Editorial

Operations research methods in maritime transport and freight logistics

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The current decade has witnessed a remarkable growth in container transportation and vessel sizes. This has come alongside an increasing need for optimisation of both on the seaside and on the landside. As the linking nodes, container terminals are facing great challenges in handling, stacking and transferring large numbers of containers, and high productivity is the key factor in maintaining terminal competitiveness.

At the same time, terminals' major customers demand reliability and efficiency at low costs. The changes that have taken place in the liner shipping industry require terminal operators and logistics service providers to continuously improve their performance and guarantee seamless operations. In particular, the increasing integration of container supply chains and the consequent higher vulnerability of the chains to disruptions in container flows and operations, place more pressure on controlling and improving the performance of the various segments of the chain.

Furthermore, additional pressure has been put on terminal operators with the current soaring of bunker prices. When fuel prices are high, vessels tend to use *slow-steaming* in order to cut on fuel costs and fast terminal handling becomes, therefore, even more crucial in maintaining vessel time schedules.

In these circumstances, and even more when terminal capacity becomes scarce and competition among carriers increases, it is natural to turn to operations research (OR) in search of better ways to optimise the use of (terminal) equipment and infrastructure.

It is thus not surprising that maritime logistics, a term coined by this Journal, is advancing as an independent discipline of particular interest for practitioners and academics alike within the OR and management science domains. In the literature, noticeable attention is devoted to the use of quantitative methods for container operations at marine terminals, and influential publications in these areas continue to appear in all major OR and management science journals. The terminal and shipping industries have not only offered the opportunity to apply established techniques and methods in an original way, but have also challenged researchers with new problems and, as technology evolved, have provided new incentives for research.

MEL has always looked at these developments with keen interest and it is increasingly publishing the work in this area. The opportunity for this special issue has been offered by the thirty eighth AIRO Conference on *Optimization and Decision Theory* that took place in Genoa, Italy, between 5 and 7 of September 2007. Conference papers were subjected to a double-blind review process. The best six papers were selected for inclusion in this special issue.

Optimisation of Container Supply Chains: The Terminal Link

The introduction of the container and the consequent development of intermodality have allowed the dramatic reduction in transportation costs and the increase of intercontinental cargo flows. The movement of each container is the result of a number of separate operations (loading, unloading, yard movements, hinterland transportation, gate clearance and so on) often entrusted to the expertise of different agents. More than 20 components can be identified in the container supply chain for a standard intercontinental move, and high levels of coordination are required to ensure the flow of millions of boxes every year. Increasingly, the responsibility of ensuring the seamless, efficient and low-cost movement of containers is entrusted by cargo owners and transport providers to logistics operators, freight forwarders or third-party logistics providers, who are expected to optimise the chain for the benefit of their customers.

The complexity of the supply chain and the necessity to customise it for every shipment and every shipper makes the job of logistics providers more of an art than a science. For this reason, attempting to formalise all decision parameters of the various agents involved in the container supply chain in a single OR model is far from realistic (and probably also of limited practical use) and this type of problems have been analysed in the literature through the use of economic models[1] or more general decision support systems.

Thus the formalisation of the optimisation of the *overall* container supply chain entails such a high level of complexity that discourages the use of OR techniques. The independent optimisation of individual supply chain components, however, has become increasingly common and a popular tool for the managers and operations officers. Although again this may not be equivalent to a joint optimisation, and may even generate results and recommendations that might be conflicting with each other, the value of these applications for operators and for the industry as a whole is immense.

We could ideally identify three major components of the (maritime) supply chain: the terminal component, the maritime component and the hinterland component. The terminal, in particular, is the crucial node in the maritime supply chain, as it acts as a buffer for the shipping line, being also the point

where containers are assigned to different modes of transport. In particular, although the role of terminals and ports may vary substantially from country to country, it is widely recognised that they have the potential of being driving forces in the supply chains. Increasing emphasis is presently given to the concept of port-centric logistics (Mangan *et al*, 2008). In this perspective, optimisation of the terminal node becomes particularly important. In addition, large capacity gains and substantial transit-time savings can be obtained from efficiency improvements and from the redefinition of the processes within the terminal. Short terminal handling times and reliability of operations are some of the characteristics mostly demanded from terminals.

It is impossible to manage a container terminal without its recourse to optimisation; to design liner-shipping networks without making use of route and ship planning techniques; or to deal with intermodal transportation without the help of simulation. *Maritime logistics* has become an essential aid for the decision-making process of operations managers and executive officers in all phases of the supply chain. It is the task of the management to make use of this aid in order to make decisions consistent with company objectives, priorities and strategies.

From the application and operation's point of view, typical problems discussed in the literature include ship planning and scheduling, for example, berth allocation, stowage planning, crane split, quay-yard movement optimisation, yard-gate movement optimisation and other problems related to hinterland transport.[2] The papers selected for this issue of *MEL* are representative of the major research streams discussed in the literature and essentially cover the most common problems arising in both transhipment and gateway marine terminals. From a purely methodological point of view, readers can find a wide spread of quantitative models and methodologies, ranging from mathematical programming techniques to simulation and data envelopment analysis.

Overview of the Papers

Moccia *et al* provide a clear review of the main optimisation problems in container terminals, such as yard and berth optimisation, and the various methods to solve them. Although the paper is applied to the container terminal of Gioia Tauro, it clearly illustrates the features and the typical problems arising in large transhipment terminals in general, which are surely of interest beyond the Mediterranean. Five problems are addressed and for each of them suitable solution algorithms are designed, tested and compared. For human resources management, both long-term and short-term planning are investigated and an efficient *ad hoc* branch-and-bound algorithm is proposed. The Berth Allocation

Problem is treated as a scheduling problem and a vehicle routing problem, respectively, and the two approaches are compared. Two algorithms: branch-and-cut and tabu search are tested for the Quay Crane Scheduling Problem. In terms of yard management, the authors aim at modelling-related problems both at tactical and operational levels. Finally, for straddle carrier routing and dispatching, scheduling-based models and a real-time assignment model are described. In all cases, the authors show interesting results, derived from real size instances that will certainly stimulate further research as well as practical use.

Another important aspect of terminal performance concerns about yard equipment optimisation. Canonaco *et al* focus on a more dynamic assignment of Rubber Tyred Gantry Cranes (RTGC). The paper analyses the yard flow of containers in Gioia Tauro, combining discrete event simulation techniques with the optimisation ones. By exploring various scenarios, the paper provides a useful evaluation tool to decide on the best policy for deploying yard cranes to meet a constantly changing yard system. In this way the paper constitutes an important contribution to the limited literature on RTGC managed yards.

Alessandri *et al* approach the terminal as the *interface* between the maritime component of the supply chain and the hinterland transportation component. The paper adopts a mixed-integer nonlinear programming approach and advocates the use of nonlinear predictive control to manage the intermodal flows of containers arriving to and departing from a three-berth medium-size container terminal in the north-west of Italy.

The remaining three papers provide OR applications from the container terminals located in the port of Genoa and in Liguria, one of the regions with the highest container gateway traffic in Italy. In particular, Parola and Sciomachen also focus on intermodal traffic and on the terminal interface. The paper proposes discrete event simulation techniques to reduce the modal split imbalances between rail and road at the Voltri Terminal Europe of Genoa. The paper is particularly interesting, not only because of the limited literature on the interface between the terminal and the hinterland connections, but also because it recommends an increase in the use of railways *versus* road transport.

The terminal–maritime interface of the supply chain is also the topic of Ambrosino *et al*. The paper focuses on the stowage bay planning problem and presents a heuristic, developed through case studies at the SECH terminal in Genoa. The application is interesting not only because stowage bay plan problems are NP-hard, but also because the approach proposed contributes to reducing terminal handling time in loading operations.

Finally, the Basta and Ferrari paper analyses the efficiency of the major container terminals in the port of Genoa. The paper proposes a terminal-concession model where concession fees are linked to terminal performance.

The model is tested against the current fees charged in the port of Genoa with respect to the efficiency of the eight terminals in Genoa and in other comparable ports in Italy. The efficiency evaluation is done by means of data envelopment analysis techniques with one output (annual container throughput in TEU) and three inputs (total terminal surface, quay length and maximum depth at quay).

Concluding Remarks

The above overview has provided an indication of the problems that are dealt by maritime logistics and of the contents of this special issue of *MEL*. In particular, the focus is on the important role that container terminals play as key links between the maritime and the hinterland components of the container supply chain. The approaches proposed in this issue emphasise the importance of optimisation of the various sub-processes and interfaces of the terminal, without neglecting the need for overall optimisation of the container supply chain.

We believe that this issue presents a stimulating and broad overview of a set of very relevant topics in maritime logistics, where the application of OR and management science techniques proves to be particularly appealing and fruitful. The papers presented not only draw from the existing OR theory, expanding existing methodologies and developing new approaches, but also complement the analysis with a broad spectrum of case studies, applications and examples drawn from the Italian container sector.

We owe special thanks to the referees and all authors for their contribution to this special issue of *MEL* that we organised.

Notes

1 See Nagarajan and Sošić (2008) and Cachon and Netessine (2004) for an example of supply chain coordination.

2 A detailed review of the major problems discussed in the domain of maritime logistics at terminals is provided by Stahlbock and Voß (2008).

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