

Supply chain scheduling coordination: A game theoretic perspective

March 20, 2015

Candidate : MSc degree in OR, scheduling and planning theory, game theory

Supervisor : Mohamed-Ali Aloulou (MdC, HDR), aloulou@lamsade.dauphine.fr

Duration : 3 years starting from October 1st, 2015

1 Context and motivation

A supply chain (SC) is the set of all the stages at which value is added to a manufactured product. The chain involves a large number of actors, who are responsible for supplying raw materials and components, manufacturing the product, and handling the transportation, warehousing, and logistics operations. It is well understood that, to enhance supply chain performance and to improve customer service level, it is crucial to coordinate the decisions of involved actors.

As the production and the distribution are the main business processes in the supply chain, the coordination of production and distribution issue is crucial in the supply chain management. Indeed, the logistics market volume in Europe accounted in 2012 for 930 billion euros (Kille and Schwemmer [11]). The weight of the transportation sector is around 44% of the value added and 48% of the total employment. According to Eurostat data 2012 (Palmer et al. [13]), third party logistics (3PL) providers fail to consolidate client transport orders: about 24% of all road freight kilometers driven in Europe are empty vehicles and the average vehicle is loaded to 56% of its capacity in terms of weight.

The first EU transport policy target in the 2011 Transport white paper¹, is to growing transport and supporting mobility while reaching the 60% emission reduction target by 2050. To reach this challenging target, one should identify appropriate collaborative business models inter and intra supply chain collaboration, and develop methods that can be used to generate successful joint business models.

¹http://ec.europa.eu/transport/themes/strategies/2011_white_paper_en.htm

2 Thesis objectives

We will consider during the thesis several models in which different actors are involved in the production and delivery operations, taking into account the fact that the actors may have conflicting objectives and/or asymmetric bargaining power. Among these models, one can consider the case where a set of manufacturers producing time-sensitive products in a make-to-order context, decide to pool delivery resources rather than acting individually. In this case, the delivery can be outsourced to one of several third party logistics providers (3PL) (see [1, 2].e.g. when there is one manufacturer only).

The objective here is to design coordination mechanisms between the actors (the manufacturers and the 3PL). In supply chain scheduling research, few papers have considered collaborative game theory, where a solution is computed and the profits are shared between the actors, see e.g. [3, 5, 10]. Depending on whether or not it is possible/desirable to share money between the actors, we get the following two directions:

- *Coordination with cost sharing:* In the context of different actors, it may be difficult to compute in a centralized manner an optimal solution for the supply chain problem. One difficulty is that the different actors have all their own benefits and costs during the production process. A globally optimal solution may greatly disadvantage some of the actors. While this could be handled by computing the Pareto optimal solutions, there is another important aspect. There is a need to distribute the benefit of the overall production process to all the involved actors in a manner that will satisfy everyone. In particular, this means that a cost and profit sharing mechanism has to be designed, and needs to be considered during the optimization. This mechanism could be evaluated by comparing with the integrated production and delivery optimum, not taking into account the net benefit of each actor, and leads to a measure called the price of fairness by Berstimas et al. [4]. We may also consider decentralized optimization, by focusing on individual optimization under some benefit and cost sharing mechanism. Stable outcomes, which are pure Nash equilibria, will be evaluated by comparing their social cost with the centralized computed solutions, leading to a measure called price of anarchy [12, 9, 8]. We may focus on mechanisms that are simple to implement and have additional useful properties, such as truthfulness (see e.g. [5] in the supply chain context).
- *Coordination without transferable money:* When several actors have their own objectives, and when it is not possible or not desirable to share the profit between these actors, cooperative game theory cannot be used. However, cooperation may still be desirable and useful for all the actors. One way that has recently be explored for scheduling and matching problems is to design algorithms that compute an overall solution that is of globally good quality (for a considered social cost) while its cost for each actor is at most the cost he would have without cooperating (in the best solution he could have alone). It is then interesting to analyze the gain that can be obtained by each actor in such a solution. We can also analyze the loss in performance due to the fact that the actors are selfish: we can analyze the quality of the solutions returned compared with the quality of an optimal solution for this social cost (in this solution some actors may have a cost higher than if they were alone). We could also design an algorithm that computes solutions acceptable by all the actors and in which each actor decreases its cost in a fair

way (we may for example calculate if it is possible that each actor decreases its cost of a certain factor). This approach has been considered for scheduling problems when the actors are organizations that own tasks and machines [6, 7], but it has not, to our best knowledge, been used in supply chain scheduling.

Finally, notice that the research can take advantage of collaborations (and even co-supervising) with other colleagues from LAMSADE (the new transversal project members) and other French and European universities (Mines Paris Tech and Univ. of Sienna).

References

- [1] A. Agnetis, M.A. Aloulou, and L-L. Fu. Coordination of production and interstage batch delivery with outsourced distribution. *European Journal of Operational Research*, 238(1):130 – 142, 2014.
- [2] A. Agnetis, MA Aloulou, L-L. Fu, and M.Y. Kovalyov. Two faster algorithms for coordination of production and batch delivery. *European Journal of Operational Research (under revision)*, 241(3):927 – 930, 2015.
- [3] T. Aydinliyim and G. L. Vairaktarakis. Coordination of outsourced operations to minimize weighted flow time and capacity booking costs. *Manufacturing & Service Operations Management*, 12(2):236–255, 2010.
- [4] D. Bertsimas, V. F. Farias, and N. Trichakis. The price of fairness. *Operations research*, 59(1):17–31, 2011.
- [5] X. Cai and G. L. Vairaktarakis. Coordination of outsourced operations at a third-party facility subject to booking, overtime, and tardiness costs. *Operations Research*, 60(6):1436–1450, 2012.
- [6] D. Cordeiro. *The impact of cooperation on new high performance computing platforms*. PhD thesis, Université de Grenoble, 2012
- [7] P.-F. Dutot, F. Pascual, K. Rzadca, and D. Trystram. Approximation algorithms for the multiorganization scheduling problem. *Parallel and Distributed Systems, IEEE Transactions on*, 22(11):1888–1895, 2011.
- [8] L. Gourvés, J. Monnot, and O. Telelis. Strategic scheduling games: Equilibria and efficiency. In R. Z. Rios-Mercado and Y. A. Rios-Solis, editors, *Just-in-Time Systems*, Springer Optimization and Its Applications, pages 209–244. Springer New York, 2012.
- [9] L. Gourvés, J. Monnot, and O. A. Telelis. Selfish scheduling with setup times. In *Internet and Network Economics*, pages 292–303. Springer, 2009.
- [10] N. G. Hall and Z. Liu. Capacity allocation and scheduling in supply chains. *Operations Research*, 58(6):1711–1725, 2010.

- [11] C. Kille and M. Schwemmer. Top 100 in european transport and logistics services 2013/2014. 2013.
- [12] E. Koutsoupias and C. Papadimitriou. Worst-case equilibria. In *Proceedings of the 16th Annual Conference on Theoretical Aspects of Computer Science*, STACS'99, pages 404–413, Berlin, Heidelberg, 1999. Springer-Verlag.
- [13] A. Palmer, M. J. Saenz, T. V. Woensel, and E. Ballot. Characteristics of collaborative business models. 2012.