Virtualisation of floricultural supply chains: A review from an Internet of Things perspective ☆

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ABSTRACT

Supply chains are increasingly virtualised in response to market challenges and to opportunities offered by nowadays affordable new technologies. Virtual supply chain management does no longer require physical proximity, which implies that control and coordination can take place in other locations and by other partners. This paper assesses how the Internet of Things concept can be used to enhance virtualisation of supply chains in the floricultural sector. Virtualisation is expected to have a big impact in this sector where currently still most products physically pass through auction houses on their fixed routes from (inter)national growers to (inter)national customers. The paper defines the concept of virtualisation and describes different perspectives on virtualisation in literature, i.e. the organisational, team, information technology, virtual reality and virtual things perspectives. Subsequently it develops a conceptual framework for analysis of virtualisation in supply chains. This framework is applied in the Dutch floriculture to investigate the existing situation and to define future challenges for virtualisation in this sector.

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1. Introduction

The floricultural sector in the Netherlands is of world-class quality, and serves as main trading hub for Europe. It is internationally renowned as a strong cluster (Porter, 1998). The sector has a big impact on the Dutch economy (Berkhout and Roza, 2012; PT, 2013). It is the largest exporter of fresh-products in Europe and belongs to the top-3 largest exporter in the world with still significant opportunities for further growth (CBI, 2008a,b; van der Vorst et al., 2012). Despite the current leading position, the sector needs to look forward and innovate to stay in the lead.

In floriculture currently most products physically pass through auction houses on their fixed routes from (inter)national growers to (inter)national customers. Physical presence of goods seems to be still necessary to allow for physical inspection, quality control and break-bulk activities. However, it is now widely accepted in the sector that virtualized supply chains are an important answer to challenges posed by the markets and the opportunities offered by nowadays affordable new technologies (van der Vorst et al., 2012; Verdouw et al., 2012). In such virtual supply chains, planning, orchestration and coordination are based on virtual representations of physical products and resources, enabled by new information and communication technologies. The actors responsible for planning, orchestration and coordination are not necessarily the ones handling and observing these physical objects. They can be at total different locations. As a consequence, virtualized networks enable the decentralization or decoupling of physical flows from (centralized) planning, orchestration, and coordination taking place in other locations and by other partners. As a result future chains might by-pass current actors and aim for shorter more responsive routes from grower to end consumer.

Virtualisation has been an important topic in research already for a long time. Traditional research streams in particular focus on virtual machines (e.g. Goldberg, 1974), virtual reality (e.g. Steuer, 1992), virtual organisations (e.g. Davidsow and Malone, 1992) and virtual teams (e.g. Townsend et al., 1998). More recently, the virtualisation of physical objects as digital representations has received much interest, in particular due the emergence of the Internet of Things concept (IoT). In the IoT, physical entities have digital counterparts and a virtual representation; things themselves become context aware and they can sense, communicate, interact, exchange data, information and knowledge (Guillemin and Friess, 2009). We believe that the introduction of virtual objects as a central means for planning, orchestration and coordination has the potential to revolutionize supply chains. However, available literature on virtual Supply Chain Management (SCM) is mainly considering virtualisation from an organisational perspective, for

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example Chandrashekar and Schary (1999), Ho et al. (2003), Gunasekaran and Ngai (2004) and Manthou et al. (2004). In this perspective, virtual supply chains are dynamic and digitally connected organisational structures that temporally bring together resources of different organisations to better respond to business opportunities. To the best of our knowledge it is not yet researched how the virtualisation of physical objects in the Internet of Things (IoT) can impact SCM practices.

This paper aims to contribute to this gap by assessing how the IoT concept can enhance virtualisation of supply chains in the floricultural sector. This sector is an highly instructive example because it is currently making major progress in the virtualisation of transactions, including remote auctioning, and in the virtualisation of logistics processes. More specifically, the paper aims to analyse the existing situation and to define future challenges.

The paper is structured as follows. It first defines the concept of virtualisation and describes main perspectives identified in literature on virtualisation. Subsequently the paper develops a conceptual framework for analysis of virtualisation in a supply chain context. Next, the paper presents the existing situation concerning the virtualisation of supply chains in the Dutch floriculture. This analysis focusses on the enabling role of Information and Communication Technologies. The paper concludes with the main future challenges concerning supply chain virtualisation in the floricultural sector.

2. Research method

The research is carried out as part of the DaVinc³i project in close interaction with the involved business partners, which represent the majority of the Dutch sector, including auction, traders, growers and industry associations (van der Vorst et al., 2012). The research was organised in four steps: (i) definition study, (ii) development of a framework for analysis, (iii) investigation existing situation and (iv) definition of future challenges.

The research started with a definition study based on literature review. There is much confusion about the concept of virtuality because it is applied in many domains and consequently it is used in different meanings. The definition study has therefore identified the main perspectives on virtualisation in literature and subsequently it defined virtual supply chains from a virtual things perspective.

The next step was the development of a conceptual framework, i.e. a systematic classification of concepts for analysis of virtualisation in a supply chain context. This framework for analysis comprises three parts. The first part is an object system definition, which is a conceptual view of the object of research, i.e. virtual supply chains. The model was developed by reviewing SCM literature from a general systems perspective. The second part is a basic information systems architecture for enabling virtual supply chains, which was derived from the IoT literature. The third part is a definition of key themes within this architecture that can be used to analyse the existing situation regarding the Information and Communication Technologies (ICT) that enable virtualisation in floriculture.

The subsequent research step was an investigation and analysis of the existing situation (i.e. between Q3 2011 and Q2 2012) concerning the virtualisation of supply chains in the Dutch floriculture. We first conducted an in-depth desk research that identified and described a list of virtualisation practices in floriculture (see Appendix). The results were reviewed and completed in unstructured interviews with key industry experts. In total 30 interviews were conducted with 35 experts with the following roles: 9 traders, 3 auction staff, 9 growers, 7 service providers (software vendors and consultants) and 7 experts from industry associations.

The analysis was based on the framework discussed above and focussed on the enabling role of ICT in virtualisation.

Last, main future challenges for the virtualisation of floricultural supply chains were defined. This was done by the team of the Da Vinc3i project by a synthesis of the investigation results.

The remainder of the paper introduces the results following the research steps as described above.

3. Perspectives on virtualisation in literature

3.1. Basic notions on virtualisation

The concept of virtualisation has been used as a compelling catchphrase to describe the revolutionary impact of ICT on business processes, organisations and society (Crowston et al., 2007). Basically, the word "virtual" contrasts with "real" or "physical", which implies having the essence or effect without a real-life appearance or form (World English Dictionary). Virtualisation is used in reference to digital representations of real or imaginary real-life equivalents. As such, virtualisation removes fundamental constraints concerning:

- *Place*: virtual representations do not require geographic presence, i.e. physical proximity, to be observed, controlled or processed.
- *Time*: besides the representation of actual objects, virtualisation can reproduce historical states, simulate future states or imagine a non-existing world.
- *Human observation*: virtual representations can visualise information about object properties (such as temperature information or X-rays) that cannot be observed by the human senses.

Although dealing with the same basic concept, virtuality has been applied to different domains and the concept has been used in different meanings and with different focuses. The main perspectives as apparent in literature will be discussed in the following sections.

3.2. Virtual organisation perspective

The term 'virtual organisation' or 'virtual enterprise' became popular in the 1990s to characterise the development towards dynamic organisational structures that temporally bring together resources of different organisations to better respond to business opportunities (Davidsow and Malone, 1992; Goldman et al., 1995; Venkatraman and Henderson, 1998). It can be seen as a consequence of the focus of companies on core competences (Prahalad and Hamel, 1990). End customers can only be served by the collaboration between independent companies that form a network of complementary resources, i.e. a virtual organisation.

More recently the network perspective of virtual organisations is stressed by using terms such as virtual networks or virtual supply chains (Chandrashekar and Schary, 1999; Ho et al., 2003; Gunasekaran and Ngai, 2004; Manthou et al., 2004). Virtual networks are formed on-the-fly during business operations based on a selection of capabilities and enabled by flexible inter-organisational information systems (Vervest et al., 2004; Grefen et al., 2009). Basically, the underlying concepts are the same as at virtual enterprises or virtual organisations. However, the focus slightly differs since the emphasis is in particular on the rapid (re)construction of supply chain configurations that plan, coordinate, execute, monitor and control the business processes required to achieve a specific value proposition at a specific moment in time. Consequently, in virtual networks a dynamic variety of chain processes, connecting