AN APPLICATION OF ONE-MACHINE SEQUENCING GAMES TO FAIR SHARING OF DEMURRAGE CHARGES IN SHIPPING

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ABSTRACT

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In this paper the problem of fair cost-sharing of demurrage charges for shipping in the presence of a vessel queue is considered. A recent example of the occurrence of this problem in Australia was the vessel queue at Dalrymple Bay coal terminal in Queensland. Dalrymple bay is utilised by a number of coal producers - Rio Tinto, Xstrata, Anglo-Coal and the BHP-Billiton-Mitsui alliance. Capacity constraints at Dalrymple Bay coal terminal have led to a lengthening of the vessel queue to around 50 ships in early 2005. Delays in loading coal for export onto these ships mean that produces incur demurrage charges for the delay. The costs to the Australian coal industry of demurrage charges at Dalrymple bay were forecast in 2005 to be between $350-550 million for the year (DBCTPL 2005). If cost savings could be generated and fairly passed on to producers utilizing the port these charges could be substantially lower.

A queue management system was proposed by Dalrymple Bay Coal Terminal Pty. Ltd. (DBCT) in 2005 to address the problem and this was approved by the ACCC in April 2005 for a fixed period until december 2008. Regardless of the merits of the queue management system implemented by DBCT, the problem may also have other solutions.

One such solution involves using one-machine sequencing games to schedule the use of port facilities. These have been used in machine scheduling with multiple users is frequently modelled using sequencing games. In this paper we will view a shipping terminal or port as a machine. As such sharing of cost savings from re-ordering vessel queues at ports is quite amenable to analysis using one-machine sequencing games. An example of the type of costs generated by vessel queues is demurrage costs. These are the costs associated with delays in loading or unloading ships and the ship remaining idle.

The main contribution of the paper is to apply the theory of one-machine sequencing games to the problem of fair sharing of demurrage costs which arise due to vessel queueing.

The application port management that we consider here is motivated by the following situation: “Ships queue outside Cape Town Ships have been queuing outside Cape Town since before Christmas thanks (or no thanks) to a combination of events the holidays, bunching of vessels and Cape Towns south-easter. With a resumption of normal services this week following the disruption of the Christmas and New Year holidays Cape Town loses on those two days the line of ships at anchor in Table Bay is expected to begin reducing. Meanwhile Durban is experiencing exactly the opposite, with few container or other ships at the many vacant berths in the port. Even the roadstead outside looks comparatively empty compared to a few weeks ago during the height of the busy season. The Durban Container Terminal expects to have recorded its highest ever volume of containers handled for 2005. Durban remained open throughout the holidays but by late December the number of ships calling had reduced considerably": (http://www.ports.co.za/news/article_2006_01_3_5034.html#Capetown).

This quote illustrates that vessel queueing is not uncommon and has a variety of causes. The particular case that will be considered in this paper involves Dalrymple Bay coal terminal in Queensland, Australia.

Firstly, an outline of the sequencing games literature is needed. Sequencing games involve situations in which multiple decision makers wish to minimize total costs by finding the order of jobs to be processed on 1 or more machines.

Consider a set of n jobs $N = \{1,...,n\}$ to be processed on a machine in this case the machine represents a port facility. These jobs are assumed to be generated by managerial decisions made by different people in different area of the facility. So that there is no clear hierarchy of responsibility or that the machine is a general purpose machine, such as a lathe which is used by a number of divisions within the factory. Alternatively, in an office environment photocopying jobs are a good example of the type of machine we have in mind. The application considered here treats a port facility as a general purpose machine in the above sense.

Each client of the machine is attempting to minimize costs to themselves. In our situation the clients of the port are the coal producers with queued vessels acting as their agents. So that costs are born by the producers but the player set consists of the queued vessels. This situation defines a coalitional form game $\langle N, c \rangle$ the value function c requires further explanation. If we consider c to represent costs to the coal producers and coalitions of coal producers. Then we define a time dependent cost function $c_i(t) = \alpha_i t + \beta_i$, where t is the sum of the service time (maskespan) and the waiting time. A sequencing situation is a triple (σ_0, α, p) where σ_0 is a given initial permutation of N that describes the order in which ships are loaded. p is a vector of processing times or the time it takes to load ships and c a cost vector representing demurrage charges. For a given processing order $\sigma \in \Pi(N)$, $t_{\sigma,i}$ is the finishing time of job i, so that:

$$t_{\sigma,i} = \sum_{k \in N : \sigma \leq \sigma(i)} p_k \tag{1}$$

and

$$C(\sigma, S) = \sum_{k \in N : \sigma(k) < \sigma(m)} p_k \tag{2}$$

where m is the last ship in the vessel queue S that is to be loaded.

$C(\sigma, S)$ is the moment in time that all jobs are completed based on a given processing order. The aggregate cost of S for a given order of processing σ due to punctuality is:

$$c_{\sigma}(S) = \sum_{i \in S} f_i(C(\sigma, i)) \tag{3}$$

where $f_i(C(\sigma, i))$ is the cost due to demurrage at a particular completion time of loading.

This paper is concerned primarily with cost sharing between multiple users. Consequently, the problem is one of a coalitional form sequencing game for sharing the costs of an efficient job processing schedule.

The cost savings due to a rearrangement of the order in which ships are loaded is:

$$\begin{aligned} v(S) &= \max_{\sigma \in \Sigma_S} \{c_{\sigma_0}(S) - c_{\sigma}(S)\} \\ &= \{c_{\sigma_0}(S) - \min c_{\sigma}(S)\} \end{aligned} \tag{4}$$

This problem is a combinatorial optimization problem. To be able to apply sequencing games to the problem of fairly sharing demurrage charges we need to introduce a particular mapping that that describes the contractual relationships between ship operators who incur the costs of waiting in the vessel queue and coal producers to whom the costs of waiting are passed on by ship owners in the form of demurrage charges. We will assume for the moment that each ship in the queue has a contract with a single coal producer. Consequently demurrage charges may be associated with each ship. More complex contractual relationships may be envisaged that require one to modify the cost function slightly.

There are two candidate solution concepts of interest here: the Equal Gain Splitting rule (Curiel, Pederzoli and Tijs (1989)) and the μ-rule of Hendrickx (2004) and Ambec and Sprumont (2002). The paper applies and compares these solution concepts to a stylized vessel queue based on the Dalrymple Bay Coal Terminal.

The approach taken can be extended to allow for the calculation of demurrage charges on the basis of due dates and to allow for improved handling of cargo at the port due to improved equipment and facilities and the general expansion of capacity. The latter requires using sequencing game with compressible processing times (van Velzen (2006)).

Key Words: Sequencing games, Vessel Queues, Scheduling

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