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Scheduling of Trucks at the Crossdocking Centre Using Auction Mechanism

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Abstract— Crossdocking centre is one of the critical elements of lean supply chain. Crossdocking is a practice in logistics wherein material is unloaded from inbound trucks and then loaded directly into outbound trucks with little or no inventory holding of these materials. There are several research works focussing on the optimum allocation of trucks in crossdocking centre, such that it minimizes the total cost. There are also lots of research works related to the use of auction mechanism in allocation problems. In this article we review all the literature in those areas and try to introduce a new concept for the optimum scheduling of trucks in crossdocking centres, by integrating crossdocking operations with auction mechanism.

Keywords— Supply chain management, Crossdocking centre, Auction mechanism, Winner determination problem, Allocation of trucks.

I. INTRODUCTION

A supply chain consists of all the stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturers and suppliers, but also transporters, warehouse, retailers, and customers themselves [1]. Every manufactures try to satisfy the customer demand by deliver the requested shipment in right place, on time, in right quantity with affordable price. Transportation cost and storage cost play an important role for fulfil the above goals. One concept which is defined for reaching the goal of lower transportation cost and storage cost is crossdocking centre.

Crossdocking is a concept that aims at minimizing the transportation cost in supply chain. It is one of the critical element of lean supply chain. It is a kind of warehouse management where incoming products are moved directly to outbound trucks without any intermediate storage [2]. Crossdocking centre is an attractive alternative to warehouse because inventory cost is very low in case of crossdocking centre compared to ordinary warehouse. There are several successful implementation examples of crossdocking facility to their supply chain system, those includes Wal-Mart and Toyota etc. The main function of crossdocking centre is consolidation and deconsolidation of materials. Consolidation means smaller product quantities from several destinations which is unloaded from different inbound truck are combined into larger lots at the crossdocking centre and loaded in to outbound truck. Deconsolidation is the breaking down of large shipments into smaller ones intended for different destinations. Incoming trucks usually contain different shipments for different destinations; they are unloaded at the crossdock and then items for each destination are loaded to the dedicated truck for the respective destination [3].

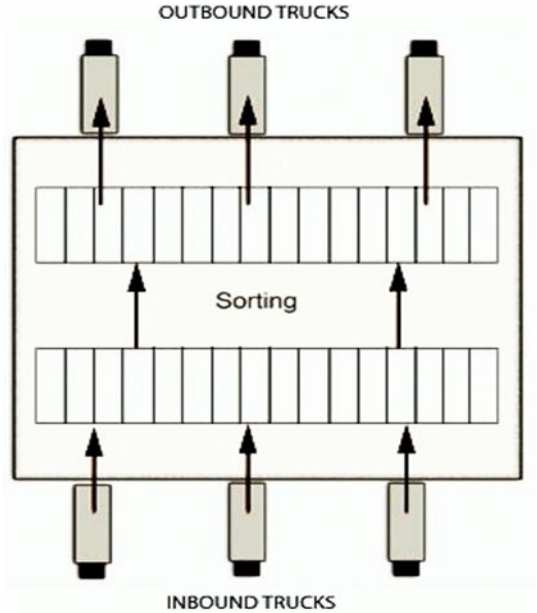

Fig. 1 Crossdocking Centre

Crossdocking centre infrastructure involves a number of doors in the inbound and outbound area for loading and unloading from trucks and, a storage and sorting area for consolidation and deconsolidation of goods and for some value added services.

One of the important factors which affect the whole operation process of crossdocking centre is truck scheduling problem which decides the assignment of inbound or outbound trucks to crossdocking centre door and to fix timeslots for processing the loading or unloading job. Handling trucks at crossdocking terminals constitutes a complex planning task which comprises several executive steps as shipments delivered by inbound trucks are to be unloaded, sorted according to their designated destinations, moved across the dock and finally loaded onto outbound trucks for an immediate delivery elsewhere in the distribution system.

There are several research works related to the area of scheduling of trucks in crossdocking centre. Some of the literature review about this explained in the chapter II of this journal. Here we introduce a new concept for the optimum allocation of trucks in crossdocking centre by integrating crossdocking operations with auction mechanism.

An auction is a market institution with an explicit set of rules for determining resource allocation and prices on the basis of bids from the market participants. In the traditional sequential auction model, each item or indivisible bundle of items in an auction is auctioned one at a time. Winner determination is done simply by picking the highest bidder for each item. [4]. Sequential auction is commonly used in ordinary auction mechanism where objects are sold one by one in separate auctions. These sequential auctions might be organized as sequential first-price, second-price, or English auctions. If there are complementarities between different items, sequential auctions may provide inefficient allocation. Combinatorial auction model solves inefficiency of sequential auction by allowing bidders to submit bids on combinations of different items. In this model, all items are available to the bidders and the bidders are free to express their own valuations of any combination of items. The combinatorial auction model is applicable to many real world situations such as the auctions for airport slot allocations, radio spectrum rights, course registrations, transportation services, and commercial time slot allocations.

In combinatorial auctions bidders can bid on combinations of items, tend to lead to more efficient allocations than traditional auctions in multi-item auctions where the agent's valuations of the items are not additive. However, determining the winners so as to maximize revenue is NP-complete. [5]

The allocation of items to the bidders in combinatorial auctions is done by solving winner determination problem. It's simply determining what items each bidder gets. So efficient scheduling can be done by solving winner determination problem.

The advantage of integrating auction mechanism to ordinary allocation problem is final allocation after solving this model will maximize the utility of the bidder. So bidder will get higher satisfaction by this allocation compared to ordinary allocation mechanism. This integration will helpful for several allocation application such that it maximize the bidder utility as well as crossdocking centre revenue.

Solving winner determination problem in combinatorial auction mechanism is computationally complex. For a general winner determination problem formulation [5], let M be the set of items to be auctioned. Then any agent i, could place any bid b_i (S) for any combination of items S ϵ M.

$$MAX \quad \sum_{s \epsilon M} b_i(S)\ x_i$$

$$Subject\ to, \quad \sum_{s \epsilon Ms} x_i \ \leq 1$$

$$x_i \ \epsilon \{0,1\}$$

The winner determination problem is to label the bids as winning (xi = 1) or losing (xi = 0) so as to maximize the auctioneer's revenue or total utility of bidders under the constraint that each item can be allocated to at most one bidder.

II. LITERATURE REVIEW

There are several literatures describes the methodology of optimizing truck allocation in crossdocking centre. Most of literatures focused on the allocation of trucks that minimize the total transportation cost and inventory cost. Different methodology including exact and heuristics have used to solve this allocation problem.

A. Crossdock allocation models

For a crossdocking operation, truck scheduling or allocation is the one of the important management decisions for better performance of crossdock. The smoothness of the crossdocking operation is directly related to the truck scheduling. Poor scheduling leads to long makespan time, poor product flow. Therefor most of the literatures are focused on to better allocation of trucks in crossdock such that it minimize the total makespan time and there by total cost of operation.

Some researchers focused on optimization of vehicle routing problem with cross-docking allocation. They proposed algorithm for generating the vehicle routes is based on the Large Neighbourhood Search. The idea of the Large Neighbourhood Search is to start from an initial set of routes, and then step-wise perform modifications to these routes, and thereby gradually obtain better solutions [6].

Another study in the area of crossdock allocation is scheduling problem with fixed outbound schedule and its complexity. The proposed problem considered the arrangement of products in the incoming trucks based on the outgoing trucks which are assigned to destinations, this assumption results in a more efficient scheduling of trucks and a more realistic view about total operation time of the crossdock operation. They proposed a new model for crossdock scheduling considering product arrangement. They developed a mathematical model with objective function minimizes number of delayed products [7].

An integer programming model used for optimize the truck arrival times and departure times when the number of trucks is greater than the capacity of a crossdock with the objective to minimize the operational cost of the cargo shipment and the number of unfulfilled shipments. By giving each truck several parameters such as operational time, operational cost per unit time and penalty cost per unit cargo, the two objectives are combined into one term: the total cost, a sum of the total dock operational cost and the total penalty cost for the unfulfilled shipments [8].

Reference [9] proposed a zero-inventory crossdocking allocation model for minimizing the total storage in crossdocking centre. There is no storage process in this case. As a result, outbound trucks are scheduled to leave the facility at the earliest point in time as possible. This model has a new idea of minimizing the total storage inside the cross-docking facility which will affect the handling process and the departure time requests of the trucks.

A detailed scheduling problem model for single truck in inbound and outbound dock and combine it with the assignment of the products. The model used to determine product allocation and truck scheduling. The objective function of the model is to minimize the total operation time when a temporary storage buffer to hold items temporarily is located at the shipping dock [10].

Reference [11] describes a generic model by combining the truck scheduling problem with the crossdock door assignment problem. It is a mixed integer problem.

Scheduling problems in crossdocking centre have some changes based on the kind of product passing through a crossdocking centre. For example for a food industry, products from inbound trucks are loaded immediately to the outbound truck because of strict cooling requirements. The objective of such scheduling model is to minimize the processing time flow time, and tardiness of outbound trucks. Dynamic programming and Simulated Annealing are proposed to solve the model in [12].

A just-in-time scheduling policy implemented truck scheduling optimization model developed in [13]. Every truck has a deadline for arrival and departure, and a penalty will occur if the due date of each truck is missed. The objective of the model is to schedule inbound and outbound trucks to minimize the total earliness and tardiness of incoming and outgoing cargo.

B. Auction mechanism models

Auction model is applicable to many real world situations such as the auctions for airport slot allocations, radio spectrum rights, course registrations, transportation services, delivery routes, network routing and commercial time slot allocations. There are several literature works related different real world application using auction mechanism. For such an application where limited resources with different complementarities between the resources. Bidders have preferences not just for particular items but for sets or bundles of items that is called combinatorial auctions. The economic efficiency can be enhanced if bidders are allowed to bid on bundles or combinations of different assets.

Auction is a good approach for finding of an efficient schedule of resources. The allocation problem is concerned with determining the particular subset of bids that maximizes the total social welfare among all the bidders and it is called the winner determination problem.

Auction is actually a two stage game: In first stage the auctioneer designs the set of rules including how the allocation of goods is determined and what payments the bidders are charged. In the second stage the bidders will calculate and submit their bids. Hence the auction designer´s task is to device the set of rules in a way as to enforce bids that are beneficial towards his goals [14].

One assumption while designing an auction mechanism is that all participants except the auctioneer have utility functions for the resources to be allocated which indicate their preferences for certain item. It is assumed that participants can assess their valuations in monetary terms and that utility is transferable among the participants via money [15].

Combinatorial auction is commonly used in all auction mechanism problems. In a combinatorial auction bidders are allowed to bid not only on single items but on combinations of items with the result that many items are sold simultaneously. Combinatorial auctions are preferred whenever the value that bidders assign to an item depends on which other items they are awarded. This is the case for bidders who have complementarities in their utility functions. In a combinatorial auction, bidders may submit bids on combinations of items. This allows the bidders to express complementarities between items instead of having to speculate into an item's valuation the impact of possibly getting other, complementary items [16].

A combinatorial auction formulation for allocation problem occurs at a company where profit-centres compete for execution of jobs at a single central machine. This central machine is a limited resource because it has only limited capacity. Each profit centre has private valuations for the jobs whose execution consumes a certain time interval [17].

A sealed bid combinatorial auction is developed in [18] for the allocation of airport timeslots to competing airlines. This auction procedure permits airlines to submit various contingency bids for flight-compactable combinations of individual airport landing or take-off slots. An algorithm for solving the resulting set-packing problem yields an allocation of slots to packages that maximizes the system surplus as revealed by the set of package bids submitted [18].

A preliminary study which aims at developing auction mechanisms for decentralized scheduling which exhibit minimal communication overhead and an efficient usage of resources are presented in [19] and methodology used to solve the problem is progressive Lagrangean heuristic. Computational results have shown that an auction mechanism based on a progressive Lagrangean heuristic is able to provide results comparable to those provided by centralized heuristics.

A new dynamic traffic congestion control scheme proposed in [20] called tradable network permits, and demonstrated its efficiency properties for general road networks. To implement tradable permit markets, this paper proposes a novel auction mechanism with capacity control. The day-to-day auction mechanism comprises an auction phase and a path capacity adjustment phase. In the auction phase, the manager sells bundles of permits to the users through an ascending auction for fixed path capacities. The procedure of this ascending auction corresponds to solving the sub-problem using a primal–dual algorithm.

Combinatorial auction based resource co-allocation model for grids has proposed in [21]. Resource co-allocation problem is one of the challenging problems in grids. In order to model this problem, a new combinatorial auction based resource co-allocation approach is proposed. This economy based model provides efficient allocation of resources in a grid environment by allowing bidders to submit bids on the combinations of different resource types. In order to solve the model, combinatorial auction based problem is defined and formulated using integer programming.

C. Crossdock truck allocation using auction mechanism

Crossdocking is a concept that aims at minimizing the transportation and inventory cost in the supply chain. One of the important problems, which affects the performance of the crossdock system, is scheduling of incoming and outgoing trucks on the dock doors. From the previous literatures it can concluded that number of real life applications are using auction mechanism for the optimum allocation of limited resources.

Handling trucks at crossdocking terminals constitutes a complex planning task which comprises several executive steps as shipments delivered by inbound trucks are to be unloaded, sorted according to their designated destinations, moved across the dock and finally loaded onto outbound trucks for an immediate delivery elsewhere in the distribution system. Auction mechanism is very much suitable to the crossdocking operations where we can use this mechanism for the allocation of inbound truck and outbound truck such that it maximize the total valuation of bidders (trucks) or the total utility of the all bidders. By integrating auction mechanism to the nature of crossdocking operation it will improve the performance of crossdock operation as well as the utility of bidders.

III. CONCLUSIONS

Several models are used for the planning of crossdocking scheduling operations. These models used for finding the optimum schedule of trucks in crossdocking center which are working in different context. This different context is driven by the process in the crossdocking and the product characteristics and requirement. The existing models designed mainly for the scheduling of trucks that minimize the total transportation cost and storage cost by considering the assignment of the dock doors to truck. The review found that there is no model that uses the concept of auction mechanism for the scheduling of trucks in crossdocking terminal. By incorporating auction mechanism in to a crossdocking operation total utility of all trucks will increase without declining the performance of the crossdock. From the review of auction models it is found that auction mechanism can be implemented in different allocation problem and it is very much suitable to the operational sequence of the crossdocking operations. It will be a challenge in future research to develop a model uses auction mechanism for the allocation of trucks in crossdocking center. Developing such a model will be very helpful in solving the truck scheduling problem which will in turn maximize the total utility of trucks.

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