

## The dry port concept – Theory and practice

*Maritime Economics & Logistics* (2012) **14**, 1–13. doi:10.1057/mel.2011.14

### Background

Driven by the long-term stimulus of increasing worldwide trade and globalisation, the international freight transport industry thrives on continuous change and development, as reflected in managerial, regulatory and technological innovations within the sector. For container ports, in particular, the dynamic nature of such an environment has been most acutely felt in terms of considerable increases in the size of containerships (Cullinane and Khanna, 1999, 2000; Imai *et al.*, 2006), the rationalisation of cargo handling operations in pursuit of greater efficiency (Cordeau *et al.*, 2001; Imai *et al.*, 2001; Zhang *et al.*, 2002; Kim and Moon, 2003; Park and Kim, 2003; Vis and Koster, 2003; Christiansen *et al.*, 2004; Guan and Cheung, 2004; Hansen *et al.*, 2008; Cullinane, 2010), the devolution of port governance (Brooks and Cullinane, 2007) and the need to reorient the marketing of port services for strategic positioning within inherently competitive supply chains, rather than simply within essentially captive hinterlands (Robinson, 2002).

For the most part, the container port industry itself and the agencies (both governmental and otherwise) which influence its performance, have responded in a most positive and successful manner to this constantly changing environment and the challenges it poses; international trade has continued to expand virtually unabated, despite the many occurrences of congestion and bottlenecks in and around ports that must interfere with the pace of what is otherwise an inexorable trend. It is inevitably the case, however, that the development of transport corridors and associated infrastructure to facilitate access to ports lags behind the response of the ports themselves to the difficulties they are sometimes faced with. In addition, the availability of sufficient container storage space within ports is a matter of significant concern, especially for those ports in traditional locations – close to, or even within, suburban or urban areas.

For facilitating the future evolution of container ports, therefore, it is crucially important that a viable solution is found that overcomes the potential multifaceted conflicts which may exist between the need for capacity expansion, environmental considerations, community restrictions (not least those



imposed by the geography of a port) and the continued embedding of freight transport and logistics functions within integrated supply chains. One prospective solution that is emerging more and more often, both in practice and as an identifiable field of research in the relevant literature, is the 'dry port' concept.

As originally conceived, a 'dry port' was defined as an inland terminal to and from which shipping lines could issue their bills of lading, with the concept being initially envisaged as applicable to all types of cargo (UNCTAD, 1982). In both theory and practice, however, the concept has evolved not only to be closely associated with the rapid expansion of containerisation and related changes in cargo handling (UNCTAD, 1991), but also to be applied in a variety of different contexts having the common characteristic of relating simply to 'a place inland that fulfils original port functions' (Cullinane and Wilmsmeier, 2011). As a consequence, usage of the term 'dry port' has become rather vague, with numerous different definitions appearing in the literature (see, for example, Cardebring and Warnecke, 1995; UN ECE, 1998; Lévêque and Roso, 2002; Jaržemskis and Vasiliauskas, 2007; Beresford, 2009; Roso *et al.*, 2009; UNESCAP, 2009). In contrast, there does seem to exist a common understanding that the successful implementation of the 'dry port' concept will have the joint effects of lessening congestion, alleviating pressure on storage space and reducing handling operations in port, as well as delivering lower transaction costs to shippers (Padilha and Ng, 2011).

Cullinane and Wilmsmeier (2011) have aligned port development and, specifically, the 'dry port' concept to the Product Life Cycle (Kotler and Armstrong, 2004). In their exposition, where a port has evolved to attain the *maturity* phase, the space required for container storage and other port-related activities approaches, and eventually encounters, either a physical constraint on further expansion, or possibly a competitive constraint from other activities and land use in areas adjacent to the port. It is for this reason that much investment during the maturity stage of the port development cycle focuses on the rationalisation of port services, as well as on process innovations primarily aimed at capacity effects (for example, conversion to more effective storage technologies), particularly as land becomes a scarce commodity and commands premium prices or rents. The argument continues that ports enter the *decline* phase of the Product Life Cycle once the point has been reached when the limits to feasible rationalisation, investment and access are reached and it is then that port activity reduces. At this point, the supply of port capacity becomes fixed, since neither further expansion of the physical port area nor any other efficiency gains are possible. With an inevitable increase in the level of congestion within the port, market share is lost to competing ports with overlapping hinterlands and this soon manifests itself as declining throughput and sales volume.



In accordance with this alignment of port development to the Product Life Cycle (Cullinane and Wilmsmeier, 2011), the 'dry port' concept can be implemented to extend the product life cycle of a port; specifically, by elongating the *maturity* phase and deferring a port's entry into a state of *decline*. In consequence, any required expansion of a port is redirected from the seaward to an inland location (UNCTAD, 1991). Of course, for this to work, the 'dry port' option must be practically feasible, with available and suitable physical site locations and the appropriate means of connectivity to the port itself either already present or potentially implementable.

In the final analysis, however, it is the outcome of an economic appraisal of feasible capacity expansion alternatives which informs the ultimate decision taken (Bergqvist *et al.*, 2010). The implementation of the 'dry port' option may, thus, be justified purely and simply on the basis of the private profit motive, even to the extent that it becomes economically desirable before some of the more conventional approaches to capacity expansion are considered. While this might imply that the 'dry port' concept may be more relevant during periods of economic expansion or boom periods than during times of recession or depression, capacity expansion is not the only reason why the dry port concept might be implemented (Bergqvist and Woxenius, 2011). There are also benefits in terms of accessing the existing hinterland, expanding a port's hinterland and the capturing of cargo closer to source and/or further up the supply chain. It is also reasonable to recognise, however, that on some occasions, the economic case may require the receipt of some form of subsidy (for example, large infrastructure grants are sometimes available from public sector authorities and agencies) and that, of course, there also certain sets of circumstances where there exists no realistic level of subsidy that will prompt the adoption of the concept (Bergqvist *et al.*, 2010).

In order to provide a suitable forum for disseminating the current state-of-the-art in dry port theory and practice, but also with the intention of gaining a common understanding of the definition of the term 'dry port', the *South-East of Scotland Transport Partnership* and the *Transport Research Institute* at Edinburgh Napier University jointly organised the 'Dryport Conference' in Edinburgh in October 2010. The event formed an integral part of a multinational project partly funded under the European Union's Interreg IVb North Sea Region programme and to which the glitterati of the 'dry port' world were invited to deliver their perspective. Although, unsurprisingly, no consensus was arrived at on a definition of the term 'dry port', numerous interesting and illuminating papers were presented on both the theory and practice of 'dry port' implementation. This Special Issue presents just some of the excellent papers to emerge from that conference.



## Content of the Special Issue

In terms of private sector developments of dry ports in practice, there are perhaps several motives underpinning ECT's investments in dry port projects in Venlo, Duisberg and Willebroek (Cullinane and Wilmsmeier, 2011). In the first of the papers in this Special Issue, Veenstra *et al* (2011) suggest, however, that the major prompt for ECT's actions was the unpredicted and unprecedented surge in demand in all the ports of the Hamburg-Le Havre range in 2004/2005, on the back of a steep rise in Europe's trade with China and the resulting congestion which emerged. This was particularly acutely felt at the port of Rotterdam.

As an innovative response to the problems being faced, the authors describe the implementation within ECT's Rotterdam operation of what is referred to as the 'Extended Gate' concept, whereby a container terminal operator might unilaterally and independently push blocks of containers back into hinterland locations without the involvement of other interested third parties. Although the authors go to some effort to distinguish the 'Extended Gate' concept from the more generic 'dry port' concept, the existing literature on the topic and the contents of most of the papers delivered at the Edinburgh Dryport Conference in 2010 would suggest that the term 'dry port' covers an extensive range of potential configurations, including the specific form of an 'Extended Gate'. As the authors provide evidence for, however, the 'Extended Gate' concept, certainly as applied by ECT, can be considered to lie at one end of the 'dry port' continuum of possible configurations.

Following a detailed description of ECT's implementation of its 'Extended gate' concept, the authors provide us with their vision of hinterland networks into the future. This vision encompasses the selective development of preferred transport and logistics hubs within port hinterlands that share common, though as yet undefined, characteristics; not least of which is their direct connection to one or more seaports. The authors assert that it is the location and connectivity of these hinterland hubs that will define the strategic freight transport network within Europe, with seaports becoming intimately bound to these networks in order to move cargo into the hinterland, primarily by barge and rail. The possible impacts of this emergent strategic freight network within Europe are described as being: a reduction in road freight transport into and out of ports; the loss of value-added logistics activities from seaport locations and the reversion of seaports to focusing solely on port-related activities; the relocation of many ancillary activities back into the hinterland – most critically, customs clearance and; greater externalities (particularly, congestion and pollution) occurring in and around the inland location of hinterland hubs.



The authors go on to finally suggest that whether this vision ultimately comes to fruition will depend upon the future decisions and actions of both logistics practitioners and policymakers. For instance, the efficiency of hinterland terminals will need to be improved to a level expected from terminals in a seaport; local governance structures in hinterland hub locations should be fit for the purpose of meeting the challenges that will arise; administrative systems for freight cargoes should be pushed back further along the supply chain – possibly even to the countries of origin of shipments and; novel business partnerships between terminal operators and multimodal transport service providers will need to be facilitated by changes to the legislative environment so that greater flexibility and integration can be provided within the multimodal hinterland network.

Iannone (2011) presents an analysis of container logistics within the Southern Italian region of Campania. Its main focus lies with import and export container movements between the coastal seaports of Naples and Salerno and the inland dry ports at Nola and Marcianise. The analysis involves the development of a comprehensive and large-scale linear programming model of the spatial network under scrutiny, given the assumption of capacitated transshipment. The objective function is specified as the minimisation of aggregate generalised logistics costs, defined as comprising transportation costs (by both road and rail), terminal handling and storage costs, customs control costs, in-transit inventory holding costs and container leasing costs. As such, this equates to the objectives and perspective of a generic multimodal operator that takes its own decisions with respect to hinterland container transport and other logistics choices.

In converging to an optimum network solution, the model yields simultaneous solutions to: (a) the optimal routing of import and export containers throughout the hinterland, including distinguishing between full and empty containers and identifying appropriate transshipment locations; (b) the associated subsidiary problem of allocating demand to infrastructure nodes within the network (that is seaports, dry ports and other inland nodes); (c) estimating modal split between rail and road flows and; (d) determining whether customs clearance takes place at dry port or seaport locations.

The outcomes from the model point to several shortcomings in port-hinterland container logistics within the Campania region, such as low utilisation rates on existing railway capacity linking seaports and dry ports, high container dwell times at the port of Naples because of customs-induced congestion and the general dearth of modern customs and intermodal procedures. The author suggests, however, that the numerical solution to the model also provides direction as to how to improve upon current performance levels. In particular, he advocates that Campania's existing dry ports should be developed as extended gates of



the regional seaport system, following a similar development path to that of Rotterdam as described in the previous paper by Veenstra *et al* (2011). Although the author asserts that the potential savings from rerouting customs clearance activities from the region's ports to its dry ports are significant, he also recognises that improved customs facilitation at dry ports will be of little help as long as railway connections between seaports and dry ports remain inadequate.

The outcomes from the model lead the author to conclude that rail and dry port capacity utilisation needs to be improved through the imposition of more streamlined regulation and by better organisation and administration, all of which should be supported by logistics marketing initiatives that disseminate the improvements achieved. All of these recommendations clearly have implications for political leaders in the region. In addition, the answer to the question of how they are to be implemented, if at all, will depend upon the nature of the existing governance structure underpinning logistics provision within the Campania region and whether the appropriate incentives exist to prompt the taking of such decisions by either the public or private sector players. What is predictable, however, is that any improvement in capacity utilisation will obviously mean a reduction in aggregate logistics costs, but will also bring with it associated benefits such as the mitigation of the environmental impact of logistics in the region and increased local value-added and employment.

There is ample and obvious evidence that China's container ports have developed dramatically in the past two decades as a response to rapidly increasing demand for Chinese exports. However, inland transport and other logistics costs are high and there exists significant pressure, as well as the political will, to improve matters so that the economic benefits of China's container trade are extended to all parts of the country, not just the areas in and around the nation's major ports. There are also obvious implications for both national and port competitiveness. As such, China is proving to be a dynamic and fertile arena for the implementation of the dry port concept where, as attested to in the paper by Beresford *et al* (2011), they are used primarily as 'extended gates' through which flows can be better managed (Roso and Lumsden, 2010).

On the basis of considerable evidence collected through a variety of different means, Beresford *et al* (2011) classify existing dry port developments in China into three spatial categories – 'Seaport-based', 'City-based' and 'Border-based' and go on to provide detailed case studies of specific dry port locations within China that are representative of each of the three categories. As might be expected, the authors' analysis reveals that different dry ports in China are at different stages of development, as determined by their core functions and institutional expectations. Perhaps what is more surprising is that, whatever the stage of their development, this paper is generally critical of the dry port concept as implemented in China, with the case study analysis revealing numerous



problems and inefficiencies within the sector. The most damning assertion is that, in many cases, shippers are actually very reluctant to use dry ports; suggesting, therefore, that China's dry port operations are simply failing to fulfil the role or potential for which they were established.

As an outcome of their case-study analysis, the authors attribute the ultimate *raison d'être* for this performance malaise on the inadequacy of the governance and regulatory framework within which China's dry ports have to operate. More specifically, they are critical of the current institutional arrangements whereby: (a) responsibility for planning, operating and regulating inland intermodal transport systems is fragmented between three central government ministries, each of which operates independently and has a different role and priorities and; (b) local government has considerable autonomy to interpret central government policy decisions according to local need. The authors conclude that, given the current variations in institutional structures and the way that they operate in practice, central government intervention has become necessary in order to systematise the policy framework within which dry ports are operated and developed and to implement universally applied standards in governance. They envisage this involving the establishment of an overarching coordinating and regulatory institution or body and the development of an associated comprehensive regulatory framework for dry port development. All of which is predicated, of course, upon the development of a precise, easily interpreted and legally recognised standard definition of what constitutes a 'dry port'; one of the fundamental problems alluded to in an earlier part of this introduction.

The next paper in this Special Issue focuses on Brazil, another of the world's fastest developing economies. Similar to the Chinese context addressed in the previous paper, Padilha and Ng (2011) suggest that it is also the case in Brazil that the role of dry ports goes far beyond simply providing a route to greater port competitiveness by improving hinterland access. In support of the work of Do *et al* (2011), Ng and Tongzon (2010) and UNESCAP (2006), they point out that the political and economic significance of dry ports to the promotion of regional integration and development is also of critical importance within the context of developing economies.

Setting the scene with a review of port development theory and basing their analysis on archival research and in-depth interviews with key stakeholders, Padilha and Ng (2011) analyse the spatial evolution of dry ports in the state of Sao Paulo. Their specific focus rests with relating and linking the current spatial configuration of the state's dry ports to the parallel evolution of the major port of Santos. Their pivotal finding is that the spatial pattern of port development implied by accepted theory may vary significantly from the practice in Brazil and, by imputation, in other developing countries; where key



phases in the established evolution of ports may be observed to be poorly developed and/or to occur late, out of sequence or even not at all. In the specific case of Brazil, the authors identify the relative absence of intermodal systems (particularly involving the use of rail), the continuous concentration of freight flows within ports (particularly at Santos) and the de-concentration of flows through inland freight facilities (particularly dry ports) as manifestations of this phenomenon.

In seeking to explain their fundamental finding that port evolution within the state of Sao Paulo has deviated from what might be expected from established theory, Padilha and Ng (2011) argue that institutional inefficiencies are pervasive within the developing economy context and have led to this distortion of expected outcomes in the case of Brazil. As such, they reaffirm the conclusions of the preceding paper by Beresford *et al* (2011) and the previous work of Garnwa *et al* (2009), Ng and Cetin (2011), Ng and Tongzon (2010) and Ng and Gujar (2009), all of which suggest that institutional factors are pivotal to dry port performance within the developing economy context. In order to eliminate the institutional inefficiencies which exist within the state of Sao Paulo, the authors advocate: (a) the implementation of integrated planning – though do not go so far as to suggest that this should be centralised; (b) greater clarity in regulations to incentivise infrastructure investment and; (c) new legislation to encourage collaboration between ports and dry ports and the efficient use of inland logistics infrastructure in order to reap both economic and environmental benefits. At the same time, it is explicitly acknowledged that, particularly within the developing economy context, such key changes in policy are likely to prove difficult to implement (if not impossible) in the face of what the authors themselves refer to as ‘entrenched vested interests and political forces’.

Again addressing the particular problems of a rapidly developing economy, the focus of the final paper in this Special Issue is dry ports in India, by Haralambides and Gujar (2011). This geo-political context, however, is very different from that which applied to the two previous studies. In India, a recent deregulatory shift in government policy has resulted in what was intended – the positive promotion of private sector participation in dry ports and the railway sector. This has prompted the injection of significant new investment capital into the dry port sector, the immediate short-term effect of which has been a surfeit of surplus supply over and above what is demanded in the market. This is a situation that, of course, places considerable pressure on prices in what is a highly competitive market and, ultimately, this phenomenon will become reflected in the bottom lines of the organisations involved.

The current disequilibrium in the market is clearly unsustainable and, inevitably, the market mechanism will come into play to ensure a resolution is arrived at. The detailed evolution of the marketplace in terms of which of the



current participants will actually continue to survive into the long-term future and with what market share, will be largely a function of the relative operational efficiency of each of the market players. The authors suggest that the particular nature of production and operations associated with any industry will relate very closely to the definition of efficiency which should be applied and that, in the specific case of dry port operations, this should cater equally for intangible factors as it does for the more obvious tangible aspects. Thus, they advocate that the inevitable, but undesirable, 'negative output' of carbon emissions from the productive activities of dry ports should also be taken into consideration in any evaluation of efficiency within the sector; a view supported in the research undertaken by Growitsch and Wetzel (2009).

In pursuit of this objective, the paper describes the empirical estimation of the efficiency of dry ports in the North Capital Region of India using data covering the period 2006–2009. The widely accepted technique of Data Envelopment Analysis is chosen as the preferred approach to the empirical application but, in line with the recommendation of Dyckhoff and Allen (2001), is further refined to account for the associated complexity of the 'negative output' of carbon emissions from the sample of dry ports. As the authors themselves suggest, therefore, the efficiency scores that are derived really represent some measure of *social* or *eco-efficiency*.

On the basis of their empirical analysis and in stark contrast to conventional approaches, the authors conclude that their proposed *eco-model* provides decision makers with unequivocal and transparent information on the efficiency effects of carbon emissions and allows them to assess the direct efficiency effect of ameliorative actions on emissions. As environmental impacts gain greater emphasis in logistics decisions, it is certainly the case that this capability is becoming increasingly important. This is particularly the case as greater recognition is given to the potential of 'green-gold' solutions for the industry, whereby actions taken (and investments made) to reduce environmental damage can exert a positive influence on sales figures, especially through the appropriate marketing of 'green credentials'. As a final aside on this issue, from a methodological perspective, establishing and dealing with any prospective functional relationship which may be hypothesised to exist between both desirable and undesirable outputs (in any dynamic context for efficiency estimation) brings its own modelling challenges that, while not insurmountable, can hardly be described as trivial.

A second major conclusion of the paper is that the pursuit of technical efficiency cannot be unconstrained and that environmental impacts and consequences also need to be taken into consideration within India's dry port operations. There are important implications of this for the governance of the sector. The authors propose, for example, that given their fundamentally social,



rather than commercial, objectives, the public sector dry port operators in India should be leading on environmental initiatives. However, the government has not provided them with any such remit, objectives or incentives. Since they are competing head-to-head with private sector dry ports that are intent on profit maximisation and cost minimisation, it is difficult to envisage how this might even be attempted in the absence of any greater stringency in environmental regulation and while national economic development through a strategy of export-led growth remains a priority.

## Conclusions

Although no clear consensus has been produced as to an unequivocal definition of a 'dry port', the content of this Special Issue does highlight the diverse range of possible 'dry port' scenarios, with the 'extended gate' form emerging as the ultimate manifestation of the 'dry port' concept. Most importantly, the content also reveals a number of key common features of 'dry port' development:

1. With the exception of the pure 'extended gate' version of the concept, a 'dry port' does not necessarily have to be initiated, controlled, owned and/or operated by the port(s) to which it is linked.
2. There is scope for both private and public sector involvement in all aspects of 'dry port' development and implementation, with most applications in practice exhibiting quite significant degrees of public-private cooperation, collaboration or even partnership.
3. Depending on the objectives of the entity that is driving the initiative, the justification for 'dry port' development may be purely financial (profit maximisation) or economic (social welfare maximisation). However, in both cases, environmental considerations are exerting an increasing influence and are becoming an important *raison d'être* for the implementation of the 'dry port' concept; hence, the focus on intermodal solutions in most of the literature, including this Special Issue.
4. Irrespective of the extent of its direct involvement, government has a role to play in formulating appropriate policy and regulatory controls to both foster and facilitate suitable 'dry port' developments, while delivering on environmental goals.
5. The success or failure of 'dry port' projects can be commonly attributed to the inadequacy of policy and/or regulatory regime and/or to the existence of institutional barriers, which prevent the efficient and effective operation of a 'dry port'.



Ultimately, however, it is apparent that the 'dry port' concept will continue to evolve as it is increasingly applied across the globe as a response to the challenges facing contemporary logistics in general, and ports and their hinterlands in particular.

## Acknowledgement

The authors would like to express their gratitude to the European Union's Interreg IVb North Sea Region programme for providing the co-funding which has underpinned the 'Dryport' project, and which has allowed the 'Dryport Conference' in Edinburgh in October 2010 to take place. As editors of this Special Issue, we certainly feel that the success of that conference is self-evident in the quality of the papers selected for inclusion herein.

## References

- Beresford, A. (2009) Dry ports: A comparative study of the UK and Nigeria. Paper presented at the *International Forum on Shipping, Ports and Airports*, Cardiff, UK.
- Beresford, A., Pettit, S., Xu, Q. and Williams, S. (2011) A study of dry port development in China. In: K.P.B. Cullinane, R. Bergqvist and G. Wilmsmeier (eds.) *Maritime Economics and Logistics*, Special Issue on Dryports 26: 73–98.
- Bergqvist, R., Falkemark, G. and Woxenius, J. (2010) Establishing intermodal terminals. *International Journal of World Review of Intermodal Transportation Research (WRITR)* 3(3): 285–302.
- Bergqvist, R. and Woxenius, J. (2011) The development of hinterland transport by rail – The story of Scandinavia and the Port of Gothenburg. *Journal of Interdisciplinary Economics* 23(2): 161–177.
- Brooks, M.R. and Cullinane, K.P.B. (eds.) (2007) *Devolution, Port Governance and Port Performance, Research in Transportation Economics*, Vol. XVII. Amsterdam: Elsevier.
- Cardebring, P.W. and Warnecke, C. (1995) *Combi-terminal and Intermodal Freight Centre Development*. Stockholm, Sweden: KFB-Swedish Transport and Communication Research Board.
- Christiansen, M., Fagerholt, K. and Ronen, D. (2004) Ship routing and scheduling: Status and perspectives. *Transportation Science* 38: 1–18.
- Cordeau, J.-F., Laporte, G. and Mercier, A. (2001) A unified tabu search heuristic for vehicle routing problems with time windows. *Journal of the Operational Research Society* 52: 928–936.
- Cullinane, K.P.B. (2010) Revisiting the productivity and efficiency of ports and terminals: Methods and applications. In: C. Grammenos (ed.) *Handbook of Maritime Economics and Business*. London: Informa Publications, pp. 907–946.
- Cullinane, K.P.B. and Khanna, M. (1999) Economies of scale in large container ships. *Journal of Transport Economics and Policy* 33(2): 185–208.
- Cullinane, K.P.B. and Khanna, M. (2000) Economies of scale in large containerhips: Optimal size and geographical implications. *Journal of Transport Geography* 8(3): 181–195.
- Cullinane, K.P.B. and Wilmsmeier, G. (2011) The contribution of the dry port concept to the extension of port life cycles. In: J.W. Böse (ed.) *Handbook of Terminal Planning, Operations Research Computer Science Interfaces Series*, Vol. 49. Heidelberg, Germany: Springer, pp. 359–380.



- Do, N.H., Nam, K.C. and Ngoc Le, Q.M. (2011) A consideration for developing a dry port system in Indochina area. *Maritime Policy and Management* 38(1): 1–9.
- Dyckhoff, H. and Allen, K. (2001) Measuring ecological efficiency with data envelopment analysis (DEA). *European Journal of Operational Research* 132: 312–325.
- Garnwa, P., Beresford, A. and Pettit, S. (2009) Dry ports: A comparative study of the UK and Nigeria. *UNESCAP Transport and Communications Bulletin for Asia and the Pacific* 78: 58–81.
- Growitsch, C. and Wetzel, H. (2009) Testing for economies of scope in European railways: An efficiency analysis. *Journal of Transport Economics and Policy* 43(1): 1–24.
- Guan, Y. and Cheung, R.K. (2004) The berth allocation problem: Models and solutions. *OR Spectrum* 26(1): 75–92.
- Hansen, P., Oguz, C. and Mladenevic, N. (2008) Variable neighborhood search for minimum cost berth allocation. *European Journal of Operational Research* 191(3): 636–649.
- Haralambides, H. and Gujar, G.C. (2011) On balancing supply chain efficiency and environmental impacts: An eco-DEA model applied to the dry port sector of India. In: K.P.B. Cullinane, R. Bergqvist and G. Wilmsmeier (eds.) *Maritime Economics and Logistics*, Special Issue on Dryports 16: 122–137.
- Iannone, F. (2011) A model optimizing the port-hinterland logistics of containers: The case of the Campania region in Southern Italy. In: K.P.B. Cullinane, R. Bergqvist and G. Wilmsmeier (eds.) *Maritime Economics and Logistics*, Special Issue on Dryports 40: 33–72.
- Imai, A., Nishimura, E. and Papadimitriou, S. (2001) The dynamic berth allocation problem for a container port. *Transportation Research B* 35(4): 401–417.
- Imai, A., Nishimura, E., Papadimitriou, S. and Liu, M. (2006) The economic viability of container mega-ships. *Transportation Research E* 42(1): 21–41.
- Jarżemskis, A. and Vasiliaskas, A.V. (2007) Research on dry port concept as intermodal node. *Transport 2007 XXII*(3): 213.
- Kim, K.H. and Moon, K.C. (2003) Berth scheduling by simulated annealing. *Transportation Research B* 37: 541–569.
- Kotler, P. and Armstrong, G. (2004) *Principles of Marketing*, 10th edn. Upper Saddle River, NJ: Pearson Education.
- Lévêque, P. and Roso, V. (2002) Dry port concept for seaport inland access with intermodal solutions. Master's thesis, Chalmers University of Technology, Gothenburg.
- Ng, A.K.Y. and Cetin, I.B. (2011) Locational characteristics of dry ports in developing economies: Some lessons from Northern India. *Regional Studies*, (forthcoming).
- Ng, A.K.Y. and Gujar, G.C. (2009) Government policies, efficiency and competitiveness: The case of dry ports in India. *Transport Policy* 16(5): 232–239.
- Ng, A.K.Y. and Tongzon, J.L. (2010) Transportation improvements as a catalyst for regional development in India: The role of dry ports. *Eurasian Geography and Economics* 51(5): 669–682.
- Padilha, P. and Ng, A.K.Y. (2011) The spatial evolution of dry ports in developing economies: The Brazilian experience. In: K.P.B. Cullinane, R. Bergqvist and G. Wilmsmeier (eds.) *Maritime Economics and Logistics*, Special Issue on Dryports 23: 99–121.
- Park, Y.M. and Kim, K.H. (2003) A scheduling method for berth and quay cranes. *OR Spectrum* 25: 1–23.
- Robinson, R. (2002) Ports as elements in value-driven chain systems: The new paradigm. *Maritime Policy & Management* 29(3): 241–255.
- Roso, V. and Lumsden, K. (2010) A review of dry ports. *Maritime Economics and Logistics* 12(2): 196–213.
- Roso, V., Woxenius, J. and Lumsden, K. (2009) The dry port concept: Connecting container seaports with the hinterland. *Journal of Transport Geography* 17(5): 338–345.
- UNCTAD. (1982) Multimodal transport and containerisation. TD/B/C.4/238/Supplement 1, Part Five: Ports and Container Depots. Geneva: United Nations Conference on Trade and Development.



- UNCTAD. (1991) *Handbook on the Management and Operation of Dry Ports*. Geneva: United Nations Conference on Trade and Development.
- UN ECE. (1998) UN/LOCODE – *Code for Ports and Other Locations*. Recommendation 16, Geneva.
- UNESCAP. (2006) *Promoting Dry Ports as a Means of Sharing the Benefits of Globalization with Inland Locations*. Bangkok: UNESCAP Committee on Managing Globalization, E/ESCAP/CMG (3/1)1.
- UNESCAP. (2009) *Development of Dry Ports*. Bangkok: UNESCAP Transport and Communications Bulletin for Asia and the Pacific.
- Veenstra, A., Zuidwijk, R. and van Asperen, E. (2011) The extended gate concept for container terminals: Expanding the notion of dry ports. In: K.P.B. Cullinane, R. Bergqvist and G. Wilmsmeier (eds.) *Maritime Economics and Logistics*, Special Issue on Dryports 19: 14–32.
- Vis, I.F.A. and Koster, R.D. (2003) Transshipment of containers at a container terminal: An overview. *European Journal of Operational Research* 147: 1–16.
- Zhang, C., Wan, Y., Liu, J. and Linn, R.C. (2002) Dynamic crane deployment in container storage yards. *Transportation Research B* 36(6): 537–555.

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