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Bundle-based auction framework for Québec timber allocations

Dua Weraikat, Marc-André Carle*, Sophie D'Amours, Mikael Rönnnqvist

Université Laval, Québec, QC, G1V 0A6, Canada
*marc-andre.carle.1@fsa.ulaval.ca

Abstract. Timber allocation problem is complicated and generally involves multiple stakeholders and cross-chain coordination decisions. Due to their well-defined economic environment and structure, auctions are used in allocation timber similar to other natural resources allocation problems. In Québec, the government provides 25% of the public forests through an auctioning system. However, the current wood allocation system lacks the flexibility to allow bidding for a bundle of available lots or areas. Consequently, few companies are interested in participating in the auctions offered by the government and a significant number of the auctions remain unsold. In this article, we highlight some issues regarding the current allocation system and suggest new mechanism in order to make the auction process more beneficial to all parties involved.

Key words: Forest Industry, Auctions, Natural Resources, Québec

1 Introduction

Québec's forests play a crucial role in the economy of the province. They account for 20% of Canada's forests and 2% of the world's forests. In terms of area, 92% of Québec's forests are under public ownership. The forest industry crisis in recent years highlighted the limitations of the timber supply and public forest management system used in Québec. That is, some companies had difficulty obtaining timber supplies, while volumes of wood were set aside for companies that were not operating at their full capacity. To remedy the situation, a new forest regime was put in use in 2013. The new system stipulates that 25% of the maximum allowable annual cut (AAC) of the timber will be allocated via a public auction mechanism. It is also required by international trade agreements, which Canada has signed, in order to open access to new biomass based businesses. The government authorized the Timber Marketing Board, Bureau de mise en Marché des bois (BMMB), to sell the aforementioned wood through organizing sealed-bid one winner auctions [1]. More details are provided in section 3.

Auctions are typically defined as market techniques with predetermined set of rules of which bidders compete for the right of resource allocation and prices [2]. Four standard types of auctions can be found in practice; English auction, Dutch auction, first-price-sealed-bid (FPSB) auction, and second-price-sealed-bid (SPSB) auction. In the English auction (also called the oral open or ascending-bid), the price is raised until one bidder remains. The main feature of this kind of auctions is that each bidder has an access to the level of the current best bid. In the Dutch auction, in contrary, the auctioneer calls first for an initial high price and then lowers that price until one bidder accepts that price. With the sealed bid auctions, the highest bidder is awarded a good for the price he bid in the FPSB auctions, but he is awarded a good for a price equal to the value of the second highest bid in the SPSB auctions. FPSB auctions are widely used by governments for natural resource allocations, while SPSB auctions are seldom used in practice. Any auction, however, has to have the following conditions in order to be considered as a successful one; large number of bidders, well-defined and public rules for the auction, a specific item to sold, and no side payments or hidden fees [3].

In Québec, forests with several species and age classes are typical. Therefore, each stand in the forest has specific characteristics that make it suitable for particular types of usage, while they may not be appropriate for others. In other words, a part of the available stands in a FPSB auction might be in the best interest of a bidder while other parts are not. Moreover, a bidder might have a preference for sets of stands rather one stand. More specifically, if a company needs to win 3 bids out of the 5 available ones in order to meet its timber needs, it might win more if they bid on all 5 lots. However, the currently used auction system lacks the flexibility to allow bidding for many lots simultaneously. This strategy restricts the flexibility of requirement and compromises the efficiency of allocation result. Obviously, it is not beneficial to bidders, i.e., a significant number of the lots offered for auctions in Québec had zero bids. As it can be observed in Table 1, around 22% of the sectors offered for auctioning were unsold in years 2013-2014.

Year	Characteristics	Offered	Sold
2013-2014	Total number of sectors	223	173
	Total volume (m^3):	6,911,000	5,244,000
	SPEM	5,211,000	4,128,000
	Softwood	93,000	42,000
	Hardwood	1,106,000	735,000
	Aspen	501,000	339,000
	Auction price ($\$/m^3$)		10.07
	Total auction sales ($)	-	52,976,000

Table 1: Summary of auction sales data in Québec, after BMMB [4]

Combinatorial auction systems allow bidders to bid on any combination of items or stands rather than just an individual item. We refer to any combination of items in a bid submitted to an auction as "a bundle". By doing that, bidders can reflect their preferences towards the items in their bundles, which would consequently enhance the efficiency of allocation result [5, 6]. Such auctions were successfully implemented to solve airport time slots allocation problems [7]. Therefore, in this article, we aim at using the concept of combinatorial auction in order to improve Québec timber allocation auction and to make it more beneficial for all parties. From the bidder perspective, the new system provides bidders with better species composition with respect to their preference. When bidders win lots that are nearby, logistics and transportation costs will be lessened. Therefore, bidders will submit higher bids value in order to win the lots they prefer. Consequently, the government overall revenue from the auction improves.

This paper is structured as follows. A brief summary of the literature related to auction systems used in allocation natural resources in general and timber in particular is provided in section 2. Section 3 presents the description of the Québec auction system context. Section 3 also propose a framework to improve the current auction system. Section 4 presents results from using the model on a case study in northwestern Quebec. Finally, concluding remarks and future recommendations are provided in section 5.

2 Literature Review

In this section, we briefly provide a literature review on natural resources allocation techniques. We first focus on types of auction models that have been used to solve natural resources allocation problems, then literature on auction systems used for the forest industry are provided.

Systems for allocating natural resources are used to create economic wealth where governments transfer property rights from public to private control. Very early, research was dedicated to highlight the importance of how to allocate natural resources rather than to whom rights are allocated [8, 9]. The existing systems for transferring property rights in the natural resources were reviewed by Crowley [3], who stated that the most common used system is auction in its different forms.

In auctions, bidders usually request receiving adequate incentives from natural resources allocated to maximize their expected output. In reality, governments, as natural resource agents, have less attention to this coincidence of interest [3]. Most often, governments choose different type of auctions for allocating a huge volume of their natural resources, such as agricultural products, oil, water, energy, etc. This is referred to well-defined economic environment and structure that auctions can provide. For example, governments in the U.S., Australia, and Canada use auctions to distribute lease and license rights to petroleum, natural gases, and timber. The leases are granted for three-to-five-year periods and can be in some cases renewed if minimum productivity requirements are met.

A large stream of the available literature identifies conditions under which auction type or the other might be preferred on the grounds of efficiency or seller's revenue [10]. However, less empirical evidence on how the choice affects bidder competition, because many auction markets operate under a given set of rules rather than experimenting with alternative designs. Generally, revenue differs among auction types because of differences in the ability to observe market signals. Theoretical models predict that the English auction is more vulnerable to collusion than sealed biddings [11]. This effect arises because unlike English auctions, bidders cannot observe market signals under sealed auctions, and thus they overbid.

Several formats of auctions have been used in electric-energy allocation problem. For example, Dutch auctions are widely used in Brazil for electricity procurement allocation problem [12]. In addition, auctions with long-term contracts to allocate electric-energy are used in Chile, Colombia, Peru, South America, and in the U.S. However, other governments do not prefer using this type of auctions at a higher-than-expected final price, fearing that participants may sell their energy at an excess profitability. On the other hand, the first-price-sealed-bid (FPSB) has been extensively used for mineral allocation problems [13, 14]. The results for the mineral allocation model highlighted the importance of providing information of items and prices on bidder profits. Also, auctions are used for allocation wind energy leases in the U.S. [15]. Another sector that uses auction is the fishery industry. For example, auctions handle more than seventy percent of fish landed in Denmark [3]. The fish auction market in Iceland has been serving users for the last 30 years, since it was established in 1987. More recently, some states in the U.S. started using Dutch auction system to purchase crabbers' rights for harvesting [16].

An interesting application of combinatorial auction in improving allocation problems were investigated by Epstein et al. [17]. The authors developed an integer linear programming model (NP-hard problem) for combinatorial auctions to assign meal contracts for real schools in Chile. The results showed a significant improvement in the auction system efficiency and transparency of the allocating process when using combinatorial auction instead of the traditional one.

Utilizing auction systems for timber allocation are used in many countries. As aforementioned, the U.S. uses auction systems for timber allocation problems, where state governments play a prominent role in the management of public forests. They have historically employed both open and sealed bid auctions to sell timber from public forests. An intricate debate on the design of federal timber auctions was early faced. A study by Mead [18] argued that open auctions generated less revenue. Thereafter, the U. S. government proposed the use of sealed bidding auctions. However, the new law allowed forest managers to use open auctions if they could justify the choice. As a result, sale method has varied geographically. Using data from U.S. Forest Service timber auctions, Athey et al. [19] stated that sealed-bid auctions attract more small bidders. Recently, the decline in the U.S. stumpage prices has raised questions about the impact of state policies on the price paid for stumpage. Brown et al. [20] ensured that more than sixty percent of the problem refers to state allocation strategies, such as season of sale, harvestable volume density, length of the sale contract, seasonal operating restrictions, total appraised volume, and auction method.

In Germany, the forest economy has recently faced different challenges, such as increasing competition between the timber and energy markets for available resources and changing demand for timber. Brodrechtova [21] declared that long-term timber contracts, similar to the ones used for gases and oil, have been negotiated to cope with these challenges and problems concerning the exchange of timber. However, the results show that motivation for the use of long-term timber contracts was based upon transaction cost advantage and also upon cost-economizing occurs with the bundling of timber volume which improve auction prices and performance. Reiffenstein and Hayter [22] evaluated auction system used in Japan for local timber allocation problem. According to the authors, the auction system in Japan is still very new and many opportunities are available to improve it. Li and Perrigne [23] simulated random reverse price FPSB auctions of standing timber organized by the French forest service. The results demonstrated that the optimal reserve price allows the government to extract more of bidders' willingnesses to pay.

After signing the international trade agreements, timber allocation problem in Canada has been tackled by several researchers in order to evaluate and assess the new regulations. Farnia et al. [24] designed and simulated a sealed first-price multiple round auction. More recently, Farnia et al. [25] proposed a time-based combinatorial auction based on delivery period. According to the authors, coordination among auction winners would improve the economic value obtained. Very recently, Boukherroub et al. [26] proposed a sustainable framework for Canada timber allocation problem. The authors highlighted the importance of allocation strategy to guarantee fairness between forest companies in order to maximize their optimal targeted value and develop a sustainable public resource allocation.

It is worth mentioning that all of the contributions reviewed above on forest allocation problem has developed models based upon the traditional timber auction systems. In contrast, designing a bundle-based auction framework has been capturing no attention.

3 Québec timber auction system

3.1 Québec timber auction system context

In order to obtain the best possible and fairest prices, the Timber Marketing Board (BMMB) has to make timber available to as many buyers as possible across all regions. Processing mill owners, contractors, co-operatives, forestry groups and log dealers are all permitted to take part in the auctions organized by the board. The auctioning process is as follows.

An auction starts from posting a public tender document (DAO) by BMMB, which is used to identify the goods offered in the bid. The same document is also used to provide more information about the auction, namely; description of the sale, instructions to bidders, contract to sign, the volume of timber estimated by species (or group of species), quality of timber, and time limits. It is worth mentioning that auction numbers are varied from one year to another. Nonetheless, there is a minimum number of three auctions annually [27]. According to the BMMB plan, seven auctions will be conducted in 2016 [4].

Bidders who are interested submit bids either in person or through an electronic submission using the BMMB website. They also have access to the territories without the BMMB supervision in order to check woods types and species that they would like to bid for. Their quotes are usually evaluated with respect to the following aspects: location(s), description of work, forest roads, time limit to harvest, forest certification, inspection procedure, and bid security amount. The bid security amount is a fixed amount requested by BMMB and it is proportional to the estimated price of a bid. It is there to guarantee that the winner will sign the contract and in addition provide a good performance work. However, the BMMB automatically returns this amount to the bidder after signing the contract.

Upon the end of the time limit to submit a bid, bids are opened and checked by a BMMB representative. An external observer can also participate to monitor compliance of bids with the rules for opening and selection procedures, then s/he completes and signs a declaration compliance report indicating, where appropriate, the reasons for refusal or procedural defects and their impact on the awarding of bids. It is worth mentioning that, the BMMB office documents have mentioned two kind of bidding, namely; the basic bid and the combinatorial bid. On one hand, the basic bid is a closed auction price for the first one sector. The winner is the bidder who submitted the highest total amount. Combinatorial auction is a sealed first-price auction where multiple products are offered simultaneously.

The winner of an auction is selected based on the highest amount submitted for a bid. It is worth mentioning that this amount has to be greater than the reserve price, i.e., the lowest price the BMMB is willing to accept for a bid. To avoid bidders' collusion, BMMB has the authority to cancel any auction that received less than three bids. In addition, the office does not allow mills that belong to the same company to submit separate bids. In case of ties between two bids, the winner is determined by drawing. Afterwards, the winner has to harvest all species in the land assigned. The winner can also sell part of the wood harvested to another company [27].

Nonetheless, currently, the BMMB is rarely using the combinatorial auctions, and when it is used, it is as follows [4]. Combinatorial bids are only allowed on specifically designed sets of two territories which are offered at the same time and are very close to one another. Companies are allowed to bid either on a single territory or on both, and the sets of offers that maximize the auctioneer's revenue over the two lots are accepted. In this particular context, determining the winning bids is straightforward; but it would not be if companies were allowed to bundle more than two lots at a time or to decide which territories to combine in a bundle.

3.2 How to improve the auction system in Québec?

As expounded earlier, bidders typically have preferences not just for one particular stand but for sets of them. That is due to many reasons, such as better species composition, closer lots to the bidder, i.e., lower harvesting and relocations costs as well as shorter transportation routes. Currently, the Québec auction system prohibits companies from submitting a bid for more than one item simultaneously except when two lots are offered as a bundle. As a result, not all areas offered by the BMMB for auctions are sold (Table 1). We believe that giving companies the opportunity to submit bids in bundles could increase the number of participants in Québec timber auctions. In addition, economic efficiency would enhanced if bidders are allowed to bid on bundles or combinations of different assets with respect to their own benefits. To achieve this goal, a combinatorial auction can be employed [6].

Auction theory suggests that when bidders have preference structures, i.e. bundles, then simultaneous bidding is the best design of an auction [28]. This is because combinatorial auctions will promote efficient pricing and allocation of the bundles with respect to their budgets constraints. In addition, using bundle-based auction system may increase the government revenue out of a bid. Another crucial advantage of combinatorial auctions is its tendency to assign bundles for those best able to use them. Companies with the highest interest in a bundle are likely to be willing to bid higher than others, therefore tend to be the bundles' winners. In other words, when sawmills offer bundle bids of their best of interest, they will be able to reflect on the economies of scale in the prices they offer. As a result, the auction becomes more efficient. However, it is risky; the bidder either gets entire combination or nothing. Such auctions are also more complex. The bidder has to decide on number of choices, such as the best collection of bundles on which bids are allowed to be restricted or not, how much price to allocate for each bundle, and so on. The problem becomes even more complex if conflicting bids are authorized.

To understand how bundle-based option can improve the efficiency of traditional auction systems, consider the example shown in Fig. 1. Three identical bidders in size and capacity (i.e., sawmills A, B, and C) are bidding on ten areas that have mixed species (1-10). Suppose that bidder-A has interest in areas 1, 2, 3, 5 and 6 due to the species available in these lots. In the context of the current system, bidder-A has to submit bid for each area separately. Since the lot in area 1 is relatively far, transportation and logistics costs is expected to be $ 60 for bidder-A. Knowing that his/her break-even point is $100, then bidder-A would submit a bid of $40. By the same token, bidder-A will bid on lot 6. On the other hand, if the bidder submits a bundle of lots 1, 2, and 5 (R1), the costs would become $40 and then he/she would pay $60 for the bid. R1 lots are close to bidder-A, hence paths which are required have many segments in common, i.e., less time and cost are needed to build the desired routes.

Since the first model proposed by Rassenti et al. [7], combinatorial auctions have received much attention as an allocation technique with different applications, such as airport landing slots, truckload transportation, and industrial procurement. Yet, less literature can be found on their application for natural resources since it is not a straightforward process.

Combinatorial auctions present challenges compared to traditional auctions in the sense of computational and/or economic challenges. The collection of bundles on which bids are allowed be restricted or not and how to efficiently determine the allocation once the bids have been submitted to the auctioneer are good cases in point. The latter is usually called in literature the winner determination problem while the former is called bid generation problem. Resource constraints on some bidders usually limit the number of combinations bids which they will submit. In addition, the auctioneer could restrict the collection of bundles on which bidders might bid in order to overcome the bid generation intricacy. However, it is challenging to find the best allocation winner of goods or set of goods to bidders, including the possibility that the auctioneer may keep some goods, that maximizes the auctioneer's revenue. The complexity of this problem increases for large instances. It becomes a NP-hard problem with no known polynomial-time algorithm to find the optimal allocation. It is not a straightforward to find an optimal solution; i.e., it might be solved by a mixed-integer programming (MIP) formulation with a good solver or a specialized (custom) algorithm might be required.

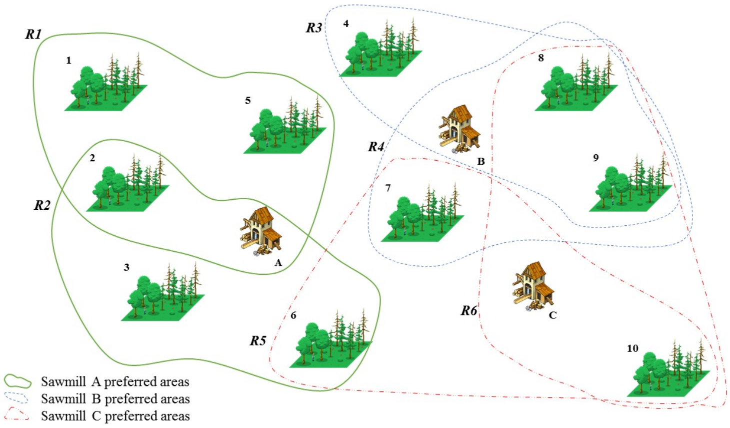

Fig. 1: Example of bundle-based auction system

A general mathematical model to determine the winner of a bundle-based allocation timber auction is provided in Equations (1- 4). Given a set of bidders n and a set of b of m individual items to sell. A bidder j can submit a bid of a bundle $S \subseteq b$ and pay $p_{j,S}$ [29]. The objective function (1) is to maximize the revenue from allocation or selling items to the bidders ($x_{j,S}$). The first constraint (2) ensures that each item has a maximum of one winner. The second constraint (3) ensures that a bidder wins either a single bundle or nothing. $\delta_{i,S}$ is a binary parameter that is equal to 1 if $i \in S$, and 0 otherwise. Other constraints might be used, such as maximum number of bundles by each bidder or maximum number of items in each bundle.

$$Maximize \quad \sum_{j \in n} \sum_{S \subseteq b} p_{j,S} x_{j,S} \tag{1}$$

s.t.

$$\sum_{j \in n} \sum_{S \subseteq b} \delta_{i,S} x_{j,S} \leq 1 \qquad \forall i \in b \tag{2}$$

$$\sum_{S \subseteq b} x_{j,S} \leq 1 \qquad \forall j \in n \tag{3}$$

$$x_{j,S} \in \{0,1\}, \quad \forall S \subseteq b, \quad \forall j \in n \tag{4}$$

Finding an optimal solution to such a model, and whereas more than one optimal solution exists, is essential. In other words, a close to, but not, optimal solution for a good might be unfair wood allocation, such as benefit certain companies over others. Efficient solution algorithms for solving such a problem are then necessary. Therefore, implementing the combinatorial auctions for Québec timber allocation problem would be worth being investigated.

4 Case Study

A case study was assembled to test the model and provide illustration of the benefits of bundle-based auctions; it consists of 44 territories that were auctioned through the BMMB in the Northwestern part of Québec during 2015. Eight (8) softwood sawmills owned by five (5) different companies operate in the area; 3 companies own 2 mills while the latter two each operate a single mill. As explained in section 3, the sawmills are expected to obtain 25% of their wood supply through the auctioning system. Two bidding systems are compared: (i) the current FPSB system and (ii) the combinatorial auction system outlined in 3.

Each company assesses the value of each territory as follows. Each mill sets a sets a target cost per cubic meter for wood supply that covers harvest, transportation as well as wood purchasing. A company's willingness to pay for a given territory is equal to the (target cost - sum of expected harvest cost plus transportation cost to the company's nearest sawmill) times the territory's estimated volume to harvest. We therefore assume that buyers are only interested to bid on territories where it is possible to harvest and bring the wood to the mill's gate at or under the targeted supply cost.

Under the FPSB bidding system, each company registers bids as follows: territories are ranked in descending order of willingness to pay, then bids are registered until total bids equal to more than 150% of the company's required wood supply through the auctioning system. Bid values are equal to 90% of the company's willingness to pay times the volume of wood to harvest in the territory if the company's mill is the closest to the territory, and 100% of the willingness to pay if a competitor's mill is closest. Then auctions are granted to the highest bidder; results are shown in 2. A total of 75 bids were registered on 32 territories. Two companies (B and E) win much larger supply than hoped, while companies C and D win significantly less. As a result, both C and D are unlikely to be able to operate at full capacity.

Companies		Territories		Wood supply (m3)			Expenses	
Company	Mills	Bids	Won	Needs	Won	%	$	$/m3
A	2	19	9	278100	305750	109.9%	5828886	$19.06
B	2	22	10	302725	420000	138.7%	6032942	$14.36
C	2	14	6	341500	279050	81.7%	5197116	$18.62
D	1	9	2	150775	73100	48.5%	1747559	$23.91
E	1	11	5	146300	221300	151.3%	4180571	$18.89

Table 2: Number of bids, wins, total volume and cost for the FPSB system

Under the combinatorial system, each company is allowed to register a maximum of five (5) bundles, each consisting on any number of territories. Each company assembles bundles whose total volume is between 95% and 105% of their needs. Whenever possible, territories that are close to one another are included in the same bundle so as to minimize logistics and harvesting costs. The resulting winner determination problem is solved with CBC in less than a minute of computing time; results are outlined in 3. A single optimal solution exists, wherein a bundle from each company is selected. As a result, each company gets between 99.9% and 105% of their required volume. In addition, because companies are able to bundle together territories that are close to one another, a 16.3% reduction in travel distances required to transport harvesting equipment from one territory to the next can be achieved.

Companies		Auctions		Wood supply (m3)			Expenses	
Company	Mills	Bundles	Won	Needs	Won	%	$	$/m3
A	2	5	1	278100	287100	103.2%	5663640	$19.73
B	2	5	1	302725	310800	102.7%	5844000	$18.80
C	2	5	1	341500	341000	99.9%	5370800	$15.75
D	1	5	1	150775	158250	105.0%	2164100	$13.68
E	1	5	1	146300	147050	100.5%	2182333	$14.84

Table 3: Number of bids, wins, total volume and cost for the combinatorial auction system

5 Conclusions and implications

Current Québec timber allocation auction system needs to be improved in order to better incorporate the bidders' interest and preference. In this article, we suggested a new mechanism based on a combinatorial auction system that allocates available forests in bundle-based forms. Giving companies the opportunity to submit bids in bundles increases the number of the right winners of the right lots. Early evidence from a realistic case study based on 2015 data from the Abitibi region shows that bundle-based strategies increase the likelihood that the companies get the amount of wood they need while reducing logistics costs.

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