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COORDINATION AND VALUE OF INFORMATION IN A DECENTRALISED PRODUCER-DISTRIBUTOR SUPPLY CHAIN

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Synopsis

- We analyse the coordination and the value of information in a decentralised production-distribution supply chain. The impact of sharing two vital pieces of information of this supply chain (SC) – (i) production capacity and (ii) resource constraint – are examined with an example from a coal supply chain.
- Our aim to define the value of information and then study the impact of it in designing a coordination mechanism for a decentralised SC.
- The value of the information is computed using a decentralised algorithm developed on the based of an iterative Lagrangian relaxation (LR) algorithm.

Background problem - Coal supply chains

- Several independent mines are connected to a common terminal by a single rail operator.
- Each mine has to complete a set of delivery 'jobs' before their due dates. A job is a portion of the cargo that needs to be moved by a certain train type from a mine to the terminal. Each job requires a certain train type that is provided by the rail operator from a finite pool of trains.

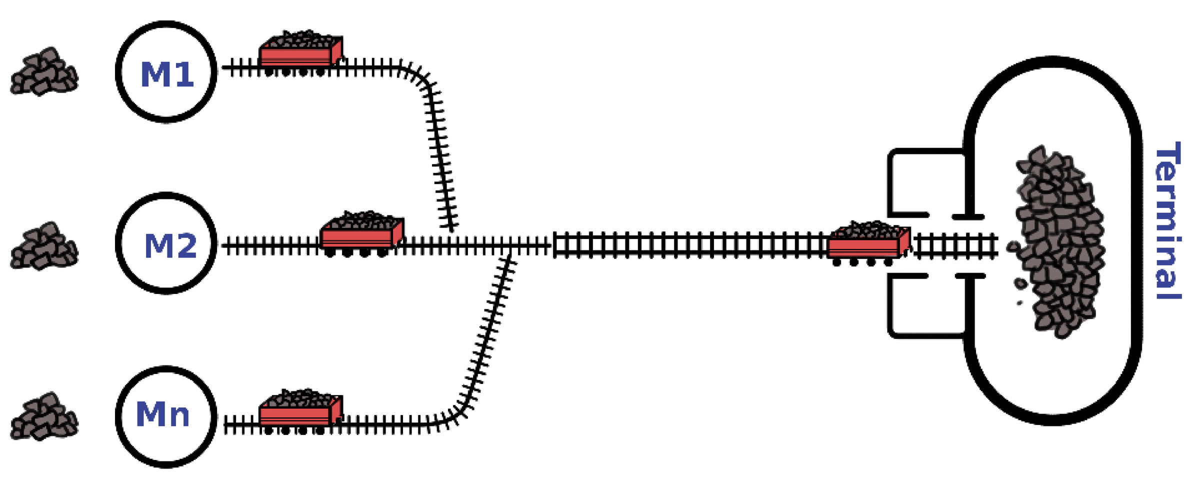


Figure: Schematic diagram of coal mines and terminal network

Decentralised Supply Chain Coordination (DSCC)

Global supply chain consists of many independent decision-making units (DMUs) in different geographical locations and are "naturally" decentralised in its nature.

Decentralised models Models can be decentralised in operational or decision-making level.

Coordination It is commonly seen as joint decision-making, joint operations, agreements, strategies etc.

- Decentralised decision-making and coordination of DMUs are explored to reduce the complexity and size of the centralised model.

Main components of DSCC

1. Decisions makers and decisions For example, production plan, train allocation and train scheduling are the major decisions in the above coal supply chain. The train allocation can be done by the rail operator or the mines.
2. Information sharing Production capacity and train availability are two vital informations.
3. Multiple objectives The objective of the mine is to minimise the total cost and the objective of the rail operator is to minimise total running time and the total weighted tardiness and earliness.
4. Coordination mechanism Different coordination mechanisms can be designed based on the level of information sharing and different grouping of decisions. It can be iterative or sequential.

Value of information sharing

We define the value of information (VoI) as a relative ratio of the performance measure (utility) both with and without sharing information. For example, the value of information 'a' w.r.t. lower bound (LB) is,

$$\mathcal{V}_{LB}(a) = \frac{LB_{no\_info} - LB_{with\_info}}{Best(LB_{no\_info}, LB_{with\_info})}$$

where LB_{no_info} = Best LB computed without sharing information 'a' and LB_{with_info} = Best LB computed with sharing information 'a'.

- The VoI is analysed for different performance measures such as the lower-bound, upper-bound, relative gap, number of iterations, run time.

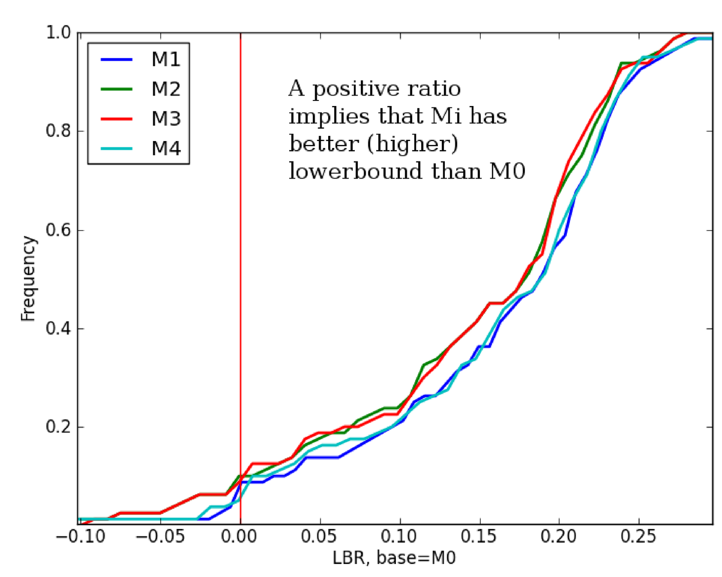
Decentralised solution approaches

- Thomas et al.(2013)[1] proposes a decomposed solution algorithm using the LR. This framework is extended to a decentralised scenario.
- The traditional LR / a decomposed centralised approach has centralised coordinating player/agent to compute the lower bound (LB) and the upper bound (UB) in each iteration.
- We propose a *truly* decentralised approach where the LB is computed using a *secure-sum* (Singh & O'Keefe(2013)[2], Clifton et al.(2002)[3]) method and the UB is computed using decentralised heuristics.
- We analyse the impact of two sections of information in a decentralised modelling environment using the following versions.

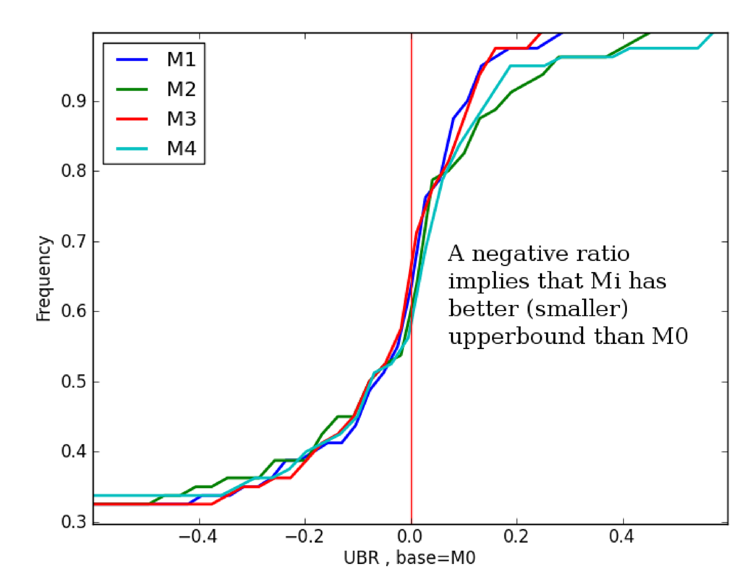
Version	Information sharing	Production capacity	Resource constraint
M0	Centralised model		
M1	Complete	Shared	Shared
M2	No	Not shared	Not shared
M3	Partial	Shared	Not shared
M4	Partial	Not shared	Shared

Computational experiments - results

Cumulative frequency comparison w.r.t. M0

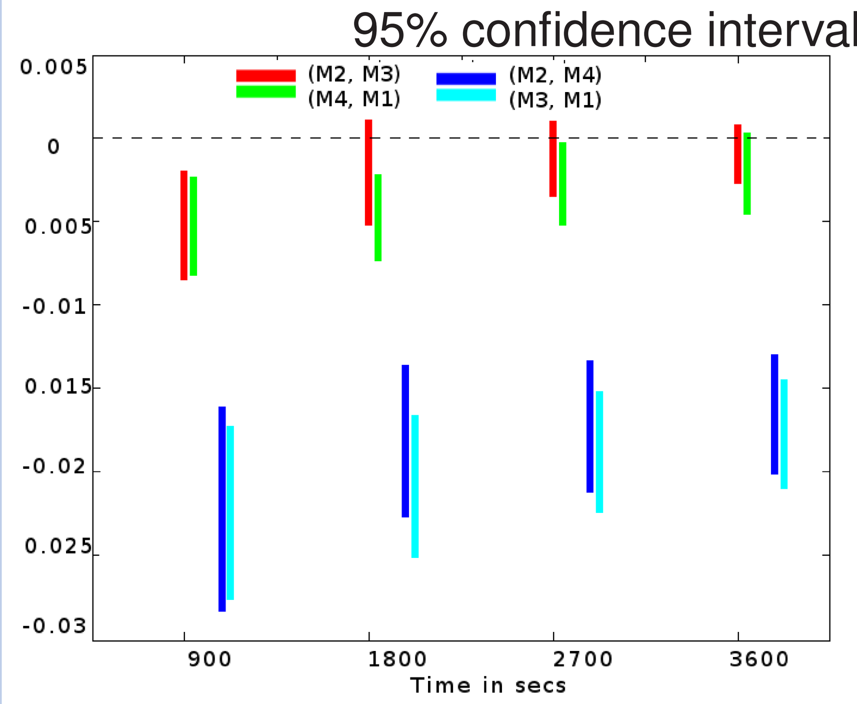


(a) Lower bound - LBR

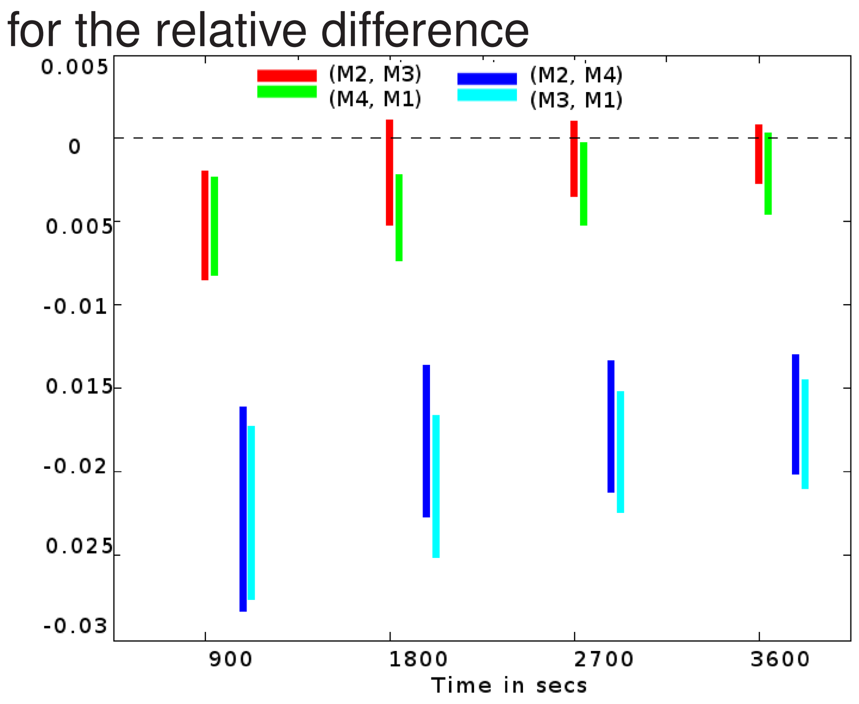


(b) Upper bound -UBR

95% confidence interval for the relative difference



(c) Lowerbound



(d) Upperbound

Summary and conclusions [4]

The comparison of (M2, M3) and (M4, M1) is used to observe the impact of production capacity and the comparison of (M2, M4) and (M3, M1) is for the resource availability.

- ✓ The decentralised models outperform the centralised in 90% of the instances in LBR comparison. More than 50% of data instances shows that the improvement is more than 20%.
- ✓ M3 and M2 have better lower bound in this overall comparison. M1 and M3 have better upper bound.
- ✓ The results shows that the lower bounds of the iterative algorithm can be significantly improved by sharing necessary information.
- ✓ The overall comparison using the confidence intervals shows that resource availability information is more critical than production capacity information.
- ✓ The performance measures obtained at different time points show the gradual change in the behaviour.

References

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