A Literature Review and Further Research Direction in Cross-docking

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Abstract

Cross-docking is a logistic technique that can help in cutting inventory costs while increasing the goods. The paper reviews literature in cross-docking regarding to operation problems and the metaheuristic methods used for solving those problems in order to support the future research in developing a new decision models. The result showed that though there are many articles of relevance with regard to either truck or dock door, there were found very few articles that focus on the tasks scheduling in cross-docking. Thus, it needs to be stated that the research gap in the cross-docking platform would need to be filled by focusing on task scheduling and including resource capacity in models more practical in real world problems. In addition, taking into consideration other objectives or even multiple objectives could be an alternative approach for future research. Furthermore, modern technology makes cross-docking feasible and able to develop suitable business models. Therefore to enhance cross-docking operations to be a smart and intelligent logistics system especially for small and medium enterprise (SME), creating adapted concepts and design solutions should be developed for providing a systematic management of smart operation in cross-docking and synchronized to the other cross-docking problems.

Keywords

Cross-docking, Differential evolution, Task scheduling, Literature review

1. Introduction

In most manufacturing environments, it is difficult to ship directly from the manufacturer to the customer. Therefore, an intermediate point is necessary to connect manufacturers and customers. One type of intermediate point in a supply chain system is the warehouse. A traditional warehouse has four main operations: receiving, storage, order picking, and shipping. These warehouses are also called distribution centers in which products are processed in real time and moved in and out on schedule. In competitive environments, the pressure is on to make the supply chain fast while keeping the prices low since more accurate and timely shipment is what the customer demands. Nevertheless, storage and order picking are usually the costliest operations of traditional distribution centers because of the inventory holding costs from storing and the costs of the labor-intensive task of order picking. Thus, the logistic techniques that can help in cutting inventory costs while increasing the goods flow and shortening the shipping cycle are considerable as a cross-docking approach. Cross-dock is a specific kind of warehouse, where the received products are loaded immediately within 24 hours to the outbound dock door; as a result, order picking and storage activity could be minimized or eliminated. Cross-docking provides more benefits than the traditional warehouse in terms of reducing transportation cost and inventory holding cost and increasing cycle time and customer satisfaction; cross-docking raises numerous questions with regard to optimization in order that more research studies are conducted to improve and make the operations in cross-docking more efficient and effective.

In recent times, a number of articles have been published about operation problems in cross-docking with relevance to dock door assignment, truck sequencing, and truck scheduling. There are very few articles, however, that focus on the tasks between inbound and outbound dock doors of cross-docking. Therefore, the aim of this review is to provide a comprehensive literature review of the operation problems in cross-docking, especially the task scheduling problem, and to suggest an appropriate solution for each problem.

The remainder of this paper is organizes with three main parts. The first part presents a literature analysis of the operation problem in cross-docking. The second part discusses the research opportunities in the fields that are identified, and the third part presents the details of further research direction.

2. Literature analysis

Operational cross-docking problems are an NP-hard problem; therefore, while attempting to solve the problem optimally, it should be noted that exact algorithms can work fully only for small-scale problems. Real-world problems, however, have complexity on a large scale; therefore, metaheuristics are often more appropriate for such NP-hard problems. So, the review includes articles from different sources such as international journals, conferences, book chapters, and PhD theses during the period 2001–2017 which are related to operation problems in cross-docking with metaheuristic as a whole. Figure 1 gives an overview of the metaheuristic methods used in the different operation problems in cross-docking. According to Figure 1 the various metaheuristic methods could be applied to different cross-docking operation problems. The optimal solution from each method drives researchers to seek a high performance metaheuristic to solve cross-docking problems. Besides, articles related to the truck scheduling and truck sequencing problem were found to be significantly higher in number than articles related to other problems; also, very few articles that addressed the task scheduling problem were found to exist.

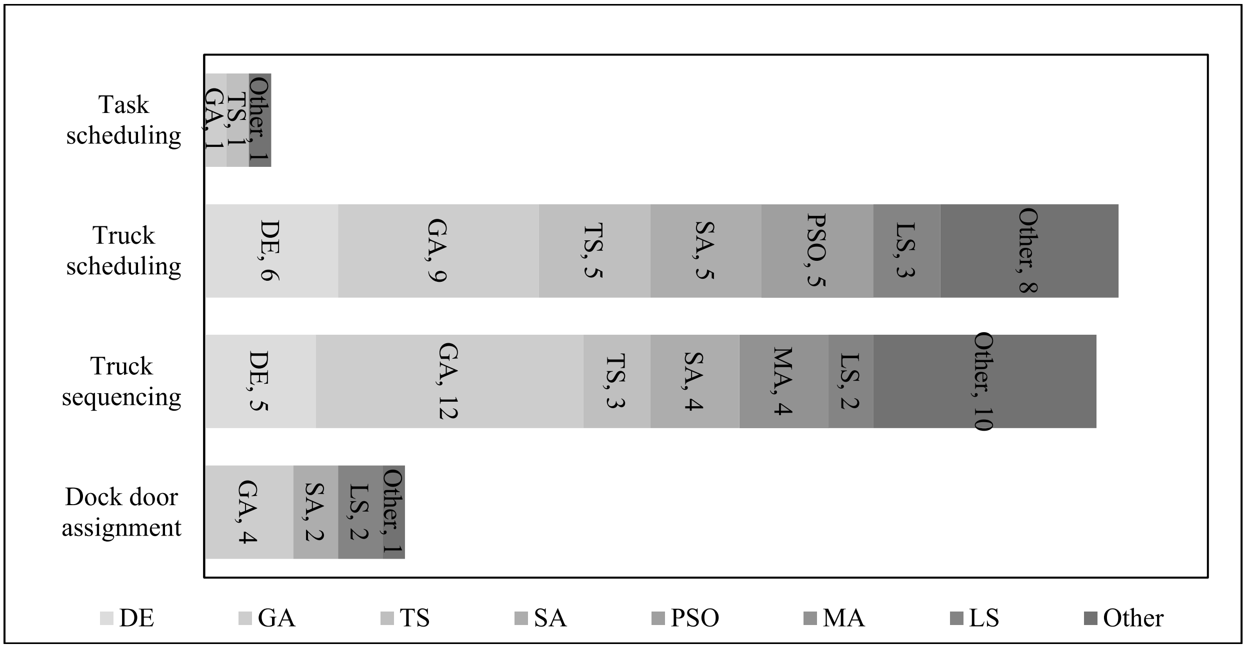

Figure 1. Number of articles applying metaheuristics solution method on cross-docking

2.1 Dock door assignment

The aim as regards the dock door assignment problem is to find the optimal method of assignment of inbound and outbound trucks to dock doors. Minimizing the travel distance is the common objective of this problem. The articles mentioned in Table 1 consider a set of doors (inbound or outbound, or both) and a set of trucks, with the number of trucks being less than or equal to the number of doors; therefore, it was not necessary to consider the time dimension. The paper dealing with the dock door assignment problem appeared in the beginning of the 20th century, and GA, SA, and LS were used to solve the problem.

Table 1. Metaheuristic methods used in dock door assignment problems

	DE	GA	TS	SA	PSO	MA	LS	Other
(Bartholdi III and Gue, 2000)				√				
(Bermúdez and Cole, 2001)		√						
(Brown, 2003)							√	
(Ley and Elfayoumy, 2007)		√						
(Ko et al., 2008)		√						
(Yu et al., 2008)		√						
(Bozer and Carlo, 2008)				√				
(Yu et al., 2008)							√	
(Guignard et al., 2012)								√

2.2 Truck sequencing

In contrast to the dock door assignment problem, there is another problem that only determine the sequence of truck without considering the assignment of truck to door. In the case of the truck sequencing problem, the exact location of the door is not taken into account, and the problem focuses on the order in which the trucks are processed at the doors. Minimizing the makespan is the common objective of this problem, and the inventory level is also an important aspect. Table 2 shows the articles dealing with the truck sequencing problem; some articles also determine the exact door at which each truck is processed. These kinds of problems are quite complex and more realistic due to the number of doors and the dynamic nature of the problem; for that reason, many such articles belonging to the middle of the 20th century until recent years were found, and it was also found that several metaheuristic methods were used to solve the problems.

2.3 Truck scheduling

The truck scheduling problem considers the same scenario as the truck sequencing problem: that the dock doors as resources used by the trucks have to be scheduled over time. However, in the case of the truck scheduling problem, the dimension of time is modeled explicitly by explicitly determining the arrival/departure times instead of the order in which the trucks arrive. Minimizing makespan is the common objective of this problem; at the same time, any deviation in the truck processing time and the distance traveled are also important aspects. Table 3 shows the articles dealing with the truck scheduling problem; some articles also determine the exact door at which each truck is processed. Because of the complexity and reality of this problem, it has been found that a vast number of articles related to truck scheduling have come into existence in recent years and that various metaheuristic methods have been used to solve the problem.

Table 2. Metaheuristic methods used in truck sequencing problems in cross-docking

Article	Door Assignment	Truck Sequencing	DE	GA	TS	SA	PSO	MA	LS	Other
(McWilliams et al., 2005)	√	√		√						
(McWilliams, 2005)		√				√				
(Baptiste and Maknoon, 2007)		√			√					
(McWilliams et al., 2008)	√	√		√						
(McWilliams, 2009)	√	√		√						
(Miao et al., 2009)	√	√		√						
(Maknoon and Baptiste, 2009)		√								√
(M. Golias et al., 2010)	√	√				√				
(Ji, 2010)	√	√				√				
(Forouharfard and Zandieh, 2010)		√		√						√
(Davoudpour et al., 2012)	√	√		√						
(T. W. Liao et al., 2012)		√	√							
(M. M. Golias et al., 2012)		√		√						
(Guo et al., 2012)		√		√				√	√	
(T. Liao et al., 2013)	√	√	√							
(Konur and Golias, 2013)	√	√		√						
(T. Liao et al., 2013)	√	√			√	√				
(Joo and Kim, 2013)		√		√						√
(M. M. Golias et al., 2013)	√	√				√				
(T. Liao et al., 2013)		√	√							
(Boysen et al., 2013)		√				√				
(Madani-Isfahani et al., 2014)	√	√				√				√
(Yazdani et al., 2015)		√							√	√
(Zarandi et al., 2016)		√		√						

Table 3. Metaheuristic methods used in truck scheduling problems

Article	Door Assignment	Truck Scheduling	DE	GA	TS	SA	PSO	MA	LS	Other
(Lim et al., 2006)	√	√		√	√					
(Bartz-Beielstein et al., 2006)	√	√								√
(Miao et al., 2009),	√	√		√						
(Chmielewski et al., 2009)	√	√								√
(Naujoks and Chmielewski, 2009)	√	√								√
(AR Boloori Arabani et al., 2010)		√	√	√			√			
(Behnam Vahdani and Zandieh, 2010)		√		√	√	√			√	√
(B Vahdani et al., 2010)		√		√						√
(Boysen, 2010)		√				√				
(Soltani and Sadjadi, 2010)		√				√			√	
(AR Boloori Arabani et al., 2011)		√	√	√	√		√			√
(A Boloori Arabani et al., 2012)		√								
(Van Belle et al., 2013)	√	√			√					
(Kuo, 2013)	√	√				√			√	
(Guignard et al., 2013)	√	√								√
(Bjelić et al., 2013),	√	√		√						
(B Vahdani et al., 2013)		√								√
(Shiguemoto et al., 2014)		√		√						
(Wisittipanich and Hengmeechai, 2015)		√	√							
(Wisittipanich and Hengmeechai, 2015)	√	√	√							
(Assadi and Bagheri, 2016)		√	√							
(Wisittipanich and Hengmeechai, 2016),		√					√			
(Wisittipanich and Hengmeechai, 2017)		√					√			
(Ladier and Alpan, 2018)		√			√					

2.4 Task scheduling

In the previous section, operations at the inbound or the outbound dock doors (or both) are discussed as dock door assignment, truck sequencing, and truck scheduling. Tasks between the inbound and the outbound dock doors, that is, sorting and repacking, were not taken into account. The aim of the existing articles related to the task scheduling problem is to support a given truck schedule.

As can be seen in Table 4, Li et al. (Li et al., 2004) studied the tasks involved in the cross-docking scheduling problem by considering, as described above, that it can be modeled as a machine scheduling problem, a job which has to be processed by teams which are assumed as machines. Each container can be set as a job that has a release time after which it can be processed, with the due date and the processing time assumed to be known beforehand. Therefore, the cross-docking problem was viewed as a machine scheduling problem, and the integer programming model can be formulated for a single objective function as earliness and tardiness are minimized. The objective for the problem is closely related to those for just-in-time (JIT) models where a service or job is expected to be completed in a time window. The constraint is that only a limited number of operation teams is available since teams are able to operate simultaneously. Then, two heuristics were implemented to solve the problem. The first uses Squeaky Wheel

Optimization embedded in a Genetic Algorithm and the second uses Linear Programming within a Genetic Algorithm. Both heuristics offer good solutions in experiments where comparisons are made with the CPLEX solver.

Later, A´lvarez-Pe´rez et al. (Alvarez-Perez et al., 2009) extended the work done by Li et al. (Li et al., 2004) by application in the context of the present work, like having teams with fixed costs, teams with different speeds, stochastic sick days for some members of the teams (equivalent to those for stochastic failures of the machines), stochastic processing times for the jobs, and job-dependent earliness and tardiness costs. So, the article presents an alternative to the approach studied in Li et al. (Li et al., 2004) for the same problem. Then, the approach to solve the problem was based on a combination of two metaheuristics, Reactive GRASP and Tabu Search (RGTS), which can offer good results with modest computational effort.

Table 4. Metaheuristic methods used in task scheduling problems

	DE	GA	TS	SA	PSO	MA	LS	Other
(Li et al., 2004)		√						
(Alvarez-Perez et al., 2009)			√					√

3. Opportunities for research and characteristic of task scheduling in cross-docking

In recent times, a considerable number of papers have been published about the cross-docking problem. However, only a few papers are about task scheduling between inbound and outbound dock doors of cross-docking; hence, there is no dearth of opportunities to improve and extend the current research.

Figure 2 shows the internal operations of cross-docking. As shown, there are many tasks that could come up, and each incoming cargo could be required to undergo different tasks to be cleared as outgoing cargo. In addition, each task has to face the presence of scarce resources which can be indicated by res $\lambda\sigma\varsigma$ (Blazewicz et al., 1983), where λ, σ, and ς are characterized as follows: λ is the number of resources, σ is the size of each resource, and ς stands for the resource requirements. Thus, it would be more practical in the case of real world problems if the restriction of scarce resources is considered for additional constraints in the task scheduling problem in cross-docking. Moreover, other objectives such as minimizing makespan, or even multiple objectives, for example, minimizing makespan versus minimizing tardiness, could be an alternative for future research.

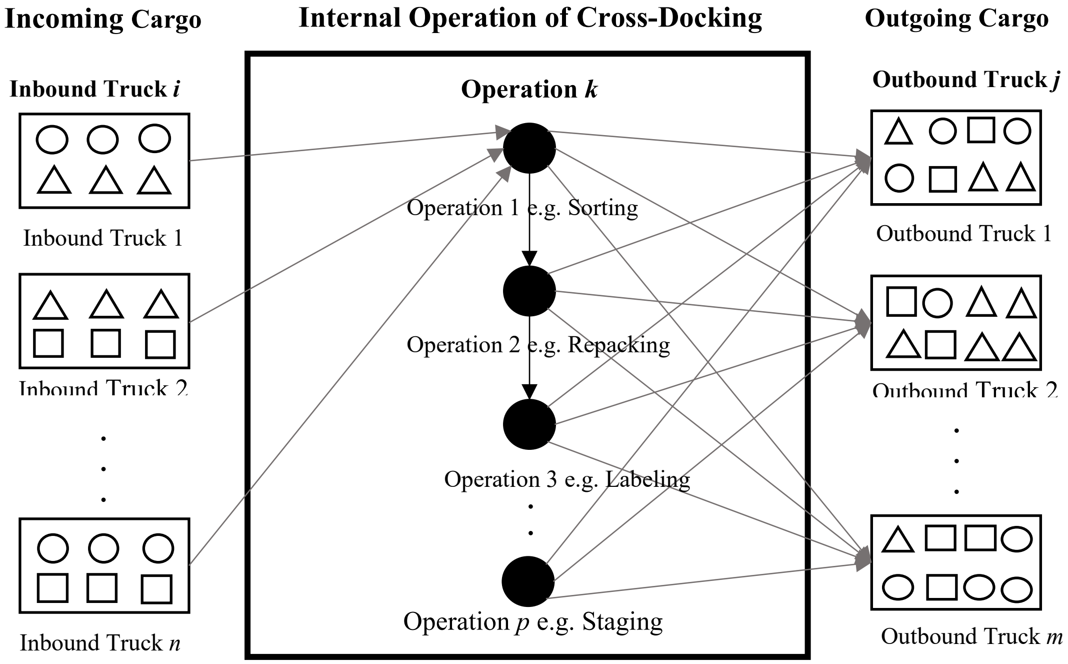

Figure 2. The internal operation of cross-docking

Since there are opportunities to improve and extend the current research about task scheduling in cross-docking. So, the literatures related to problems characteristic of task scheduling in cross-docking are reviewed. Bartholdi, Gue, and Kang (Bartholdi III and Gue, 2000) suggested classifying cross-docking as pre- and post-distribution cross-docking. In the pre-distribution cross-docking, the destinations are predetermined and labeled on the shipments before they arrive at the cross-docking. The workers can then transfer such shipments directly from inbound to outbound trailers while the shipments are in the post-distribution cross-docking; inbound freight arrives without a pre-determined destination and workers at the cross-docking assign the destinations to the shipments. In this case, the post-distribution cross-docking thus normally requires more floor space to stage freight for value-added activities such as sorting, labeling, price-tagging, and repacking at the cross-docking. Undeniably, these multiple operations between the terminals compete for scarce resources, for instance forklifts, working area, and manpower.

In general, addition of resource constraints to a scheduling problem may affect its computational complexity. In particular, certain well-solved problems, for which polynomial-time algorithms exist, may be transformed into NP-hard ones. Blazewicz, Lenstra, and Kan (Blazewicz et al., 1983) expanded this classification scheme by allowing the jobs to require the use of additional scarce resources. A schedule is feasible with respect to these resource constraints if, at any time, the index set of jobs being executed at total resource requirements is less than or equal to the resource sizes for the number of resources. Hence, the problem characteristic of task scheduling in cross-docking with the presence of scarce resources is integer programing (IP), and the problem is NP-hard.

4. Further Research Direction

A smart and intelligent production and logistics systems needs effective cross-docking that requires local and network-wide operations to be synchronized. The corresponding interdependencies between cross-docking problem classes may occur at the strategic, tactical, and operational level (Buijs et al., 2014). While the tactical and strategic cross-docking synchronization problem considers the design and layout of the cross-docks in synchronization with the interdependent network planning decisions. The operational cross-docking synchronization problem considers a cross-docking synchronization at the operational level.

Network scheduling in the operational cross-docking problem consider both inbound and outbound side. At the inbound side of the cross-docking, network scheduling decisions are concerned with dispatching shipments to each trailer departing the national distribution center (NDC) in the aim of specify which consolidated loads are assembled at the NDC and indicates the arrival times of these loads at the cross-docking. At the outbound side of the cross-docking, network scheduling is concerned with determining the vehicle routes replenishing the retailers. These vehicle routes specify the loading lists and departure times of trailers leaving the cross-docking. In the meantime cross-docking scheduling can address many internal operations including with truck scheduling, truck sequencing and task scheduling.

Consequently, for the synchronization the inputs to operational cross-docking problem stem from the network and cross-docking design and planning problem classes as shown in Figure 3. In the input phase, network planning concerned with assigning capacity to the network routes and allocating freight flows to those routes in order to determine which retailers are replenished from which regional distribution center (RDC). Meanwhile, cross-docking design and planning determine which, and how many, of the dock doors at the RDC should be dedicated to serving the cross-docking freight flow and specify the dock doors as either strip or stack door and allocating them to inbound and outbound trailers. Cross-docking and network operation result from those inputs and there is a synchronization between these output. Network scheduling decisions benefit from information about the actual cross-docking processing times and operational costs associated with different shipment dispatching and vehicle routing policies. The corresponding synchronization problem is detailed in Figure 3.

Undeniable modern technology makes cross-docking feasible and able to develop suitable business models. Cross-docking systems have two characteristics: hardware and software. Since cross-docking systems are highly automated, it is necessary to have appropriate equipment. Meanwhile in order to prevent the lack of operational management from becoming a barrier to successful cross-docking implementation, the appropriate software should be implemented simultaneously. Although operational management in cross-docking plays important role in success of implement cross-docking system, there has been very few publications about the task scheduling in cross-docking. This lack of research dealing with the complexity of working environment in cross-docking. Therefore to enhance cross-docking to be a smart and intelligent logistics system especially for small and medium enterprise (SME), creating adapted concepts and design solutions should be developed for providing a systematic management of smart operation in cross docking and synchronized to the other cross-docking problems.

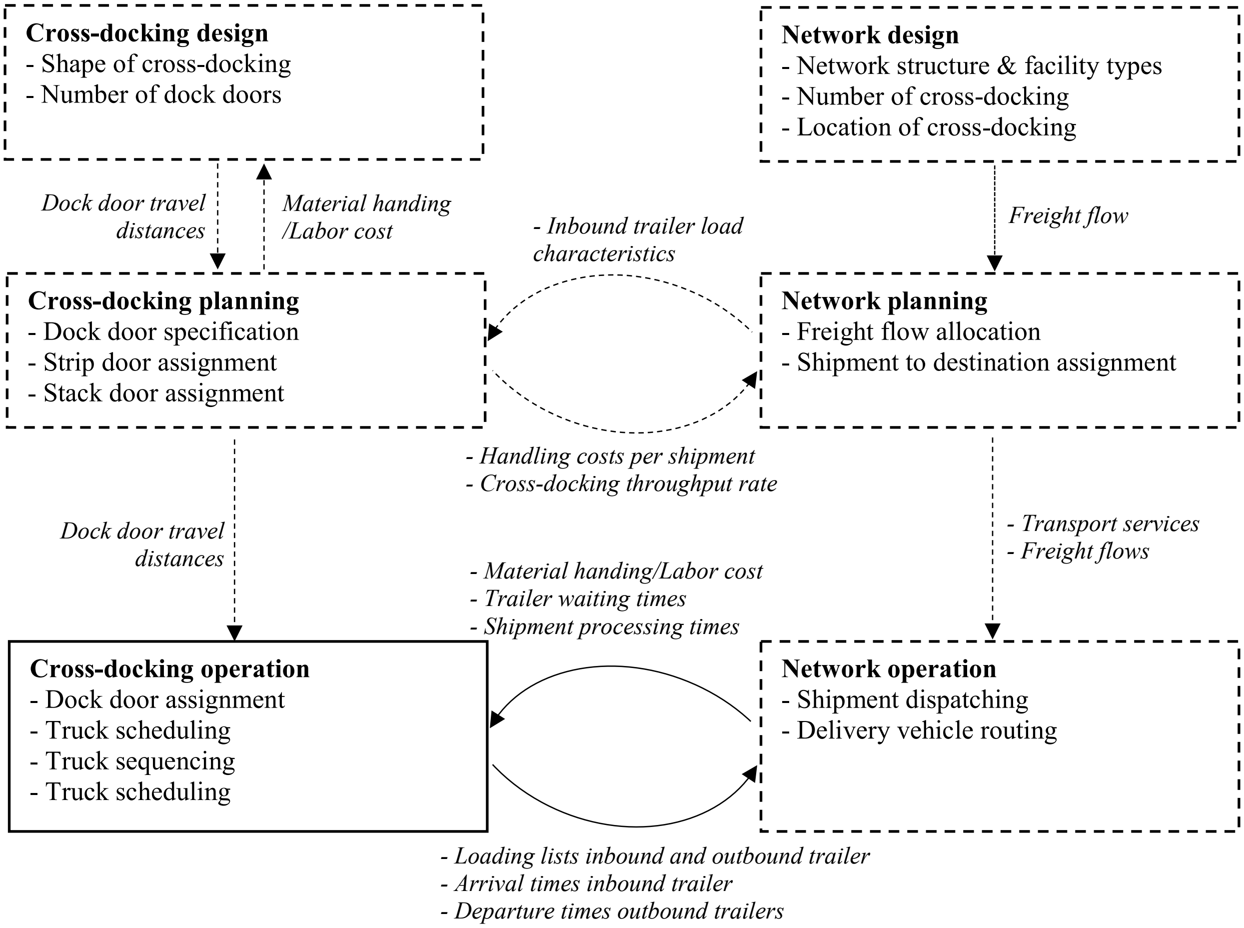

Figure 3. Cross-docking synchronization problem (adapted from Buijs et al. 2014)

5. Conclusion

Task scheduling between inbound and outbound dock doors of cross-docking, for example, sorting, repacking, or moving shipments across the docks, is a complex scheduling problem in itself since multiple resources need to be coordinated and each worker needs to be scheduled in detail. Some research studies modeling these tasks as a machine scheduling problem were discovered by the authors. However, until now, there have been very few articles that focus on the internal operations between the inbound and the outbound dock doors of cross-docking. Moreover, no research has yet focused on optimization of the time lags from these kinds of tasks in cross-docking. Thus, this research gap in the cross-docking platform would need to be filled by focusing on task scheduling inside the terminals and including resource capacity in models. In addition, metaheuristic methods that have the potential for significant future contribution in the field should be considered for handing this problem, given its complexity. Furthermore, modern technology makes cross-docking feasible and able to develop suitable business models. Therefore to enhance cross-docking to be a smart and intelligent logistics system especially for small and medium enterprise (SME), creating adapted concepts and design solutions should be developed for providing a systematic management of smart operation in cross-docking and synchronized to the other cross-docking problems.

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