective and from shipper perspective, which are two major players in the intermodal transportation. From both perspectives, they introduced some operations planning problems. They also investigated the operations in intermodal terminals, to list some limited resources that need utilization optimization, which is consistent with one of our perspective on the intermodal terminal scheduling.

Some problem-based learning approaches have been discussed in teaching the transportation relevant courses, which essentially shares the same starting point of our teaching philosophy. Alvarstein and Karen (2001) showed the case to conduct problem-based learning in a logistics and transportation course. Under this learning approach, students claimed that they are interested into the course when learning the real-world problems and this helps them contribute to the field. Ahern (2010) conducted a problem-based learning approach for the transportation courses in civil engineering, which helps students to be more positive about the course knowledge. Mehta (2012) adopted the problem-based learning approach to the course of transportation engineering. He drew the conclusions that the learning approach is very effective such that students feel more involved in the processes and this helps them significantly in their careers. These problem-based learning approaches are in line our teaching strategies on the intermodal transportation.

## 3. DESIGNING TEACHING MATERIALS

Starting from the design of teaching materials for the course LGT3003 Intermodalism, we first provide the students with a general picture of the intermodal transportation, including its definition and foundation. Then, we focus on the intermodal movements by rail and truck, that is to consolidate loads for cost-effective long-haul transportation by rail and utilizing the flexibility of local pick-up and delivery operations by trucks. During the intermodal movements, there are many operations problems that need quantitative methods to solve. Introducing those problems with quantitative methods for students helps them to gain more mathematical skills and to obtain more insights into the intermodal transportation. However, those problems and methods do not have a clear classification at the first glance. Delivering them to students individually will cause confusions to their learning experience. Therefore, we classify those operations problems into three categories and then systematically train the students with quantitative methods. The three categories include *intermodal routing and network*, *intermodal terminal scheduling* and *intermodal operations management*. In this section, we will describe the operations problems involved in the three categories as well as the quantitative methods for solving these problems.

### 3.1 Intermodal Routing and Network

Intermodal routing and network lead to a significant part of operations problems in the intermodal transportation. Since the cargo flows from shippers to customers via the transportation by carriers, there are many issues arising in terms of vehicle routing and network flow. For those problems, *understating quantitative methods of the graph theory is critical*.

The pick-up and delivery operations by trucks incur the classical routing operations problems, i.e., Travelling Salesman Problem (TSP) and Vehicle Routing Problem (VRP). In the intermodal transportation, the first step is to use trucks to pickup cargo from geographically located shippers and the last step is to use trucks to deliver cargo to geographically located customers. If we focus on routing a single truck to collect or distribute cargo over a given number of customers to minimize the travel cost, the problem is defined as TSP. Supposing there is a fleet of trucks that will serve the given number of customers to minimize the total travel cost of all the trucks, the problem then becomes the VRP. For solving those problems, mastering graph theory will be essential. The students should be able to understand the concept of vertices (or nodes) and edges (or arcs). In the pick-up and delivery operations, the customers are denoted as vertices. Then, solving the TSP or VRP aims to build edges between those vertices such that those vertices can form a cycle for TSP and multiple cycles for VRP. With respect to the general methodology for dealing with those routing-related problems, some construction algorithms are needed to build a solution from scratch (i.e., to build feasible cycles) and some improvement algorithms are implemented to improve the current solution.

In the intermodal transportation, when cargo is transported from the origins to destinations, the cargo will pass through several facilities, such as intermodal terminals and distribution centers. The transportation process can be well described by the flow on a network. Here, the operations problems arise in both network construction and network flow, where the former aims to build an intermodal transportation network, and the latter aims to determine the path of transportation through the network. In the network construction, the first step is to determine the shape of the intermodal transportation network. A classic shape is the intermodal Hub-and-Spoke network, where a series of spokes are connected to outlying points via a central hub, and hubs are directed with each other. In the network, we could have those hubs as the intermodal terminals that are connected by rail for taking advantage of the long-haul cost efficiency of trains and have spokes as the local distribution centers that are directed to the intermodal terminals for taking advantage of the short-haul flexibility of trucks. Once the shape of the intermodal network is determined, the next is to determine the locations of those spokes and hubs to achieve cost-effective and reliable intermodal transportation network. In the network flow, there is some cargo that regularly needs to be transported from some origin locations to some destination locations via the intermodal transportation network, with the purpose to minimize the operations cost incurred while respecting the capacity of the network. Understanding the problems related to the intermodal transportation network also resort to the graph theory. All those facilities (including intermodal terminals and distribution centers) in the network are denoted as nodes, and the transportation by trucks or trains between nodes are defined as arcs. Each arc is associated with a unit cost and a capacity restriction, where the cost represents the unit operating cost of transporting each unit of cargo, and the capacity restriction indicates the maximum load that can be carried by trucks or trains.

### 3.2 Intermodal Terminal Scheduling

In the intermodal transportation network, intermodal terminals serve as the transshipment hubs for transiting cargo from one mode to another mode, e.g., from a train to a truck, from a truck to a train, or from a train to a storage yard. Intermodal terminals face many daily operations problems to utilize their limited resources (e.g., equipment and storage spaces) for achieving high handling efficiency on the transshipment. The terminal operators make decisions for scheduling those resources in real time. To be effectively reacting to certain or random transshipment requests, *some reliable operating or scheduling policies are essential for improving the utilization of limited resources in intermodal terminals*, which should be mastered by students when they are faced by those operations problems.

Cranes are normally the most expensive and limited resources in terminals, which are used to lift, lower and horizontally move cargos among different places. One typical operation problem of utilizing cranes in intermodal terminals is the crane dispatch problem. In the problem, as shown in Figure 1, trains are loaded and unloaded using overhead gantry cranes or mobile cranes fitted with container lifting frames. At any time, there could be several trains in the intermodal terminal, each being simultaneously unloaded and loaded. Trucks arrive at random parking positions at random arrival times, bringing new containers to be loaded onto a train, collecting containers from a train, or both. When a truck arrives at the terminal, the terminal operator sends the truck to a position alongside a train, where it waits for a crane to serve it. The crane dispatch problem is to determine the order that a crane will visit the waiting trucks in a way that minimizes truck waiting time and the cost of operating the cranes. For such a problem, it is hard to derive exact scheduling to achieve the highest utilization of the crane, due to the uncertainty of parking positions and arrival times of next incoming trucks and the low computation efficiency for deriving exact scheduling. Thus, to solve this problem in practice, the students should be equipped with some reliable *operating or scheduling* policies that can in-time provide effective dispatching actions to the crane. Some well-known policies are standby for utilizing this crane resource for serving those waiting trucks that have not been served in the parking lane. (i) FIFO (First In, First Out) policy: the crane should move to the waiting truck that has parked at its position at the earliest time. (ii) Nearest policy: the crane should move to its nearest waiting truck at the moment of the decision. (iii) Loopy policy: the crane should move along one direction until there is no truck waiting, and then reverses the moving direction of the crane. However, as for the practice, different policies may be suitable for different arrival patterns of incoming trucks. Thus, the students need to test the available policies for the case where they are going to apply and try to nail down the most effective operating policy for the case. In some cases, it may be even better to combine some policies to the one that works in a robust fashion.

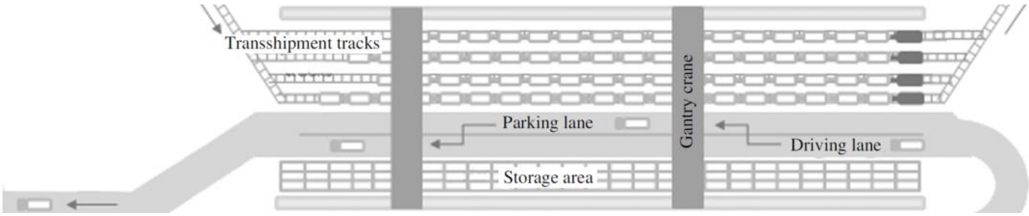


Figure 1. Crane dispatching in intermodal terminals (Boysen et al. 2013)

### 3.3 Intermodal Operations Management

Among the operations processes in the intermodal transportation, there are many once-for-all decisions of intermodal operations management that bring long-term effects on the profit or the cost of the intermodal transportation, for example, selecting a transportation mode (e.g., by road, by rail, by sea or by air) for a specific haul, or determining the size of a fleet of trucks for a road transportation. All those operations decisions seem to be straightforward, but they are not easy to be nailed. For solving those problems, *the students should pay great attention to the optimality conditions of the problems* such that they can consequently propose some algorithms to make the optimal decisions.

The trucking related operations problem fill into the intermodal operations management. One trucking problem is truck fleet sizing problem with uncertain demand. In this problem, uncertain demand arises in the transportation between two nodes, e.g., between a distribution center and an intermodal terminal hub. For such a transportation, a truck fleet needs to be deployed. Maintaining a truck in the truck fleet needs a daily maintenance cost even when the truck is idle. Using a truck in the truck fleet for a cargo transportation service incurs a further daily operating cost. Leasing a truck for a day induces a daily leasing cost (there is no other cost associated with leased trucked). Here, we have the daily leasing cost greater than the daily maintenance cost plus the daily operating cost. Cargo transportation will bring in a revenue per truckload that is greater than the daily leasing cost. The decision of this problem is to determine the number of trucks in the fleet given a random number distribution to describe the uncertain demand in the units per truckload. The objective is to maximize the total profit. To solve this problem, the students should be able to describe the objective function with respect to the decision, i.e., the number of trucks. By taking some derivation on the objective function, the student should understand the unimodality of the total profit in the number of trucks, for the optimality condition of this problem. Once the optimality condition is revealed to them, they shall be able to understand or design some algorithms to solve the problem, such as the golden section search.

## 4. PROBLEMS FROM STUDENTS AND OUR MEASURES

In this section, we show some typical problems that students would make under the classification of the three categories.

### 4.1 Intermodal Routing and Network

The concept of the TSP and its nearest neighbourhood heuristic are generally not difficult for students to understand. In our teaching, we found that students often make three types of mistakes. The first one is that although the path is correctly identified, the total travel cost is wrongly calculated. We suggest that students re-calculate using the “reverse way”. For example, if the distances of the links on the path are 5, 6, 12, 20 and 8, students should calculate 5+6+12+20+8 and then calculate 8+20+12+6+5 to make sure the two results are identical. The second one is forgetting to let the truck return to the depot. The third one is not understanding the case of asymmetric travel cost matrix. We use real-case examples (maximum working hours, one-way roads) to show the implications of the latter two mistakes.

### 4.2 Intermodal Terminal Scheduling

In crane scheduling, students have difficulty understanding what a "policy" is. This is because, in a question/assignment the arrival time of a truck is always given and students wrongly suppose that the arrival times of all trucks are known at time 0. To let students appreciate how a policy works in reality, we shall let students play a game, in which they can adopt any policy, but the arrival of trucks is gradually shown to students, and the results of different students can be compared.

### 4.3 Intermodal Operations Management

Regarding the truck fleet size problem, students have difficulty understanding the $\Sigma$ notation. Considering the focus of the intermodal transportation course, we shall try to use as little complex notation as possible. A second issue is the amount of computation of this type of problem is too large for students to use calculators, and students get bored and easily make calculation mistakes. This is an excellent opportunity to train students to use Microsoft Excel to solve a complex problem.

## 5. CONCLUSION

This paper introduces our teaching philosophy on the course of intermodal transportation. Different from the traditional way of focusing on the learning of qualitative analysis, we start to target on the learning of quantitative methods. We divide the key processes in the intermodal transportation into three categories in terms of their similarity for the operations, including intermodal routing and network, intermodal terminal scheduling and intermodal operations management. Each category is delivered to students systematically with systematic qualitative methods. Students feel active for this new learning experience. Some typical troubles emerge in their learning, for which we provide countermeasures. Although teaching intermodal transportation in a quantitative way is challenging for students, we are delighted to see that in their feedback students appreciate our efforts and comment that they have learned several practical tools.

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