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THIRTEENTH CONFERENCE ON THE MATHEMATICS OF OPERATIONS RESEARCH

CONFERENCE CENTRE 'DE BLIJE WERELT'
LUNTEREN, THE NETHERLANDS

JANUARY 13-15, 1988

Organized by the
Centre for Mathematics and Computer Science,
Amsterdam, The Netherlands

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ON THE
MATHEMATICS OF OPERATIONS RESEARCH

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AIM AND SCOPE

The aim of the conference is to promote the research activities and the cooperation between researchers in the mathematics of operations research.

The emphasis of the 1988 conference will be on two fields which are promising for further OR-research: logistics and combinatorial optimization.

Five non-Dutch specialists have been invited to give two lectures on recent developments in their field of interest. They have been asked to present a tutorial survey of their area in the first talk and discuss their own recent work in the second lecture.

The program includes a minicourse on Goodsflow control, which will be given by J. Wessels, J. Wijngaard and W.M.H. Zijm (all University of Eindhoven). Of the invited speakers A. Federgruen (Tel Aviv), J. Walrand (Berkeley) and L. van Wassenhove (Leuven) will more or less elaborate on this field. Furthermore two of the invited speakers will give lectures in the field of combinatorial optimization: D. Shmoys (Cambridge, U.S.A.) about approximation algorithms, L. Trotter (Augsburg) about duality.

The program should give ample opportunity for informal discussions.

ORGANIZATION

Organizers

The conference is organized by the Centre for Mathematics and Computer Science in Amsterdam, in particular by H.C. Tijms and B.J. Lageweg.

Sponsors

The conference is organized under the auspices of the Dutch Research Community in the Mathematics of Operations Research and System Theory, with financial support of the Dutch Mathematical Society and the Netherlands Society of Operations Research.

PROGRAM

Invited speakers

A. Federgruen (Tel Aviv):
1. Replenishment strategies for production/distribution networks with general setup costs
2. Integrating inventory control and production planning

D. Shmoys (Cambridge, U.S.A.):
1. Dual approximation algorithms: easy solutions to hard problems
2. Approximation algorithms for scheduling unrelated parallel machines

L. Trotter (Augsburg):
1. Abstract linear duality
2. Applications and extensions of the linear duality model

J. Walrand (Berkeley):
1. Ideas and methods in queueing network theory
2. Quick simulation of queueing networks

L. van Wassenhove (Leuven):
1. Capacity planning in modern production inventory control systems
2. Single level and multi level capacitated dynamic lot sizing

Minicourse: Goodsflow control

J. Wijngaard (Eindhoven):
Models around order acceptance and distribution

J. Wessels (Eindhoven):
Methods for production planning on factory level

W.H.M. Zijm (Eindhoven):
Models for flexible manufacturing systems

TIME SCHEDULE

Wednesday January 13, 1988

11:30	Opening
11:40	Walrand (1)
12:30	Lunch
14:30	Minicourse (1): Wijngaard
15:20	Tea
15:50	Minicourse (2): Wessels
16:40	Trotter (1)

Thursday January 14, 1988

9:00	Shmoys (1)
9:50	Coffee
10:20	Federgruen (1)
11:10	Minicourse (3): Zijm
12:00	Meeting Research Community
12:30	Lunch
15:00	Trotter (2)
15:50	Tea
16:20	Walrand (2)
17:10	Federgruen (2)

Friday January 15, 1988

9:00	v. Wassenhove (1)
9:50	Coffee
10:20	Shmoys (2)
11:10	v. Wassenhove (2)
12:00	Closing
12:30	Lunch

REPLENISHMENT STRATEGIES FOR PRODUCTION/ DISTRIBUTION NETWORKS WITH GENERAL JOINT SETUP COSTS

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We address the problem of identifying cost-effective integrated replenishment strategies for raw materials, work-in-process and finished goods' inventories in general production/distribution networks. Such strategies provide an optimal tradeoff between inventory carrying and production/distribution costs.

The production/distribution network is represented as a general acyclic network: each node represents a particular item at a particular location and/or production stage. A directed arc between a pair of nodes (i,j) indicates that the output of operation i is used by operation j.

External demands may occur for any of the items, i.e., at any of the nodes in the network. These demands are assumed to occur at (item specific) constant and continuous rates. Components may be assembled or disassembled in any given proportions.

Since fixed production and distribution costs are often *jointly* incurred between different items and/or operations, we allow for *general* joint setup cost structures, merely assuming a monotonicity and concavity property. We also address specific types of production/distribution *capacity* constraints.

Under a power-of-two policy each product's inventory is replenished at constant time intervals and the length of the replenishment interval is a power-of-two multiple of some (fixed or variable) base planning period. We show that the average cost of the best power-of-two policy is guaranteed to come within 2% of a lower bound for the minimum system-wide costs when the base planning period may be varied and within 6%, if the base planning period is fixed.

We show that an optimal power-of-two policy may be determined by a limited number of ordinary maximum flow computations when the cost structure is separable and by relatively simple variants of maximum flow computations when it is nonseparable. The proposed algorithms, even in the separable cost case, are of considerably smaller complexity than that of existing alternatives.

The proposed algorithms generate as a side-result a specific *cost allocation* of the joint cost structure to the individual operations/items. With this specific cost allocation, the problem with separable costs is, in fact, equivalent to the

problem with joint costs in the sense that the two systems share the same sets of optimal power-of-two policies with identical associated long run average costs.

Our models may be formulated as nonlinear integer programs. Our algorithms are based on characterization theorems for optimal solutions of the models' continuous realizations as well as of the original integer programs.

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INTEGRATING INVENTORY CONTROL AND TRANSPORTATION PLANNING

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We discuss one warehouse-multiple retailer systems in which goods are distributed through a fleet of vehicles combining deliveries in distinct locations into efficient routes. Our objective is the determination of *long term* replenishment strategies (i.e., inventory rules and routing patterns) minimizing long run average system-wide transportation and inventory costs.

Optimal policies can be very complex, and this complexity would make them unattractive even if they could be computed efficiently. Instead we restrict ourselves to replenishment strategies employing a finite collection of routes; whenever one of these routes is driven, deliveries are made to all retailers on the route. (Note: routes may overlap.) For a number of important settings we derive *easily computable lower* and *upper* bounds on the minimal system-wide costs (within this class of strategies) and prove that the ration (upperbound/lower bound) decreases to one or a number close to one (1.02 or 1.06) as the number of outlets is increased. Such bounds provide cost estimates which may be used in various design studies. In addition we design *simple* (polynomial time) heuristics achieving a similar, provable (asymptotic) degree of optimality. Experimental studies, indicate that the gap between the lower bounds and the costs of the constructed solutions is rather small, even when the number of outlets is only of moderate size. Finally, we obtain a number of qualitative properties which hold for all or most of the models and proposed schemes.

Our results are partially based on characterizations and efficient algorithms for several general classes of set partitioning problems; these results should be of interest in other application areas as well.

DUAL APPROXIMATION ALGORITHMS: EASY SOLUTIONS TO HARD PROBLEMS

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Traditional approximation algorithms find feasible, suboptimal solutions to optimization problems, where there is bound on the extent to which the solution is suboptimal. For example, the list scheduling algorithm for multiprocessor scheduling always yields a feasible schedule that has length no more than twice the optimum, so that this is called a 2-approximation algorithm. We propose a notion of a dual approximation algorithm, where the aim is to find infeasible, superoptimal solutions to optimization problems, where there is a bound on the extent to which the solution is infeasible. For example, we will present an algorithm for the bin-packing problem that never uses more bins than the optimal packing with bins of size 1, and packs each bin with pieces of total size at most 6/5, so that this is called a 6/5-dual approximation algorithm.

Dual approximation algorithms are of practical interest in their own right, since feasibility constraints for particular instances are often approximations themselves. However, this notion is perhaps more important as a unifying methodology for the design of traditional approximation algorithms, since we show that a $1+\epsilon$-dual approximation algorithm for a problem yields a $1+\epsilon$-approximation algorithm for a related dual problem. In the examples above, the bin-packing and multiprocessor scheduling problems are duals of each other in exactly this sense.

In addition to the application in multiprocessor scheduling, we will also present another example of this approach from location theory. This technique yields tradition approximation algorithms that, in both cases, can be viewed as the best possible in a strong sense, under the complexity theoretic assumption that $P \neq NP$.

This is joint work with D. Hochbaum.

Shmoys 2

APPROXIMATION ALGORITHMS FOR SCHEDULING UNRELATED PARALLEL MACHINES

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We consider the following scheduling problem. there are m parallel machines and n independent jobs. Each job is to be assigned to exactly one of the machines. The processing of job j on machine i requires time p_{ij}. The objective is to find a schedule which minimizes the maximum job completion time.

Our main result is an algorithm which runs in polynomial time and constructs a schedule that is guaranteed to be no longer than twice the optimum. This algorithm is a corollary of a theorem about the relationship of a class of integer programs and their linear programming relaxations. In particular, we show that for this class, it is possible to efficiently round the fractional extreme points of the linear program to integer points that nearly satisfy the constraints of the original integer program. In contrast to this, we prove that no polynomial algorithm for the scheduling problem can achieve a worst-case ratio less than 3/2 unless $P = NP$.

This is joint work with J.K. Lenstra and E. Tardos.

ABSTRACT LINEAR DUALITY

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There is an apparant formal similarity in the definition of the orthogonal complement of a vector subspace of $\mathbb{R}^n$ and the cone polar to a given convex cone in $\mathbb{R}^n$: both prescribe that the inner product between the elements of the initial object and elements of its corresponding "dual partner" belong to a particular subset of the reals. This subset is $\{0\}$ for the subspace case and is the nonnegative reals $\mathbb{R}_+$ in the cone case. We investigate an abstract model for linear duality which encompasses these and other special instances of interest in combinatorial optimization.

The descriptive duality present in the model is that of specifying a set in terms of linear constraints or viewing a set as being generated by certain types of linear combinations. We define the following properties of Weyl, Farkas, Minkowski and Fulkerson for the general model by analogy with classical results or (finite) cone polarity and the study of blocking pairs of polyhedra:

Weyl:	Nonempty, finitely, generated sets are finitely constrained.
Farkas:	Nonempty, finitely generated sets are closed under duality.
Minkowski:	Finitely constrained sets are finitely generated.
Fulkerson:	Finitely constrained sets have finitely constrained duals.

We show the following logical dependencies among these properties: Weyl $\Leftrightarrow$ Farkas and Minkowski $\Leftrightarrow$ Farkas and Fulkerson; Minkowski $\Rightarrow$ Fulkerson. Examples of various settings for duality in combinatorial optimization are discussed which demonstrate these dependencies.

REFERENCE

P.C.P. Carvalho, L.E. Trotter, Jr., (1987). An abstract linear duality model. Technical Report No. 638, School of OR & IE, Cornell University (revised 1987, to appear in *Mathematics of Operations Research*).

APPLICATIONS AND EXTENSIONS OF THE LINEAR DUALITY MODEL

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We discuss two specific instances and one generalization of the basic model presented in the previous lecture.

1. **Integral duality**. Here we define the **dual** of set $S \subseteq \mathbb{Q}^n$ by $S^* = \{x \in \mathbb{Q}^n : x \cdot y \in \mathbb{Z}, \text{ for all } y \in S\}$, where $\mathbb{Q}$ denotes the rationals and $\mathbb{Z}$ denotes the integers. A set $T \subseteq \mathbb{Q}^n$ is **constrained** (by S) if $T = S^*$ for some $S \subseteq \mathbb{Q}^n$ and **generated** (by S) if $T = \{\sum_{i=1}^{k} y_i a_i : k \geqslant 1; y_i \in \mathbb{Z}; a_i \in S\}$ for some $S \subseteq \mathbb{Q}^n$. We discuss the finiteness properties of the previous lecture for this model and indicate that sets for which $S = S^{**}$ are characterized as those of the form $\{yA + zB : y \in \mathbb{Q}^m, z \in \mathbb{Z}^p\}$ for some $A \in \mathbb{Q}^{mxn}, B \in \mathbb{Q}^{pxq}$. We also discuss a combinatorial abstraction for integral dependence of vectors which generalizes the matroid abstraction of linear dependence.
2. **Hilbert duality**. In this case the **dual** of $S \subseteq \mathbb{Z}^n$ is given by $S^* = \{x \in \mathbb{Z}^n : x \cdot y \in \mathbb{Z}_+, \text{ for all } y \in S\}$. Constrained sets and generated sets are defined as in 1. above, replacing $\mathbb{Q}$ by $\mathbb{Z}$ and $\mathbb{Z}$ by $\mathbb{Z}_+$. Here we indicate a characterization of sets closed under duality, i.e., sets for which $S = S^{**}$, which is related in a natural way to the concept of total dual integrality for a system of linear inequalities.
3. **Chvátal function duality**. Here we discuss an extension of the basic model which allows specification of the dual of a set by a broader-than-linear class of functions. For the specific case of integral monoids, Chvátal functions are shown to provide an analogue for the Weyl-Minkowski duality of cones.

REFERENCES

P.C.P. Carvalho, L.E. Trotter, Jr. (1987). An abstract linear duality model. Technical Report No. 638, School of OR & IE, Cornell University (revised 1987, to appear in *Mathematics of Operations Research*).

D.C. Llewellyn, L.E. Trotter, Jr. (1987). On abstract integral dependence.

Technical Report No. 737, School of OR & IE, Cornell University (revised 1987, to appear in *Mathematics of Operations Research*).

J. Ryan, L.E. Trotter, Jr. (1988). A general duality model and integral monoid duality (currently in preparation, should be available in January 1988).

IDEAS AND METHODS IN QUEUEING NETWORK THEORY

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A simple network example is used to illustrate some of the main ideas and methods of the theory of queueing networks. The topics covered are:

1) product-form
2) time-reversal
3) quasi-reversibility
4) Little's result
5) Palm distributions
6) non-Poisson flows
7) parametric optimization
8) flow control
9) nonlinear filtering
10) stochastic comparison
11) approximations

REFERENCE

J. Walrand (1988). An Introduction to Queueing Networks. Prentice-Hall.

QUICK SIMULATION OF QUEUEING NETWORKS

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Most queueing networks are intractable analytically. A number of approximation methods have been proposed. Some of these have been justified on the basis of asymptotics results. However, the absence of error bounds limits their applicability in a large class of analysis and design problems.

As a consequence, the practitioner often has to resort to simulation as the only available tool. However, simulations of stochastic networks tend to be exceedingly slow. This presentation discusses two approaches for speeding up simulations.

The first approach is an example of importance sampling. That is, the desired estimates about a given network are obtained by simulating a different stochastic process. Thus, the measure on the space of possible evolutions is changed. In our method, the change of measure is calculated by using some large deviation estimates.

The second approach consists in using a parallel computer. We will indicate some of the issues and promises of this method.

REFERENCES

S. Parekh, J. Walrand. Quick simulation method for excessive backlogs in queueing networks. IEEE Trans.Aut.Control, to appear.

R. Righter, J. Walrand. Fast simulation of discrete event stochastic systems. Proc. IEEE, to appear.

CAPACITY PLANNING IN MODERN PRODUCTION-INVENTORY CONTROL SYSTEMS

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Modern production-inventory control systems such as MRP (Material Requirements Planning, Manufacturing Resource Planning), JIT/TQC (Just In Time/Total Quality Creation with Kanbans) and OPT (Optimized Production Technology) serve many different purposes e.g. inventory control, information processing, shop flow control, etc. We discuss these systems from the point of view of capacity planning. First we deal with capacity planning in JIT/TQC and OPT. Then we analyze capacity planning steps within MRP systems. Since many companies have introduced MRP we investigate the possibilities of introducing finite capacity planning techniques in these systems. The basic tool for doing this is multi-item capacitated dynamic lotsizing. However, in order to be useful in a real-life MRP environment these lotsizing techniques should satisfy a number of requirements. These requirements together with their algorithmic implication are discussed. They are the basis for some of the lotsizing algorithms we developed in recent years.

REFERENCES

L. Gelders, L. van Wassenhove (1987). Produktiebesturingssystemen: een Vergelijking van MRP, Kanban en OPT, *Ekonomisch en Sociaal Tijdschrift*. 38, nr. 6, december 1984, 665-678. Also in: *Management-Methoden en -Technieken*, Kluwer, 1987.

L. Gelders, L. van Wassenhove (1985). Capacity Planning in MRP, JIT and OPT: A Critique. *Engineering Costs and Production Economics*, 9, 201-209.

SINGLE LEVEL AND MULTI LEVEL CAPACITATED DYNAMIC LOTSIZING

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This talk discusses our work on capacitated lotsizing over the last couple of years. Our work was motivated by many requests from industry. We started by looking at available single level capacitated lotsizing techniques in order to analyze both their structure and their computational performance (solution quality versus CPU-time). Our next step was to develop a simple, fast and flexible heuristic which could be used in a level by level MRP requirements computation. The resulting A/B/C heuristic turned out to be quite successful and therefore we looked into its extension to multilevel problem structures. It is worth noting that these extensions give rise to quite interesting complexity issues.

Another line of attack deals with mathematical programming based heuristics which are derived from optimal methods for the original problem or one of its relaxations. We discuss LP based heuristics and set partitioning approaches. All heuristics, simple as well as intricate ones, are then compared on a set of large single level problems and their pros and cons are discussed. We conclude with pointing out some interesting future research directions.

REFERENCES

P. Vanderhenst, L. van Wassenhove (1983). Planning Production in a Bottleneck Department: A Case Study. *European Journal of Operational Research*, 12, nr. 1.

M. De Bodt, L. van Wassenhove (1983). Capacitated Lotsizing for Injection Molding: A Case Study. *The Journal of the Operational Research Society*, June.

J.M. Thizy, L. van Wassenhove (1985). Lagrangean Relaxation for the Multi Item Capacitated Lotsizing Problem: A Heuristic Implementation. *IIE Transactions*, December.

J. Maes, L. van Wassenhove (1986). A Simple Heuristic for the Multi Item Single Level Capacitated Dynamic Lotsizing Problem. *Operations Research Letters*, 4, April.

J. Maes, L. van Wassenhove (1986). Multi Item Single Level Capacitated Dynamic Lotsizing Heuristics: A Computational Comparison, Part I: The Static Case. *IIE Transactions*, 18, 114-123.

J. Maes, L. van Wassenhove (1986). Multi Item Single Level Capacitated Dynamic Lotsizing Heuristics: A Computational Comparison, Part II: Rolling Horizons. *IIE Transactions*, 18, 124-129.

L. Gelders, J. McClain, J. Maes, L. van Wassenhove (1986). Mathematical Programming Approaches to Solve Lotsizing Problems. *WP 86-22.*

J. Maes, L. van Wassenhove. Single Level Capacitated Lotsizing. A Guideline for Practical Use, (in preparation).

J. Maes, L. van Wassenhove. Simple Heuristics for Multi Level Capacitated Lotsizing, (in preparation).

METHODS FOR PRODUCTION PLANNING ON FACTORY LEVEL

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On the factory level one has to reconcile the production constraints and the market requirements in order to obtain effective and efficient production. The best situation is obtained if the influence of the market is not felt directly in the factory, however, large scale buffering is usually expensive and, often, technically impossible. Therefore, there will usually be felt some influence of the market in the production. The talk will describe different forms of this influence and demonstrate how these influences can be conciliated to some extent with the typical aspects of the production process. Some important aspects of the production process are: inflexibility of capacities, set-up and change-over times, uncertainty of yields, machine reliability, availability of tools and materials.

MODELS AROUND ORDER ACCEPTANCE AND DISTRIBUTION

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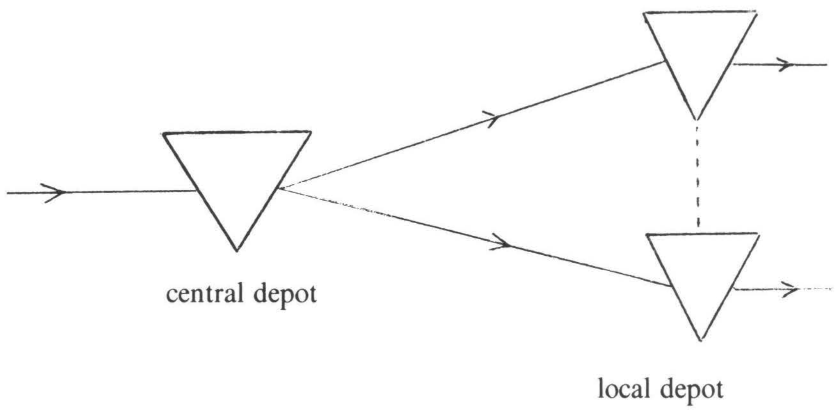
A common distribution structure is the following.



One has to distinguish here the customer order acceptance process and the control of the flows within the system. In case of very short customer order leadtimes the order acceptance reduces to concluding whether or not sufficient stock is available. This is the case that has been given most attention in the Operations Research literature: demand per local depot is modeled as a sequence of independent identically distributed stochastic variables.

Such models can be used to evaluate the influence or reorder rules and allocation rules on costs and delivery performance. Also to check points as the influence of keeping stock at the central level and the value of complete local stock information at the central level.

In many cases however there is some foreknowledge about customer orders, customer order leadtimes are longer and order acceptance procedures are more complex. In such cases, the just mentioned *stationary demand* models are no longer sufficient.

The problems that arise in such cases and the possible role of quantitative models to answer these questions will be discussed.

MODELS FOR FLEXIBLE MANUFACTURING SYSTEMS

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The need for a more flexible response to rapidly changing market demands has caused a rather dramatic change in the philosophy on the design and the lay-out of production systems, as well as on production organisation and even product development. Order leadtime and production throughputtimes have to be shortened, final stock and work-in-process inventory levels have to be reduced and at the same time service levels are to be increased. The implications of these objectives can be observed at many different levels in the industrial organisation.

In this talk, we focus exclusively on the implications at the shop floor level. We first define Flexible Manufacturing Systems and Flexible Assembly Systems, arisen as an attempt to combine the advantages of classical Job Shops and Dedicated Production Lines. Two examples will be presented: a metal cutting Flexible Machining System and a Flexible Assembly System for PCB (printed circuit board) mounting. With these examples in mind, we discuss a classification of FMS problem areas and discuss a number of models presented in the literature, covering justification, design and operational control problems.