

# Situation Awareness for Improved Operational Control in Cross Docks: An Illustrative Case Study

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**Abstract:** This paper presents research in progress aimed at developing a conceptual framework for operational control at cross docks. The proposed framework contributes to cross docking literature by including situation awareness as an important concept of operational control. The implications of the proposed conceptual framework are explored in an illustrative case study. That case study reveals that despite the availability of real-time and detailed information about the on-going operations, the ability to perform operational control is hampered by a lack of situation awareness. Therefore, this paper intends to start a debate about situation awareness in the academic cross docking community. This debate should focus on how to exploit the available information for providing the decision makers with the situation awareness necessary to perform effective operational control.

**Keywords:** Situation Awareness, Monitoring, Operational Control, Flexibility, Uncertain Dynamic Systems, Cross Docking, Transportation Control.

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## 1. INTRODUCTION

In recent years, transportation organizations have made considerable investments in IT that can capture vast amounts of information about on-going operations (Schumacher & Feurstein, 2010). An important driver for these investments is the expectation that the captured information is necessary for the detection of operational dynamics that may disrupt the execution of the transport operations as intended. Operational dynamics may cause unexpected events such as last-minute customer orders, truck break-downs, and traffic congestions. The information is captured to trigger and direct the decision making processes aimed at mitigating the negative performance impact of the operational dynamics. In this paper, these short-term decision making processes aimed at the control of on-going transport operations are referred to as *operational control*.

This paper presents research in progress aimed at developing a conceptual framework for operational control in cross docks. Cross docking is a logistics strategy where the transshipment of loads, such as containers, pallets, or parcels, is performed with little or no intermediate storage. Typically, less-than-truckload logistics providers adopt a cross docking strategy with the purpose of obtaining economies in transportation costs by consolidation of multiple smaller-sized loads to full truck loads (Apte & Viswanathan, 2000). A significant sector within the cross docking industry is represented by road-freight transportation, where cross docking is encountered in hub and spokes networks. In these networks, cross docks serve as intermediate nodes exclusively dedicated to the transshipment of loads.

The conceptual framework proposed in this paper contributes to cross docking literature by including situation awareness as an important concept of operational control. Intuitively, situation awareness can be defined as “*knowing what is going on*” (Wickens, 2008). In an attempt to develop a more formal definition, Endsley (1995) made a distinction between three levels of situation awareness: perception, comprehension, and projection. *Perception* is related to noticing the status, attributes, and dynamics of relevant elements in the operating environment. *Comprehension* is related to a holistic overview of the operating environment based on a synthesis of disjoint perception information elements. *Projection* is related to the ability to project the future status, attributes, and dynamics of relevant elements in the operating environment.

Situation awareness is a concept that originated in human factors and ergonomics literature. In this literature, situation awareness is frequently discussed in the light of human-computer interaction in various highly dynamic and complex operating environments – especially those in which human decision making is time critical (Wickens, 2008). Despite the broad academic attention for situation awareness, the concept is not yet applied in a cross docking research context. This paper argues however, that the typical nature of operations at cross docks is well suited for applying the concept of situation awareness.

### 1.1 Research problem and motivation

Boysen et al. (2010) argue that efficient cross docking requires scheduling procedures to synchronize all transport and transshipment operations in the transportation network.

This paper focuses on the transshipment operations at cross docks. There, the scheduling procedures are focused on answering the question *where* and *when* to process trucks. In operations research literature the problem of where and when to process trucks is referred to as the *truck scheduling problem* (Boysen and Flidner, 2010). Within that area, considerable research effort focuses on formulating and solving truck scheduling problems for various highly context-dependent cross docking scenarios. A review of literature describing these research efforts can be found in Boysen and Flidner (2010) and Shakeri (2010).

The operational performance at cross docks is highly sensitive to dynamics in the environment. A wide stream of operations research is aimed at improving the quality of truck scheduling procedures to reduce that performance sensitivity by including absorptive capacity in the schedule. Even if a schedule includes sufficient absorptive capacity, this capacity has to be brought into use in order to mitigate the negative performance effects of operational dynamics (Tenhiälä, 2009). This can only be done during the execution of the cross docking operations – i.e. when the schedule is implemented. In real-world cross docking settings, human dispatchers are typically the ones responsible for this implementation. Based on the provided schedule and the current operational situation at the cross dock, the dispatcher can control the operations by quickly deciding where and when each truck is actually processed. The scope of the research presented in this paper is defined by the tasks concerning the implementation of the schedule and the related real-time decision making processes. Henceforth, this set of tasks and decisions will be referred to as *dispatching*.

As part of the research presented in this paper, a study of literature revealed little academic attention for the real-time decision making aspects of dispatching. This observation is in line with Boysen and Flidner (2010) who notice a lack of empirical studies focused on the implementation of schedules in real-world cross docking settings. However, as will be argued in this paper, the operational performance at cross docks is greatly influenced by the real-time decisions made by the dispatchers in order to control on-going transshipment operations.

The lack of discussion about this subject in the academic cross docking community brings a need for a preliminary conceptualization, in terms of a framework that places the relevant concepts in relation with each other. Such a framework could support reasoning about the challenges faced by dispatchers when implementing the truck schedules in real-world cross docks. To the best of our knowledge, no such framework exists thus far.

## 2. PROPOSED CONCEPTUAL FRAMEWORK

The conceptual framework proposed in this paper is based on previous work by Meyer (2011) on operational control in logistics. Six well-known concepts in the operational control of cross docks were identified and related to the concept of situation awareness. Figure 1 depicts the proposed framework which comprises the identified concepts and their relations. The framework assumes a highly dynamic operating

environment and implies that human dispatchers are responsible for performing operational control. It is also assumed that ample information about the operating environment – and the means to obtain it – are available. It is important to point out that the framework is a high level conceptualization of operational control and not a diagram depicting the flow of information used during that process. Although the information flows are an important aspect of operational control, an illustration of these flows is considered to be at a lower level of abstraction and therefore left outside the scope of the framework.

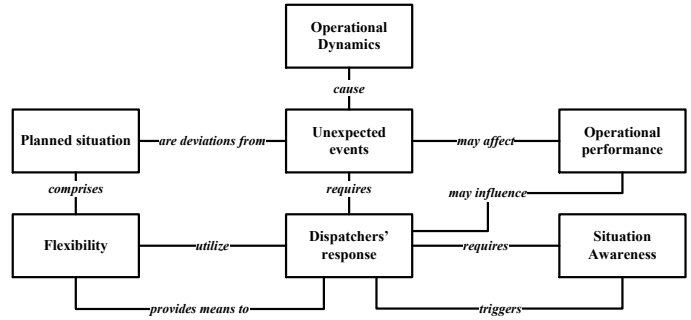


Figure 1: Conceptual framework for operational control at cross docks

To clarify the framework, the concepts and their relations are discussed next, by using typical examples from the cross docking field. *Operational dynamics* are considered to be the driving concept of the framework, as operational dynamics cause the actual operational situation to deviate from the *planned situation*. At cross docks, for example, the actual arrival times of trucks frequently deviate from the arrival times assumed by the schedule (Boysen and Flidner, 2010). If these deviations are predictable or known in advance, the dispatcher has sufficient time to respond and achieve effective operational control. However, a lack of perception and understanding about these deviations may result in events that are perceived as unexpected from the perspective of the dispatcher. These *unexpected events* may have a negative impact on *operational performance*. By definition, unexpected events appear to the dispatcher suddenly, and thus may require immediate response. Typically, operations are planned in such way that the planned situation comprises *flexibility* for such ad-hoc response (Tenhiälä, 2009). For example, an operational plan may comprise non-dedicated spots on the cross dock floor, which are intentionally left empty for unforeseen peaks in the number of loads to be processed. Utilizing the available flexibility in response to unexpected events is considered the main goal of operational control.

The complex and highly dynamic operating environment of cross docks make that unexpected events may occur frequently. In order to effectively respond to unexpected events, the dispatcher needs to get answers to the following questions. What is the potential performance effect of the unexpected event? Is a response necessary? What flexibility is available to respond to the unexpected event? What are the potential performance consequences of the intended response? To obtain a quick answer to these questions, a dispatcher needs continuous comprehension about the overall

state and dynamics of the on-going operations. Hence, when executing the cross docking operations, the dispatcher needs to perceive the relevant elements in the operating environment in order to quickly notice an unexpected event and consequently trigger a response. Moreover, the dispatcher needs to comprehend the operational situation in order to grasp what flexibility is available for responding to the unexpected event. As various potential responses may have different impact on operational performance, the dispatcher needs to project these influences in deciding how to respond effectively to unexpected events. Therefore, *situation awareness* is included in the framework and conceptualized in line with Endsley (1995).

### 3. METHODOLOGY

An illustrative case study research approach (Yin, 2009) is adopted to explore the implications of the proposed conceptual framework in a real-world cross docking setting. Illustrative case studies can be used to provide illustrations of the way in which particular theoretical categorizations occur in practice (Scapens, 2007). Therefore, that particular case study method is considered appropriate for this research.

Research performed for this paper is part of work in progress that is performed within a three-year European Union FP7 co-funded research project ADVANCE. The primary topic of the ADVANCE project is the improved utilization of resources in hub and spoke scenarios by better exploitation of detailed information present throughout the network (Kemény et al. 2011). Within that broader context, the illustrative case presented in this paper is focused on the operational control performed at a cross dock.

#### 3.1 Case selection

**Case company selection.** A leading player in the European road-freight transportation sector was selected as the case company. The selection of this particular case can be justified by the typical road-freight transportation network in which the cross docking operations are performed. Hence, the setting of the case company is in line with the cross docking setting in which the proposed conceptual framework is situated. Moreover, the case company runs an information technology department responsible for managing the information flows through the network. To manage this information flow, various hardware and software systems throughout the transportation network are integrated with the central information system, which is fully developed and maintained in-house. Consequently, the case company owns and operates a state-of-the-art information system with extensive support possibilities. A more detailed description of the case company can be found in the section presenting the illustrative case study.

**Unit of analysis.** At the start of the case study, open question interviews with the management of the case company were performed to identify the key informants, the relevant activities in which those informants participate, and the nature of those activities. This enabled a clear definition of the unit of analysis and its boundaries (Baratt et al., 2011).

The unit of analysis in this research is the dispatching task at cross docks, which was defined before as the implementation of truck schedules and the related real-time decision making processes.

**Data collection.** The case company allowed continuous access to relevant operational data and documents. The qualitative data for this illustrative case study was gathered during a period of one year. During that period, the actual operations at the cross dock were observed. Moreover, eight semi-structured interviews were conducted, that lasted between one and two hours.

Data triangulation was ensured in four ways. First, qualitative data gathered from the observations and interviews was continuously compared with quantitative data from databases and documents. Secondly, as part of the ADVANCE project, the findings from the illustrative case were constantly corroborated with the findings from colleagues at other research institutes. Thirdly, interviews were conducted with staff from different organizational layers of the company. Fourthly, three workshops were organized with researchers participating in the ADVANCE project and the management of the case company. During these multi-day workshops, all gathered data was discussed with the purpose of refining that data and developing better understanding about the implication of that data.

### 4. ILLUSTRATIVE CASE STUDY

#### 4.1 The case company

The case company coordinates a European pallet-based road-freight transportation network, which is structured as a hub and spokes model. Roughly 20,000 pallets are processed each day through a network comprising eight hubs and around 250 spokes. Consignments typically comprise between 1 and 6 pallets, with an average of 1.3 pallets per consignment. This places the case company roughly in between postal-type delivery service providers and pallet delivery companies specializing in much larger consignments. The case company owns the hubs and operates them as cross docks – i.e. transshipment of pallets occurs without long term intermediate storage. The actual transport of the pallets is performed by the spokes which are autonomous but highly collaborative transportation companies. The spokes are allocated to an exclusive delivery area in such manner that complete network coverage is ensured. The case company employs a business model that contractually binds the spokes to always collect those pallets at the cross dock that are assigned to them, based on their delivery area.

##### 4.1.1 Pallet transport

Pallets are transported through the network by means of two delivery services: premium and economy. A premium service corresponds to the fastest possible delivery time by road – typically a 24 hour service. An economy service may add an extra 24 hours to that delivery time. A typical pallet transport is characterized by the following life-cycle, involving two different spokes and a cross dock:

- A collecting spoke transports a pallet from a collection point to their depot.
- The collecting spoke transports the pallet from their depot to a cross dock.
- A delivery spoke transports the pallet from the cross dock to their depot.
- The delivery spoke transports the pallet from its depot to a final delivery point.

#### 4.1.2 Layout of the cross dock

Within the broader context as described above, this illustrative case focuses on the dispatching task at the case company's largest cross dock. To a large extent, the layout of that cross dock corresponds to the layouts typically discussed in academic literature (e.g. Gue, 1999 and Vis & Roodbergen, 2011). For example, the cross dock comprises a large open area where the pallets can be stored on the ground, which allows easy access to the stored loads. In some aspects, the layout of the studied cross dock differs from typical layouts – comprising dock doors of which roughly half are dedicated to a set of out-bound trucks carrying loads to a predefined delivery area. The layout of the cross dock studied in this case, however, has no dock doors. Each delivery spoke is allocated to a fixed segment of the cross dock floor, referred to as a *bay*, where the pallets assigned for their delivery area are temporarily stored. The trucks are loaded and unloaded from dedicated spots in the same terminal where the pallets are stored. As a result of this layout, the distance between the bays and the trucks is typically very small. Therefore, the case company management considers the decision where – i.e. at which dedicated spot – to process a truck of less importance than the decision when to process each truck.

#### 4.1.3 Operations at the cross dock

The main portion of the operations at the cross dock takes place between 21:00 and 03:00, called the *night shift*. The length of the night shift is a rough primary indicator used for measuring the performance of cross docking operations. This performance indicator can be further detailed into the processing and waiting times of trucks and pallets at the cross dock. Observations of the dispatching task and interviews with the operational management of the case company strongly suggest that the sequence in which the trucks are processed at the cross dock determines to large extent the operational performance. This is in line with observations made in cross docking literature (e.g. Apte & Viswanathan, 2000 and Boysen et al., 2010).

**Operational plan.** There is an agreement between the case company and the spokes about the arrival times of the in-bound trucks at the cross dock. On the one hand, the planning of these arrival times is based on the desire to spread out the number of trucks at the cross dock throughout the night shift. On the other hand, the arrival times are based on the truck's travel distance between the spoke and cross dock. The arrival times have evolved over many years and are only changed sporadically. The case company urges the spokes to send their in-bound trucks according to planned

arrival times. However, trucks arrivals that deviate from the planned arrival times are not penalized.

**Operational control.** After their arrival, in-bound trucks queue up to unload their pallets at the cross dock. The pallets are unloaded from the truck and sorted into the delivery area bays, based on their final delivery point. After unloading all pallets from a truck, the newly-emptied truck will often exit the cross dock and then wait on-site until it can be loaded with its out-bound pallets. However, in 25% of cases, the loading of a truck immediately proceeds after unloading – i.e. without the truck leaving the cross dock.

The sequence in which trucks are processed is influenced by the planned arrival times. Nevertheless, the actual decision to call in a truck for processing is made by the human dispatchers. To control the on-going operations, dispatchers frequently deviate from the planned sequence. As a result of such deviations, the actual sequence in which trucks are processed is largely based on the dispatchers' personal experience with the cross docking operations.

## 4.2 Case study findings

### 4.2.1 Unexpected events and flexibility

**Unexpected events.** Dispatching at the cross dock is affected by two types of unexpected events caused by operational dynamics. The first type is related to the dynamic environment of the transport operations. Traffic congestions and truck malfunctioning, among others, can cause truck arrivals to be delayed. Truck delays can have a negative impact the performance of the cross docking operations by creating additional waiting times.

The second type of unexpected events is related to the daily variability in the number of pallets transported through the network. As a result of this pallet variability, operations at the cross dock are frequently confronted with unexpected peaks and troughs in pallet numbers for particular delivery areas. In particular unexpected peaks of pallet numbers can have a negative impact on operational performance. As a result of a limited capacity to process the pallets at the cross dock, such unexpected peaks can result in bays reaching their capacity limits. Full bays cannot be used to temporarily store pallets and consequently limit the decision latitude of the dispatchers, potentially increasing waiting times as a result.

**Flexibility.** Flexibility available for the dispatching task can be utilized in response to the unexpected events described above. There are two sources of flexibility available for the dispatching task. The first and main source of flexibility is the degree of freedom in deciding the actual processing sequence of trucks. Dispatchers can alter this sequence to mitigate the negative performance effects of the dynamic transport environment. A minor truck delay, for instance, could result in additional waiting times for many other trucks and pallets. In response, a dispatcher has the freedom to decide to continue processing other trucks at the cross dock to minimize additional waiting times. Moreover, dispatchers can alter the processing sequence to mitigate the

negative performance effects of the pallet variability. An unexpected peak in pallet numbers for a particular delivery area, for instance, could result in a bay reaching its capacity limits. In the case of a full bay, no pallets for that delivery area can be unloaded before a part of that bay is cleared. In response, a dispatcher can alter the truck processing sequence so that the out-bound truck for that delivery area can be loaded earlier.

A second source of flexibility is the economy delivery service. At the moment an economy pallet arrives at the cross dock, it may be left there for a day by the delivery spoke. In case an economy pallet is collected at the cross dock the same day it arrived, the delivery spoke can decide to leave that pallet at its depot for a day. Potentially, the flexibility provided by the economy service could also be utilized by the dispatchers to mitigate negative performance effects of operational dynamics on operational performance.

#### 4.2.2 Situation awareness for operational control

In controlling the cross docking operations, dispatchers respond to unexpected events by utilizing the available flexibility. To do so effectively, the dispatchers studied in this case argued that they need to oversee the state and dynamics of the operations at the cross dock. They consider this necessary to perceive unexpected events such as truck delays as early as possible. This early visibility provides them with the time required for effectively deciding the most favorable response. Moreover, dispatchers want to be aware of potential responses, such as altering the processing sequence of trucks. To mitigate the negative performance effects of unexpected events dispatchers also need an overview of the effects of those potential responses.

Currently, several systems throughout the transportation network directly capture information for almost any physical activity performed during the pallet transport life-cycle. Due to real-time information exchange, the case company's database has recorded the information about an activity within minutes after said activity occurred. Dispatchers sometimes browse the system's databases for specific pallet information. However, the available information is not processed and presented in such a way that it provides the dispatchers with the timely and comprehensible operational overview they require.

The main finding of this case study is that despite the availability of real-time and detailed information about the on-going transport operations, dispatchers lack situation awareness. Moreover, the case illustrates that the ability to utilize the available flexibility in response to unexpected events is hampered by this lack of situation awareness. With respect to unexpected peaks in pallet numbers, for instance, the detailed information available about pallets transport is currently not used to provide the dispatchers with an early notice of peaks for certain delivery areas. Moreover, an overview of the effects of those peaks on bay capacity usage is not provided to the dispatchers. With respect to truck delays, the available tracking information of trucks is currently not used. Nevertheless, this information could be processed to provide the dispatchers with an overview of

expected arrival times. In the current situation however, the dispatchers lack awareness of the trucks available, or soon to become available, at the cross dock for processing. As a result, dispatchers are not really aware of the degree of freedom in deciding the processing sequence of trucks, which hampers the utilization of the main source of available flexibility. During multiple workshops with the case company's management, participants agreed that enhancing the situation awareness of dispatchers may lead to substantial operational performance improvements.

## 5. DISCUSSION AND FUTURE WORK

The case presented in this paper illustrates a clear need for situation awareness. A lack of dispatchers' situation awareness showed to negatively affect their ability to control cross docking operations. Due to this lack of situation awareness, dispatchers were hampered in deciding how to bring the available flexibility into use in response to unexpected events. The lack of situation awareness makes an obvious case for means – i.e. practical tools – to enhance it. Potential means to enhance situation awareness should be properly integrated with existing information technology and closely embedded in the organizational structure aimed at the control of operations (Endsley et al., 2003). For such integration to be effective, a system approach first of all recommends an extensive requirements analysis phase (Buede, 2009). A preliminary architectural analysis performed in this research hints towards two categories of requirements for tools to enhance situation awareness for dispatching in a cross docking setting. The first category is related to *information-flow* specific requirements, which indicate the potential sources of information needed to build a context-specific and comprehensive overview that enables the dispatcher's situation awareness. At a conceptual level, the case reveals three sources of required information: operational dynamics, flexibility available in the planned situation, and performance. The second category is related to *human-computer interaction* specific requirements, which stem from cognitive and ergonomically derived human information representation needs.

Future research should be conducted to further detail these categories of requirements. Within the ADVANCE project, research activities will be performed to elicit both the information-flow and the human-computer interface requirements for situation awareness enhancing tools in further detail. Based on these requirements, the ADVANCE research consortium will develop an information system prototype for the particular unit of analysis as described in the illustrative case.

In the light of recent cross docking literature, a striking dichotomy can be observed between theory and practice. A study of cross docking literature revealed that most of the research effort thus far – as well as proposed future work – centers around improved truck scheduling optimization by means of for instance dynamic scheduling or rolling planning horizons (Boysen and Flidner, 2010). However, as part of a larger research project, the presented illustrative case study confirms previous observations made in other cases at

companies which are also involved in cross docking (Meyer, 2011). Similarly, these companies gave little priority to further optimization of their truck schedules for cross docking. Within this broader case study research context, it was frequently stressed that the occurrence of unexpected events hampers the ability to adhere exactly to the proposed schedule. As a result of their highly dynamic operating environment, the case companies prioritized a focus on increased utilization of the readily available information for improving the ad-hoc decision making of their dispatchers. Accordingly, the framework proposed in this paper emphasizes the need for situation awareness to enable effective response to unexpected events.

The framework theoretically positions situation awareness to related concepts well-known in the control of cross docking operations, as depicted in Figure 1. The use of the framework as theoretical reference in conducting the case study resulted in new insights in the process of operational control. The case illustrated that operational control is not hampered by a lack of technology capturing information about on-going operations but by a lack of situation awareness. The framework contributes to cross docking literature by its emphasis on the need for situation awareness to enable effective operational control. In response to the case study findings in several real-world cross docking settings, the authors of this paper plea for an academic debate about situation awareness for the control of cross docking operations. In line with the challenges faced by companies when controlling their on-going operations, this debate should focus on how to exploit the available information for providing the decision makers the situation awareness they need for performing effective operational control.

## 6. CONCLUSION

This paper proposed a framework that introduces situation awareness as an important concept in the control of cross docking operations. The implications of the proposed conceptual framework were explored in an illustrative case study. That case study illustrated a lack of situation awareness despite the availability of real-time and detailed information about the on-going transport operations. Moreover, the case illustrated that the ability to perform operational control is hampered by this lack of situation awareness. By its emphasis on situation awareness in operational control, the proposed framework aims to contribute to the cross docking literature by initiating a new academic debate. This debate should focus on how to exploit the available information for providing decision makers with the situation awareness necessary to perform effective operational control.

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