2010

Progress in Material Handling Research: 2010

Table of Contents

11th International Material Handling Research Colloquium – 2010

SECTION I

Acknowledgments ..... **i**
Preface ..... **iii**
Event Summary ..... **ix**
Industry Day Summary ..... **xi**

SECTION II

Empirically-based Warehouse Design: Can Academics Accept Such an Approach? ... **1**
James M. Apple, Jr., Russell D. Meller and John A. White, Jr.

It is our opinion that existing research is not sufficient to support the design of a warehouse. As a result, facility designers that work in practice are left to face the design process with their own methods. These methods are in stark contrast to the analytical models developed in academia in that they are highly based on empirical observations. Supported by a collection of empirical observations, facility designers who work in practice employ an ad hoc design process. We present a design process based on empirical observations and then formalize it so that it can be taught and used. We illustrate the process with an example and discuss ways in which analytical methods can be used to supplement the process and improve the design. We conclude by describing additional work that is required if the design process is to be realized.

A New MILP Approach for the Facility Layout Design Problem with Rectangular and L/T Shaped Departments **25**
Yossi Bukchin and Michal Tzur

In this paper we propose a new approach for the facility layout problem (FLP) and suggest new mixed-integer linear programming (MILP) formulations. The proposed approach considers simultaneously the location of the departments within the facility and the internal arrangement of the machines. Two models are suggested, where the first addresses the rectangular department case and the second allows nonrectangular departments defined by an L/T shape. New regularity constraints are developed to avoid irregular department shapes.

Optimizing the Rearrangement Process in a Dedicated Warehouse **39**
Hector J. Carlo and German E. Giraldo

Determining the optimal storage assignment for products in a dedicated warehouse has been addressed extensively in the Facility Logistics literature. However, the process of implementing a particular storage assignment given the current location of products has not received much attention in the existing literature. Typically, warehouses use downtime or overtime to remove products from their current location and move them to the suggested location. This work presents the Rearrange-While-Working (RWW) policy to optimize the process

of rearranging a dedicated warehouse. The RWW policy seeks to relocate products in a warehouse from the initial arrangement to the optimal arrangement while serving a list of storages and retrievals. This study considers three scenarios: (1) when there is only one empty location in the warehouse and the material handling equipment (MHE) is idle (i.e. reshuffling policy); (2) when there is only one empty location in the warehouse under the RWW policy; (3) when there are multiple empty locations in the warehouse under the RWW policy. In the first case, the MHE can make any movement desired as it is idle. In the other cases, the movements correspond to a list of storages and retrievals that need to be served. In these cases it is assumed that products can only be moved when they are requested. After being used, they are returned to the warehouse. Several heuristics are presented for each scenario. The proposed heuristics are shown to perform satisfactorily in terms of solution quality and computational time.

Accidents will Happen. Do Safety Systems Improve Warehouse Safety Performance 49

René B.M. de Koster, B.M. Balk, I. Davelaar and M. Martens.

Safety is becoming more and more an issue in warehouses. In the literature, effective measures leading to increased occupational health and safety have hardly been researched. Most research focuses on the impact of perceived safety-related leadership of managers and worker safety consciousness on 'safety climate' and workers' safe behavior. We have carried out exploratory research into which measures really improve the safety performance of a warehouse. We particularly focus on the effects of (1) safety-related work procedures, (2) safety leadership, and (3) workers' safety consciousness. Based on a survey we show that safety leadership and safety-related work procedures significantly drive worker safety consciousness, which in turn positively impacts safety performance.

Spiral Facility Layout Generation and Improvement Algorithm 61

Fahrettin Eldemir and Hatice E. Sanli

This study is concerned with construction and improvement of a facility layout heuristic called Spiral Facility Layout Generation and Improvement Algorithm (SFLA). The algorithm starts with positioning departments from center point and continues like a hologram from center to outside. The aim of any facility layout algorithm is to better allocate the departments within facility. SFLA is compared with the existing space filling curve methods, MCRAFT and MULTIPLE, that are available in the literature. To form an initial spiral curve, a block system is used, like the bands for MCRAFT. The width and length of the blocks are given by user and departments are formed according to these values and placed around the spiral curve.

The initial layout can be selected either randomly or with a method which is called enhanced initial layout. Enhanced initial layout find the highest related department and put it into center and then add the other departments according to their relationships with the previous one.

20 departments data by Armour and Buffa (1963) have been used to test the performance of the SFLA. For bandwidth 4, SFLA gave better results than both MULTIPLE and MCRAFT. For the same flow data, 200 initial sequences selected randomly. Then initial layouts generated from these random sequences. Using pair wise exchange improvement methods both MCRAFT and SFLA layouts are improved. For bandwidth 4, SFLA often yielded better results than MCRAFT. Significance of the results is statistically tested.

Freight Sequencing to Improve Hub Operations in the Less-Than-Truckload Freight Transportation 77
Kimberly P. Ellis, Xiangshang Tong and Amy Brown Greer

In less-than-truckload freight transportation, hub operations affect the service levels that carriers are able to provide their customers. This paper focuses on improving the efficiency of hub operations by reducing freight handling time and cost. Specifically, the freight sequencing problem (FSP) is investigated to determine the freight unloading and loading sequence that minimizes the time for dock workers to transfer shipments from origin trailers to destination trailers. The FSP is modeled as a Rural Postman Problem (RPP) and three algorithms are compared: trailer-at-a-time, nearest neighbor, and balance-and-connect. Using five industrial data sets, the results demonstrate the effectiveness, advantages, and disadvantages of the approaches.

Monitoring Inventory Control Accuracy with Statistical Process Control 92
John R. English, Kyle Huschka, Todd Easton and Andrew Huschka

Inventory accuracy is critical in most industrial environments such as distribution, warehousing, and retail. Many companies use a technique called cycle counting and have realized outstanding results in monitoring and improving inventory accuracy. The time and resources to complete cycle counting are sometimes limited or not available. In this work, we promote statistical process control (SPC) to monitor inventory accuracy. Specifically, we model the complex underlying environments with mixture distributions to demonstrate sampling from a mixed but stationary process. For our particular application, we concern ourselves with data that result from inventory adjustments at the stock keeping unit (SKU) level when a given SKU is found to be inaccurate. We provide estimates of both the Type I and Type II errors when a classic C chart is used. In these estimations, we use both analytical as well as simulation results, and the findings demonstrate the environments that might be conducive for SPC approach.

Forklift Routing in Warehouses Using Dual-Commands and Stackable Pallets 112
Bill Ferrell and Ahmed Hassan

This research determines time optimal routes for loading and picking pallets that can be stacked on top of each other during transport in a manual warehouse that only contains full pallets and utilizes single deep storage. This research was motivated by the fact that we are seeing this situation on an ever increasing basis, particularly in warehouses that supply parts to automotive assembly. In practice, forklift drivers have developed strategies to take advantage of this opportunity but to our knowledge there is no literature that

addresses this problem rigorously. The important features of this work are that a time based mathematical model is required because the time spent stacking and unstacking pallets can be significant and a modeling approach to including stacking had to be developed. The basic models are included here with examples and insights into future work required for applicability to a wider range of users.

Gains in the Life-Cycle of Adaptable, Self-Organized Material Handling Systems 122
Guido Follert, Jan R. Nopper and Michael ten Hompel

Compared to conventional material flow controls, self-organized material handling systems and the Internet of Things in facility logistics promise several advantages during the life-cycle. Most important is the increased adaptability in case of expansions or modifications due to a consistent modular design; this also promotes an increased robustness due to clearly defined interfaces and a decreased complexity of each module. The use of RFID technology increases the availability of real-time data about the system and the transported units. However, the introduction of self-organized material handling systems also causes costs, e.g. for necessary RFID tags and readers. Against this background, it is unsatisfactory that the increased adaptability as the main advantage of these systems is hard to grasp. This paper proposes a methodology to analyze the advantages of adaptability in facility logistics during the life-cycle of a material handling system and illustrates its usage. The proposed methodology is based on a dynamic optimization of payoffs during the life-cycle; thereby, all payoffs which are influenced by the adaptability of the material-handling system are included; therefore, the methodology allows to consider the adaptability of all material handling systems.

Plug-and-Work Material Handling Systems 132
Kai Furmans, Frank Schönung and Kevin R. Gue

One disadvantage of automated material handling systems is their relative Inflexibility: once racks are installed and conveyors are laid, making even minor changes to a system can be cumbersome and expensive. However, recent progress in the capabilities and cost of basic system components, such as controllers, drives, and sensors, has made possible a new class of material handling systems having a much higher degree of flexibility. We propose underlying design principles for such systems and describe several prototype “plug-and-work" systems, which feature decentralized control and ease of reconfiguration.

Strategic Design of a Robust Supply Chain 143
Marc Goetschalckx and Edward Huang

The strategic design of a robust supply chain has as goal the configuration of the supply chain structure so that the performance of the supply chain remains of a consistently high quality for all possible future scenarios. We model this goal with an objective function that trades off the central tendency of the supply chain profit with the dispersion of the profit as measured by the standard deviation for any value of the weights assigned to the two components. However, the standard deviation, used as the dispersion penalty for profit

maximization, has a square root expression which makes standard maximization algorithms non applicable. The focus in this article is on the development of the strategic and tactical models. The application of the methodology to an industrial case will be reported. The optimization algorithm and detailed numerical experiments will be described in future research.

A Real-Time Picking and Sorting System in E-commerce Distribution Centers 161
Yeming Gong, Erik M.M. Winands and René B.M. de Koster

Order fulfillment is the most expensive and critical operation for companies engaged in e-commerce. E-commerce distribution centers must rapidly organize the picking and sorting processes during and after the transaction has taken place, with the ongoing need to create greater responsiveness to customers. Sorting brings a relatively large setup time, which cannot be well admitted by existing polling models. We build a new stochastic polling model to describe and analyze such systems, and provide approximate explicit expressions for the complete distribution of order line waiting time for polling-based order picking systems and test their accuracy. These expressions lend themselves for operations and design operations, including deciding between "pick-and-sort" or "sort-while-pick" processes, and warehouse performance evaluation.

The Human-Centric Warehouse..... 175
Kevin R. Gue

In theory and in practice, the objective of warehouse design has long been to meet operational requirements of throughput and service performance at minimum cost. A natural product of this "bottom line" approach has been warehouse buildings and operations ill-suited to the humans who spend their working lives interacting with them. We offer an explanation for the current approach, and argue that a new approach— a new paradigm —is needed. We then describe a comprehensive approach to warehouse design that includes human well-being as a primary goal.

Merge Problems with High Speed Sorters..... 186
Dirk Jodin and Andreas Wolfschluckner

To meet customer demands on distribution the necessity of sorting systems for unit loads in regard to quantity and capacity is growing up constantly.

Due to that, manufactures offer powerful sorting machines with a capacity up to 15.000 pieces per hour. Those machines are for instance Crossbelt or Tilt-Tray sorters. The output of these sorters is calculated by the equation of throughput.

$$\lambda = v/s\left[units/h\right]$$

The point of interest is the merge, referring to the overall efficiency of the single sorter. The motion sequence during merging has to be absolutely quick and precise to achieve exact positioning using minimized distances of the single items and high velocities on the main conveyer. Actual research activities at the Institute of Logistics Engineering at the Technical University of Graz will provide improved solutions for this problem.

The mathematical and mechanical models are representing a way how to describe and optimize the merging of single piece items. A basic example will show the transactions while merging in detail and the results will be discussed. Furthermore a layout proposal to simplify and increase the merging of goodswill be presented.

Evaluating the Effect of Operational Conditions and Practices on Warehouse Performance 197
Andrew L. Johnson

Analyzing warehouse performance across different environments is critical to improving overall productivity and reducing costs. Although two-stage DEA estimators have been shown to be statistically consistent, the finite sample bias of DEA in the first stage carries over to the second-stage regression, which causes bias in the estimated coefficients of the contextual variables. The bias is particularly severe when the contextual variables are correlated with inputs. To address this shortcoming, we apply insights from Johnson and Kuosmanen (2010), who demonstrate that DEA can be formulated as a constrained special case of the Convex Nonparametric Least Squares (CNLS) regression to develop a new semi-parametric one-stage estimator. The new model is applied to a set of warehouses to illustrate its performance.

Dispatching Vehicles Considering Uncertain Handling Times at Port Container Terminals 210
Kap Hwan Kim and Vu Duc Nguyen

This paper considers the problem of vehicle dispatching at port container terminals in a dynamic environment. The problem deals with the assignment of delivery orders of containers to vehicles while taking into consideration the uncertainty in the travel times of the vehicles. Thus, a real-time vehicle dispatching algorithm is proposed for adaptation to the dynamic changes in the states of the container terminals. To evaluate the performance of the proposed algorithm, a simulation study was conducted by considering various values of decision parameters under the uncertainty in travel times. Further, the performance of the proposed algorithm was compared with those of heuristic algorithms from previous studies.

Blocking Effects on Performance of Warehouse Systems with Autonomous Vehicles..... 227
Ananth Krishnamurthy, Debjit Roy, Sunderesh Heragu and Charles Malmborg

Distribution centers are under increasing pressure to adopt material handling systems that offer greater flexibility to improve cycle time and throughput capacity in the transfer of unit loads in their high density storage areas. Autonomous Vehicles-based Storage and Retrieval Systems (AVS/RS), have been shown to hold significant promise in this context. In these systems, loads are transferred by autonomous vehicles. Vehicles support horizontal load movement along aisles and cross-aisles within a tier, and lifts support vertical movement between tiers. Existing research in AVS/RS, do not explicitly account for the potential blocking of vehicles and lifts while they are processing

transactions. Blocking could occur when multiple vehicles use the same cross-aisle or aisle to process transactions. These blocking delays could significantly impact throughput capacity and cycle times. In this research, protocols are developed to address vehicle blocking and a simulation model is proposed to analyze system performance and quantify the effect of blocking.

Designing Automated Warehouses by Minimising Investment Cost Using Genetic Algorithms 237
Tone Lerher, Iztok Potrč and Matjaž Šraml

The successful performance of the automated storage and retrieval systems is dependent upon the appropriate design and optimization process. In the present work a comprehensive model of designing automated storage and retrieval system for the single- and multi-aisle systems is presented. Because of the required conditions that the automated storage and retrieval systems should be technically highly efficient and that it should be designed on reasonable expenses, the objective function represents minimum total cost. The objective function combines elements of layout, time-dependant part, the initial investment and the operational costs. Due to the non-linear, multi-variable and discrete shape of the objective function, the method of genetic algorithms has been used for the optimization process of decision variables. The presented model prove to be very useful and flexible tool for choosing a particular type of the single- or multi-aisle system in designing automated storage and retrieval systems. Computational analysis of the design model indicates the model suitability for addressing industry size problems.

Determining Warehouse Storage Locations Assignments Using Clustering Analysis 254
Dale Masel and Carlos Egas

The methodology used to assign products to a storage location in a warehouse can have a significant impact on the amount of time required to retrieve all of the items needed to fill an order. This paper describes a methodology that uses a clustering approach to determine storage assignments, where the metric of the strength of the relationship between two stock-keeping units (SKUs) is the number of times that the SKUs appear in the same order. Clustering is performed to maximize the frequency with which SKUs in the same cluster are ordered together. In testing, the clustering assignments were compared to a demand-based assignment strategy and showed a reduction of 20-30% in the number of aisles visited to retrieve orders.

The Future of Modeling in Material Handling Systems 261
Leon F. McGinnis

Today, when we talk about “modeling” in the context of material handling systems, invariably we are referring to a mathematical or computational model for analyzing some aspect of the system, such as its throughput rate, response time, cost of ownership, required storage capacity, etc. Creating these kinds of models requires considerable knowledge in at least two domains—the material handling system domain, and the analysis methodology domain—and considerable skill in the “art of modeling” in order to express the former in the

terms of the latter. The results can be somewhat ad hoc—e.g., two different modelers are likely to create two somewhat different simulation models of exactly the same material handling system. In the past, the situation in software development was very similar, with individual programming experts idiosyncratically driving software development. Over the past twenty years, however, computer scientists and software engineers have created a radically different approach to the process of software "modeling" called Model Driven Architecture, or MDA, that is used to create software for standard applications. The thesis of this paper is that MDA can be adapted to the kind of modeling done to support design and operational decision making in material handling systems. The paper describes MDA technologies in the context of material handling system modeling, and explains how adapting this approach to our context will transform the way we do research and the way material handling systems are analyzed and designed in practice.

Optimizing Distribution Center Configuration: A Practical View of a Multi-Objective Problem 275

Russell D. Meller and Lisa M. Thomas

The shape of a distribution center, as well as whether dock locations are on one side or two sides of the facility, impacts measures like travel distances and the number of dock locations that may be utilized. Thus, for a required number of pallet locations, there are multiple combinations of distribution center shape and dock configurations that should be evaluated against multiple measures. We have developed a practical model for making such evaluations and illustrate the model with data reflective of a partner in the Center for Engineering Logistics and Distribution.

A Flowshop Scheduling Problem with Transportation Times and Capacity Constraints 296

Abraham Mendoza, José A. Ventura and Kwei-Long Huang

Although there are numerous methodologies and research studies on machine scheduling, most of the literature assumes that there is an unlimited number of transporters to deliver jobs from one machine to another for further processing and that transportation times can be neglected. These two assumptions are not applicable if one intends to generate an accurate schedule for the shop floor. In this research, a flowshop scheduling problem with two machines, denoted as M1 and M2, and a single transporter with capacity *c* is considered. The main focus is on the development of a dynamic programming algorithm to generate a schedule that minimizes the makespan. The transporter takes t_1 time units to travel with at least one job from machine M1 to machine M2, and t_2 time units to return empty to machine M1. When the processing times for all *n* jobs on machine M1 are constant, denoted as $p_{j1} \equiv p_1$, and the capacity of the transporter *c* is at least $\left\lceil \frac{2(t_1 + t_2)}{p_1} \right\rceil - 1$, the computational complexity of the proposed algorithm is shown to be $O\left(n^3\right)$.

Towards a Physical Internet: The Impact on Logistics Facilities and Material Handling Systems Design and Innovation 305
Benoit Montreuil, Russell D. Meller and Eric Ballot

Aiming for a radical sustainability improvement, the Physical Internet has the potential of revolutionizing the fields of material handling, logistics, transportation and facilities design. It exploits the enabling concept of standardized, modular and smart containers as well as the universal interconnectivity of logistics networks and services. Its underlying paradigm shift creates a tremendous breakthrough innovation opportunity for the material handling and facility logistics community in terms of equipment, systems and facility design and operation. This paper provides a primer overview of a key subset of the physical elements serving as the foundation of the Physical Internet infrastructure, classified in three categories: containers, movers and nodes. Each element introduced is characterized and illustrated to enable visualization of their innovative nature. The paper helps uncover a wide variety of potent research avenues.

The Effect of Interaction Between the Production System (PS) and a Looped Conveyor-Based Material Handling System (LCMHS) in a Manufacturing Facility 328
Dima Nazzal and Vernet Lasrado

In this paper, we provide empirical evidence that shows the effect of the interaction between the production system (PS) and a looped conveyor-based material handling system (LCMHS) in a manufacturing facility. A rudimentary simulation model captures the interaction between the two systems. Varying several key factors, we test for a statistically significant difference in the work in process (WIP) of the production system with and without the LCMHS to find if the squared coefficient of variation (SCV) of the interarrival time distribution to the PS is affected. The results suggest the need to model the interaction between the two systems in order to obtain a more representative estimate of the WIP in a manufacturing facility.

Drive and Motion Design in Material Handling Equipment 338
Jörg Oser and Christian Landschützer

Drives account in many cases up to one third of the costs of material handling equipment. This fact justifies a closer look to important drive and motion issues. Typical design criteria for drives are energy and power consumption, wear, heat and noise generation. Engineering design activities start with the generation of the system configuration, that is to make appropriate topological decisions where to locate the drives in the equipment structure. These decisions define to a great extent the functional quality of the mechanical structure and the distribution of forces in the power train. For early design stages an elasto-kinetic model is developed, which is later enhanced by a more detailed simulation model. Another important issue is the definition of high quality motion profiles defined by selected velocity-time relationships.

Distribution Planning Considering Warehouse Decisions 351
Pratik J. Parikh, Xinhui Zhang and Bhanuteja Sainathuni

Modern supply chains heavily depend on warehouses for rapidly fulfilling customer demands through retail, web-based, and catalogue channels. The traditional approach that considers warehouses as cost-centers has affected the profitability of numerous supply chains. A lack of synchronization between procurement and allocation decisions causes warehouses to scramble for resources during peak times and be faced with under-utilized resources during drought times. Warehouses, however, have emerged as service-centers and it is imperative that warehousing decisions be an integral part of supply chain decisions. In this paper we propose a mixed-integer programming model to integrate warehousing decisions with those of inventory and transportation to minimize long-run distribution cost. Preliminary experiments suggest a sizeable reduction in the level and variance in the warehouse workforce requirements. A cost savings ranging between 2-6% is also realized.

Analysis of Picker Blocking in Narrow-Aisle Batch Picking 366
Brett A. Peters, Soondo Hong and Andrew L. Johnson

This study analyzes impacts by batch picking on picker blocking in narrow-aisle order picking, and determines appropriate batch formations for a better order picking throughput. We present multiple-pick analytical models to offer insights about picker blocking in batch picking. Several simulation studies over a variety of batching situations scrutinize order batching situations which give throughput benefits in narrow-aisle configurations by satisfying the analytical results. Our results highlight three findings for narrow-aisle batch picking processes: 1) variation of pick probability in batch picking is inevitable and is a primary driver of picker blocking; 2) a near-optimal distance-based batching algorithm can experience less picker blocking than expected, because it reduces both the number of aisles visited and the variation in the number of picks per aisle; and 3) the sorting strategy itself (i.e., pick-then-sort or sort-while-pick) causes varying amounts of congestion.

Design of Cross-Chain Internet Order Fulfillment Centres 379
Kees Jan Roodbergen, Iris. F.A. Vis and Jaap Boter

Many consumers have embraced the option of ordering via the Internet, which has resulted in an enormous increase in direct orders compared to the times when direct ordering was done by catalogue and phone. The fulfillment process in the supply chain is an important factor for these consumers impacting how long they must wait between ordering and delivery. This fact has significantly increased the importance of the back-end fulfillment process. We present a novel supply chain design to enable cross-chain coordination of order fulfillment operations for internet sales. Shared warehousing facilities are used more and more to achieve competitive advantage. This situation asks for new models to enable a smooth warehousing process for each web shop, but at the same time to ensure overall efficiency and effectiveness. This paper introduces a layout model for shared operations under one roof by simultaneously optimizing the overall facility layout and the area layout.

Multiple-Grooved Magnetic Traction Sheaves 391
Thorsten Schmidt, Thomas Leonhardt and Martin Anders

This paper discusses a new and innovative form of traction sheaves, which can be used in many hoisting applications that are driven with wire ropes in material handling systems. By use of high performance permanent magnets, integrated in the periphery of traction sheaves, a significant increase of driving capacity is achieved. In this special case it concerns high energy magnets consisting of rare earth materials known as NdFeB magnets. These magnets provide a 20 times higher force than conventional magnets. The results of the research show that the driving capacity of traction sheaves with a round groove design can be increased by around 25% through the use of NdFeB magnets. By this means it is possible to combine high driving capacity with low wearout for the wire rope. Conventional traction sheaves with high driving capacity, such as V-groove sheaves go along with fast wire rope deterioration because of the high local pressure stress on the rope.

WEBASRS – A Web-Based Tool for Modeling and Design of Abstract Unit-Load Picking Systems..... 405
Jeffrey S. Smith and Sabahattin Gokhan Ozden

This paper describes a web-based tool that supports the modeling and design of abstract unit-load picking systems. The term “abstract” implies that the model is not specific to any equipment or vendors’ products, but, instead, focuses on the generic system components such as pallets, racks, slots, forklifts, cranes, etc. that comprise typical unit-load picking systems. The objectives of the tool are to support the design of an AS/RS-based or a manual forklift-based picking system based on a set of design parameters and to be able to convert from an AS/RS design to a flat warehouse design and vice versa. The research objective is to design the formal model (the data structure and operational description) that supports the conversion from one type to the other and supports the generation of static and dynamic analysis models and the recording of the analysis results. The web implementation uses a mix of XML, HTML, JavaScript and PHP and implements two existing analysis methodologies from the literature.

Design of Warehouse for Material, Which is Non-Uniform and Difficult to Handle 419
David Sourek and Andrea Seidlova

Main goal of this paper is warehouse layout optimization with emphasis on maximum space utilization. It is about rack system design, which leads to capacity maximization of warehouse for non-uniform material with heavy weight. The warehouse system has to enable at least partial automation (the possibility to use AS/RS system), minimization of service time and minimization of man effort. Initial constraining conditions for warehouse design in our case are warehouse area, maximum load of racks or shelves, maximum allowed floor load and existing location of arrival road for material loading and unloading.

Optimization of Costs and Service Level by Choosing the Best Customer Order Decoupling Point..... 429
Detlef Spee and Michael Schmidt

The customer order decoupling point (CODP) as the link in the sup-ply chain between processes based on uncertain information, such as sales forecasts, and certain information in the form of customer orders is crucial for production efficiency, storage costs, and the quality of logistics. This paper focuses on developing an approach for identifying a CODP that provides the highest potential for achieving business objectives. Within the context of the above-mentioned topics, this paper focuses on the inter-relations and the tradeoffs that have to be made when positioning the COPD. The goal of the paper is to present an effective and chronological sequence of tasks, analyses and methods, criteria, and indicators that can help a production planner determine the CODP. In the first part of the pa-per, the factors affecting the positioning of the CODP (internal and external to the company) and their characteristics are identified. Based on extensive literature research, these factors are then mapped to manufacturing concepts, such as make-to-stock, assemble-to-order, and make-to-order. The factors that lead to moving the CODP are also identified and used as the foundation for the development of an iterative procedural method with four stages. In stage 1, the as-is state and current goals are captured and suitable CODPs are identified for the above-mentioned logistic factors. In stage 2, the products are combined into groups to reduce the complexity of the analysis and a procedure for accomplishing this is proposed. The number of suitable CODPs is reduced in stage 3 and the factors that influence the positioning of CODPs are taken into consideration. In stage 4, a financial and qualitative evaluation is performed on the various CODPs.

Investigating Possible Synergies in Intermodal Operations with Truck and Rail 441
G. Don Taylor, Mia K. Burns and Gary L. Whicker

As the trucking industry continues to examine ways to provide better service at lower cost, many companies are more heavily utilizing intermodal (IM) strategies between truck and rail, especially for those loads that are relatively non-critical in terms of delivery time requirements and that have longer lengths of haul. As IM business grows, supporting dray infrastructure naturally develops around IM rail yards. What is unknown is whether it is best to have a dedicated set of drivers performing dray operations or if efficiency and cost savings can result when utilizing a joint driving fleet to concurrently support IM and traditionally dispatched truckload freight transportation. This paper describes a set of experiments utilizing a comprehensive discrete-event system simulation model and historical data from J.B. Hunt Transport to determine whether or not operating synergies exist when IM dray operations are integrated with local, regional, and long-haul trucking operations. Performance metrics of interest to drivers, customers, and trucking companies are utilized to ensure that the research addresses issues of importance to all constituencies. The results show that there is a trade-off between different performance variables when combining operations, but that generally speaking synergies do exist when considering the needs of professional drivers. Results are more mixed with respect to the needs of carriers and customers, but the authors reach the conclusion that the positive aspects of combining OTR and IM dispatching activities outweigh the negative. Because the evaluative simulation model itself is considered to be a major contribution, it is also described in some detail herein.

Using Data Development Analysis to Evaluate the Performance of Third Party Distribution Centers..... 459
Ching-Jung Ting and Hsueh-Lin Fang

There has been considerable interest worldwide in last few years in the growth of third party logistics (3PL) providers. 3PL distribution center (DC) enables firms to achieve reduced operating costs, increased revenues, and to focus on their core competence. This research aims to find the key performance indicators through a survey of a set of DCs and then evaluate their efficiency over the period 2005-2007 using data envelopment analysis (DEA) models based on selected performance indicators as inputs and outputs. Three inputs and two outputs for all DCs from the surveyed performance indicators were selected in this study. DEA is a non-parametric linear programming technique used to evaluate the efficiency of decision making units (DMUs) where multiple inputs and outputs are involved. We adopted both the input-oriented CCR model and the BCC model that were designed to derive weights instead of being fixed in advance and handle positive inputs/outputs. A Malmquist productivity index (MPI) analysis further evaluates efficiency change and productivity growth between two time points. Our empirical results show that scale inefficiency is the major reason for the inefficient DMUs. For the future research, more DC data should be collected and different DEA models could be applied for other benchmark studies.

Determination of Operational Parameters for an Efficient Container Service in the Port of Guaymas..... 477
J. René Villalobos and Cesar Meneses

The port of Guaymas is located in Sea of Cortez in the Northern Pacific Coast of Mexico. Its hinterland is basically the Northwestern region of Mexico and the Southwestern United States. The Port currently focuses on bulk and liquid cargo and does not provide container services. In this paper, we explore some of the characteristics that a container service should have to be competitive in servicing the needs of the regional industry. Since the study deals with port selection decision from the industry's point of view, we introduce a port selection model based on a Total Landed Cost (TLC) metric. The findings show that under the right conditions, the Port of Guaymas is an attractive option for the companies located in its hinterland.

Control Policies for a Dynamic Storage System with Multiple Lifts and Shuttles..... 494
Iris F.A. Vis, Hector J. Carlo, Bruno van Wijgaarden

New types of Automated Storage and Retrieval Systems, able to achieve high throughput levels, are continuously being developed and require new control polices to take full advantage of the developed system. In this paper we study a dynamic storage system as developed by Vanderlande Industries consisting of a conveyor, two lifts, multiple transfer shuttles, and a storage rack. One of the decision problems for this system is the scheduling problem of the two lifts. In other words, which lift is going to handle which request and in which order. In this paper, we derive an integrated look-ahead heuristic based on enumeration to simultaneously assign a set of pre-defined requests to the lifts and to schedule the lifts. As main performance measure we use the total time required to serve all requests.

Class-Based Storage with a Finite Number of Items 510
Yugang Yu and René B.M. de Koster

ABC class-based storage is widely studied in literature and applied practice. It divides all stored items into a limited number of classes according to their demand rates (turnover per unit time). Classes of items with higher turnovers are stored in a region closer to the warehouse depot. In literature, it is commonly shown that the use of more storage classes leads to shorter travel time for storing and retrieving items. A basic assumption in this literature commonly is that the required storage space of items equals their average inventory levels, which is right if an infinite number of items are stored in each storage region. However, if a finite number of items are stored in the warehouse, more storage classes need more space to store the items: more classes lead to fewer items stored per class, which have less opportunity to share space with other items. This paper revisits ABC class-based storage by relaxing the common assumption that the total required storage space of all items is independent of the number of classes. We develop a travel time model and use it for optimizing the number and the boundaries of classes. Our numerical results illustrate that a small number of classes is optimal.

Compring Transport Policies in a Full-Scale 300MM Wafer Manufacturing Facility .. 525
Claude Yugma, Jean-Etienne Kiba, Stéphane Dauzère-Péres and Gilles Lamiable

Research in semiconductor manufacturing ideally wants to determine the “best” transport policy to ensure continuous production. Determining such a policy is difficult because it depends on many factors such as the layout, the product types, the equipment, etc. Most of the transport policies found in the literature combine dispatching policies (scheduling of transport requests) and routing policies (selection of the path to move from one point to another). This paper investigates a policy called "minimum service" which consists in keeping a minimum number of available vehicles in bays, so that they can quickly answer transport requests and empty travel times can be minimized. This paper aims at comparing, through experimental tests on actual instances of a real semiconductor manufacturing facility, two types of transport policies in terms of cycle time, throughput and Carrier Exchange Time. Moreover, the behavior of the “minimum service” policy is studied when the number of vehicles and the number of starting lots are varied. The results show that the “minimum service” policy is in general more effective than a classical policy, but that its key parameters must carefully be determined.