Int. J. Production Economics ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

ICT in multimodal transport and technological trends: Unleashing potential for the future

Irina Harris *, Yingli Wang [1], Haiyang Wang

Logistics and Operations Management, Cardiff Business School, Cardiff University, Aberconway Building, Column Drive CF10 3EU, UK

ARTICLE INFO

Article history:
Received 24 July 2013
Accepted 3 September 2014

Keywords:
ICT
Multimodal transport
Barriers to ICT adoption
Technological trends
Cloud computing
Internet of Things

ABSTRACT

The role of information and communication technologies (ICTs) in freight transport as key enabler is well recognised. However the uptake of recent ICT advances for multimodal freight transport provisions in the UK and Europe has been slow. The aim of our paper is to explore the potential reasons for such a slow adoption and assess how recent technological advances such as cloud computing and Internet of Things might have changed the landscape and thus help to overcome these barriers. Via an extensive review of 33 EU framework programme projects, we are able to consolidate and present current major efforts in ICT developments in the freight multimodal transport setting at European level. We further discuss barriers inhibiting quick take-up of ICT applications in multimodal transport. Resolutions were then explored by reviewing four key ICT development trends recently emerging and evaluating their potential impact in reducing such barriers for deployment. Our contribution is two-fold: it advances current knowledge by presenting an up-to-date overview of existing and emerging ICT applications in the field of multimodal transport and barriers to e-enabled multimodal transport. It also captures some of the best practices in industry and aims to provoke a debate among practitioners and academics via the analysis of how innovative use of recent technological developments could potentially lower the barriers to multimodal ICT adoption and lead to a more integrated freight transport network. Therefore it lays the foundation for further research.

1. Introduction

Growing environmental problems, increasing fuel price and congestion on many road networks require new solutions to freight transport operations. An integrated multimodal transport network is a critical factor for companies to successfully execute their supply chain processes both domestically and internationally. However, the complex nature of multimodal integration, for instance the involvement of a wide variety of operators can limit the growth of multimodality. One of the major constraints is the lack of effective and efficient information connectivity among and between various modes (water, air, road and rail).

Meanwhile, it is well recognised that information and communication technology (ICT) functions like the nerve system of a multimodal transport chain and brings multiple benefits to organisations by providing real-time visibility, efficient data exchange, and better flexibility to react to unexpected changes during shipment (Durr and Giannopoulos, 2003; Coronado et al., 2009; Gunasekaran and Lenny Koh, 2009; Perego et al., 2011; Prajogo and Olhager, 2012). Recent developments in the field of ICT such as cloud computing, social networking and wireless communication have further revolutionised the ways information is shared and supply chains are structured.

In the UK, the Digital Economy Act was published in April 2010 which outlines the United Kingdom Government's strategic vision for its digital economy. Recognising the transformational impact of digital technologies on aspects of community life, future society, and the economy, the Technology Strategy Board launched, in May 2011, an initiative aimed at accelerating the formation of the "Internet of Things" ecosystem of applications and services. As part of this initiative, the impact of Internet of Things for Transport has been examined via expert workshops which one of the authors was invited to attend (May 2011). Those expert workshops explored challenges within the transport industry that could be addressed through creative use of the Internet of Things and what needs to be done nationwide to achieve this (Technology Strategy Board, 2011). Subsequently priorities identified include development of new user-centric methodologies, managing big data, visualisation and augmented reality, service-oriented architectures across future networks.

Despite the aforementioned benefits and strong government promotion, the uptake of recent technological advances for multimodal transport provisions in the UK and Europe has been slow

* Corresponding author. Tel: +44 29 20874447.
E-mail addresses: HarrisI1@cardiff.ac.uk (I. Harris), WangY14@cardiff.ac.uk (Y. Wang), wanghaiyang@live.co.uk (H. Wang).
[1] Tel.: +44 29 20875066.

http://dx.doi.org/10.1016/j.ijpe.2014.09.005

(Huckridge et al., 2010, Perego et al., 2011, Marchet et al., 2012). The aim of this paper is to explore the potential reasons for such a slow adoption and assess how recent technological advances might have changed the landscape and thus help to overcome these barriers. The contribution of this paper therefore is two-fold: it advances current knowledge by presenting an up-to-date overview of existing and emerging ICT applications in the field of multimodal transport and barriers to e-enabled multimodal transport. It also captures some of the best practices in industry and aims to provoke a debate among practitioners and academics via the analysis of how innovative use of recent technological developments could potentially lower the barriers to multimodal ICT adoption and lead to a more integrated multimodal freight transport network, and hence lays the foundation for further research.

Our paper is mainly conceptual but a wide source of secondary data has been utilised in order to improve the validity of our analysis. An overview of the characteristics of multimodal transport is presented in Section 2 followed by a discussion of the research methods deployed in the paper in Section 3. The classification and discussion of recent ICT developments in multimodal transport are presented in Section 4. Section 5 discusses the barriers to ICT adoption in general, as well as for multimodal transport referring to both academic publications and exemplar EU projects. Section 6 tackles how recent technological developments could help reduce those barriers. Four types of merging technological trends are identified and analysed, which represent key trends in ICT developments. As those developments have only emerged recently and are still in their infancy stage, their potential application to the management of multimodal transport has not been fully explored, either in practice or by academics. We articulate our viewpoints under this section in a forward-looking fashion to invite further debate or validation from both practitioners and academia. Section 7 links technological trends to "Big Data" and decision support systems for managing multimodal transport. In Section 8 we subsequently evaluate the impact of technological trends on barriers related to the ICT adoption and finally, Section 9 concludes the paper and provides recommendations for future research.

2. Multimodal transport

Multimodal transport refers to the transportation of goods by two or more different modes of transport (such as road, rail, air or inland waterway, and short- or deep-sea shipping) as part of the contract where often a multimodal transport operator (MTO) is responsible for the performance of the entire haulage contract from shipping to destination (UN, 1980). The movement of goods could be within one country or international with additional procedures such as goods clearance at customs. Fig. 1 illustrates the whole international transport process where goods are moved from a country A to final destination in country B and the involvement of MTO during their journey. Its aim is to transfer goods in a continuous flow through the entire transport chain to make a transportation journey more efficient from a financial, environmental and time perspective (Beresford et al., 2006; Chao, 2011; SteadieSeifi et al., 2014). With the massive growth in containerisation and the great shift in thinking from a conventional unimodal to a system concept multimodal transport approach, multimodal is currently the main method used in the international transportation process as it enables the optimisation and organisation of all transport modes into an integrated continuous system in order to achieve operationally efficient and cost-effective delivery of goods in the supply chain.

Multimodal transport is often used interchangeably with terms such as intermodal, co-modal and synchromodal transport. But there are subtle differences between those terms; multimodal is considered as a type of transportation which uses at least two different modes of transport; intermodal can be seen as a particular type of multimodal transportation that uses the same loading unit (e.g. a TEU container), co-modal adds the efficient use of different modes (resource utilisation) and synchromodal emphasises the real-time aspect of the transport (SteadieSeifi et al., 2014; UN/ECE, 2001). In our paper we use the term multimodal in a broad sense, however other terms are also used occasionally in the context when we refer to specific works in the literature or to highlight the differences discussed above.

A combination of different features of each transport mode could place additional constraints on goods during transportation such as packaging, transportation conditions and storage. On the other hand, multimodal combines the specific advantages of each mode in one voyage, such as the flexibility of road haulage, the relatively large capacity of railways and the lower costs of short/deep-sea transport in the best possible way (Zaheer, 2008). Moreover, in comparison with road transport, which plays a relatively dominant role in the traditional freight transport industry in the UK, several alternative modes of transport, such as rail, inland waterway and short sea shipping, are widely recognised as being less harmful to the environment with regard to CO_2 emissions (Eng-Larsson and Kohn, 2012; Woodburn and Whiteing, 2012). Therefore, due to the advantage of multimodal transport as well as the increasing pressures to act on climate change through the reduction of carbon emissions, government studies have put more emphasis on transport mode shifts and the development of multimodal transport systems. For example, the European Commission proposes several measures aimed at developing a European transport system capable of shifting the balance between modes of transport and encouraging the use of multimodal transport (EC, 2011).

As well as having multiple characteristics of each mode, an added complication is the management of the whole seamless multimodal transportation process which is complex and involves different players such as freight forwarders, third-party logistic service providers, couriers, carriers of different modes of transport,

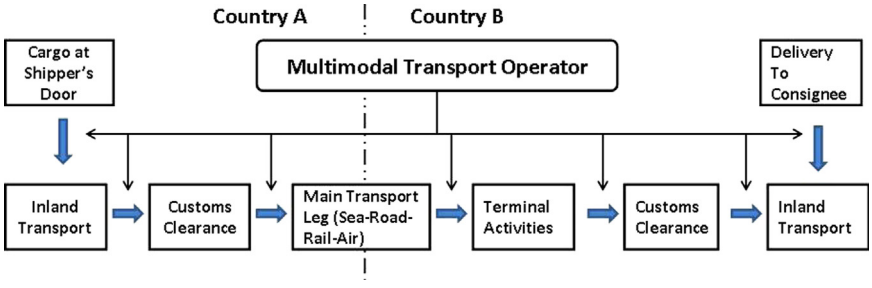

Fig. 1. Goods flow in a typical international multimodal transport chain.
Source: Chao 2011

Please cite this article as: Harris, I., et al., ICT in multimodal transport and technological trends: Unleashing potential for the future. International Journal of Production Economics (2014), http://dx.doi.org/10.1016/j.ijpe.2014.09.005