Expert Systems with Applications 41 (2014) 195–209

Contents lists available at ScienceDirect

Expert Systems with Applications

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

Acquiring logistics process intelligence: Methodology and an application for a Chinese bulk port

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ARTICLE INFO

Keywords:
Logistics process
Process mining
Knowledge discovery
Logistics process intelligence

ABSTRACT

The processes of logistics service providers are considered as highly human-centric, flexible and complex. Deviations from the standard operating procedures as described in the designed process models, are not uncommon and may result in significant uncertainties. Acquiring insight in the dynamics of the actual logistics processes can effectively assist in mitigating the uncovered risks and creating strategic advantages, which are the result of uncertainties with respectively a negative and a positive impact on the organizational objectives.

In this paper a comprehensive methodology for applying process mining in logistics is presented, covering the event log extraction and preprocessing as well as the execution of exploratory, performance and conformance analyses. The applicability of the presented methodology and roadmap is demonstrated with a case study at an important Chinese port that specializes in bulk cargo.

1. Introduction

Logistics is an industry consisting of process-oriented businesses that focuses on managing the flow of resources, both material and abstract resources, between the point of origin and the point of destination (Chow, Choy, & Lee, 2007; Langley & Holcomb, 1992). Special attention is being paid to achieve the best comparative net value for the customer. This can be observed in the efforts to optimize the processes, improve the availability or guaranteeing timely and consistent deliveries. Research has also demonstrated that the logistic operations of the service providers remain highly human-centered processes and demonstrate high degrees of flexibility and complexity, which commonly results in a series of uncertainties (Myers, Griffith, Daugherty, & Lusch, 2004).

Standard operating procedures in the form of business processes are commonly set up by logisticians in order to control the operations and maintain a satisfactory level of service. However, research has demonstrated the existence of a discrepancy between the procedures encoded in the designed processes and the actual executions of the processes (Chow et al., 2007). This discrepancy might result in serious operational risks. As highly knowledge driven organizations (Chow, Choy, Lee, & Chan, 2005; Huang, 2009), logistic companies could benefit from acquiring a full insight in the actual process executions in order to enable logisticians to improve and revise the designed processes. Several contributions have indicated the potential value of process knowledge as a strategic asset for logistics organizations (Arvis, Mustra, Panzer, Ojala, & Naula, 2007; Law & Ngai, 2008; van der Aalst, van Hee, van der Werf, Kumar, & Verdonk, 2011). These contributions describe how competitive advantage could be achieved by enhancing process transparency, improving the logistics performance and strengthening the internal control of the logistics firms. This implies the following question: how to extract process knowledge?

Contemporary logistics information systems record detailed information about the events happening in the environment. These events are occurrences of importance in the context of logistics management, e.g. the arrival of a certain ship. Consequently, the collection of events, i.e. the event log, contains an untapped reservoir of knowledge about the logistics processes. Process mining refers to the set of techniques that analyzes these event logs to acquire insights into the real business processes (van der Aalst & van Dongen, 2002; van Dongen & van der Aalst, 2004). Therefore, process mining can be considered as a set of techniques suitable for acquiring knowledge from the real-world logistics processes.

This paper contributes to the literature on logistics process intelligence by:

- Providing intelligence support for logisticians using a variety of process mining techniques that enable knowledge discovery within specific logistics processes. This results in a focused analysis leading to recommendations for logistics process improvement.

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http://dx.doi.org/10.1016/j.eswa.2013.07.021

- Proposing a comprehensive methodology for process mining in logistics that fits well with logistics processes.
- Elaborating on an extensive case study at an important Chinese bulk port.

The paper is structured as follows: Section 2 provides the state of the art of logistics intelligence and process mining techniques as well as the motivation for process mining in logistics, followed by the introduction of the methodology in Section 3 and the extensive elaboration of the case study in Section 4. Section 5 provides the discussion and future work. Finally, Section 6 concludes the paper.

2. Logistics processes & process mining: motivation & state of the art

Logistics can be considered as a process that is highly human-centric with large diversity, complexity, and flexibility. This creates the need for knowledge acquisition in the specific context of logistics processes. In this respect, process mining offers a promising way to provide logistics intelligence supporting process improvement.

2.1. Typical characteristics of logistics processes

The typical characteristics of logistics processes are investigated and identified as follows:

- Logistics is a highly human-centered process (Myers et al., 2004) with high dynamics. Most decisions in the logistics processes are made by human experts with different kinds of practical experiences (Chow et al., 2005, 2007). For example, in the cargo handling process of a bulk port, a particular batch of bulk coal may either be weighed or not depending on the personal experience of the logisticians. As a result, it is very often the case that unexpected events such as human errors can occur (Brown, 2001; Chow et al., 2007). This creates the large dynamics in logistics processes which brings about the necessity for using the various logistics documents to record the human behavior in the process.
- The logistics processes show large diversity. Persistent variation of logistics has been recognized in a volatile economic and social system that necessarily varies in time and space (Hall, 2004). Moreover, continuous service innovation is needed for building unique service capability calling for new customized logistics services so as to satisfy the customer preferences effectively (Chapman, Soosay, & Kandampully, 2003; Flint, Larsson, Gammelgaard, & Mentzer, 2005). The increasing variety of logistics services produces the large diversities in the logistics processes as well as the process knowledge heterogeneity among different logistics firms.
- The logistics processes demonstrate a high degree of complexity. Logistics is a business known for its inherent complexity. (Hofer & Knemeyer, 2009; Huang, 2009; Rao & Young, 1994). For example, port logistics is subdivided into Port Entry System, Stevedore System, Transit System, Storage System and Linkage System (Roh, Lalwani, & Naim, 2007). The complex internal organization and the considerable number of stakeholders involved in international shipping give rise to the complexities of the port logistics processes.
- Flexible processes are needed in a dynamic market or shipping environment. Flexibility is seen as one of the primary factors which have a strong, positive, and direct impact on logistics competence and capability due to the uncertainties in the environment (Choy et al., 2008; Closs, Goldsby, & Clinton, 1997; Naim, Potter, Mason, & Bateman, 2006; Zhang, Vonderembse, & Lim, 2005). For example, a ship may change its destination port because of changes in the weather conditions even after scheduling the ship.
- Logistics is a process that creates value (Mentzer, Rutner, & Matsuno, 1997; Rutner & Langley, 2000). Logistics represents a bundle of resources that can create customer value through the integration of logistics activities (Langley & Holcomb, 1992). Hence, the logistics strategy should be directed towards relevant value-added logistics activities (Bichou & Gray, 2004).

2.2. Logistics intelligence & process mining techniques

Logistics intelligence covers the set of techniques that seek to improve the logistical operations with their abilities to reduce the uncertainties and risks in logistics (Moore, 1990). The topic of constructing logistics intelligence has received a lot of attention recently (Jedermann & Lang, 2008). Various intelligent technologies such as radio frequency identification (RFID) (Chow et al., 2007; Klein & Thomas, 2009; Lee, Ho, Ho, & Lau, 2011; Wen, 2010) and multi-agent techniques (Chow et al., 2007; Davidsson, Henesey, Ramstedt, Törnquist, & Wernstedt, 2005; Gallay & Hongler, 2009) are widely applied in logistics systems to provide real-time knowledge support for the logisticians (Siror, Huanye, & Dong, 2011). As an intangible strategic resource, knowledge can be exploited towards superior logistics performance and competitive advantages enabling logistics intelligence (Hult, Ketchen, Cavusgil, & Calantone, 2006; Law & Ngai, 2008). This highlights the value of acquiring knowledge from logistics operations in practice.

Process mining aims at extracting information from event logs to capture the business process as it is being executed (van der Aalst, 2004). By extracting process knowledge based on facts, additional insights into the real process behavior are obtained by analyzing and mining the structured information on previous process executions, which is recorded in the event logs of (different) information systems. Process mining has received a vast amount of research attention resulting in a plethora of techniques, e.g. process discovery techniques (Goedertier, Martens, Vanthienen, & Baesens, 2009; van der Aalst, 2004), techniques for the analysis of event log data (van der Aalst, De Beer, & van Dongen, 2005; van der Aalst & Song, 2004), techniques for trace classifications (Ferreira, 2009), process metrics (Dijkman, Dumas, van Dongen, Käärik, & Mendling, 2011) and specific application areas (Günther & van der Aalst, 2007; Jans, van der Werf, Lybaert, & Vanhoof, 2011).

Typically these techniques allow for viewing the same reality from three distinct aspects of process models:

- Firstly, the control-flow perspective that deals with both the existence of certain process elements (e.g. activities) and the ordering in which these process elements can occur.
- Secondly, the organizational perspective that focuses on the analysis of the organization behind the business process. Consequently, the key question is "who performed which process elements".
- Thirdly, the case data perspective that represents the information elements which are produced, used or manipulated during the process.

Therefore, process mining provides a promising way to acquire insights into the real dynamics in logistics by discovering knowledge from the logistics processes (Chun et al., 2011; van Dongen & van der Aalst, 2004). While existing research has been carried out on the application of process mining in logistics for discovering knowledge in the supply chain network (Gerke, Claus, & Mendling, 2009; Lau, Ho, Zhao, & Chung, 2009) and for constructing compressed workflows to capture the general trends of the logistics processes (Gonzalez, Han, & Li, 2006), study of contemporary