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University	:	Eindhoven University of Technology
Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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**SECTION C: DOCUMENTATION PER PROGRAMME**

**1a Full title** : Stochastic Operations Research (including Mathematical Economics)

**1b Position within the Department, Research Institute, Research School, etc.**

The group Stochastic Operations Research is part of the section Operations Research and Statistics of the Department of Mathematics and Computing Science. The group participates in two Research Schools: Stieltjes and BETA. Stieltjes is a Research Institute in Mathematics: the University of Leiden is administrator. BETA is a Research Institute around Industrial Engineering: the Department of Technology Management of the TUE is administrator. The group Mathematical Economics is part of the same section and participates in the Tinbergen Institute.

**2 Programme Operations Research and Statistics**

**Subprogrammes**

- a) Stochastic Operations Research
- b) Mathematical Economics

**3 Programme members per 1 January 1996**

	<b>Name and Titles</b>
<b>subprogramme a)</b>	: Prof.dr. J. Wessels Prof.dr. A.G. de Kok (0,2) since 1-10-1992 Dr.ir. I.J.B.F. Adan since 1-10-1991 Dr. J.A.C. Resing since 1-4-1992 Dr.ir. J. van der Wal
<b>subprogramma b)</b>	Dr. J.H. van Geldrop Dr. C.A.A.M. Withagen

**4 Key words** :

- a) Operations research, neural networks, queueing, performance modelling, stochastic processes, logistic control, multi-echelon inventory control.
- b) environmental economics, general equilibrium.

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## 5 Research input of academic staff (wp)

<i>fte subprogramme a</i>		1991	1992	1993	1994	1995	total
wp1	aio's	.5	.2	.9	.9	.9	3.4
	other	1.1	1.1	2.0	1.9	1.9	8.0
wp2	oio's	2.2	2.2	1.1	1	1.1	7.6
	other						0.0
wp3	aio's						0.0
	other						0.0
total		3.8	3.5	4.0	3.8	3.9	19.0

<i>fte subprogramme b</i>		1991	1992	1993	1994	1995	total
wp1	aio's		.6	.6	.6	.6	2.4
	other	.7	.8	.8	.8	.7	3.8
wp2	oio's						0,0
	other						0,0
wp3	aio's						0,0
	other						0,0
total		0.7	1.4	1.4	1.4	1.3	6.2

### Main sources for contract research:

NWO/SMC,  
 NWO/STW,  
 Japan Environmental Agency,  
 Austrian Ministry of Science,  
 TNO,  
 LNMB,  
 Ministry of foreign Affairs,  
 General Electric Plastics,  
 several incidental contracts.

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## 6 Research output

### subprogramme a

<i>number</i>	1991	1992	1993	1994	1995	total
dissertations I+II	1	2		1	1	5
scient. publications	12	4	17	9	8	55
prof. publications and reports	11	4	7	18	17	57

### subprogramme b

<i>number</i>	1991	1992	1993	1994	1995	total
dissertations I+II						0
scient. publications	2	5	2	2	2	13
prof. publications and reports	1	4	11	3	5	24

## 7 Composition of research input academic staff 1995

<i>fte subprogramme a</i>	wp1	wp2	wp3	total
professor/associate professor	1.0			1.0
other senior staff	.9			0.9
aios and oios	.9	1.1		2.0
total	1.9	1.1	0.0	3.9

<i>fte subprogramme b</i>	wp1	wp2	wp3	total
professor/associate professor	.5			0.5
other senior staff	.3			0.3
aios and oios	.6			0.6
Total	1.4	0.0	0.0	1.4

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## 8 Programme design in brief (including a mission statement)

### Subprogramme Stochastic Operations Research

The challenge of the research programme is to develop and analyse mathematical models which help in understanding the effects of stochastics in decision problems and which will lead to better design and control of such stochastic systems.

A substantial part of the mathematical research questions is inspired by problems in logistic control and computer and communication systems. The research ranges from pure to applied. For that reason the group participates in two Research Schools: the mathematical Stieltjes Institute and in the program Quantitative Methods of the industrial engineering school BETA.

### Subprogramme Mathematical Economics

The central issues in this subprogramme are questions related to the concept of sustainable development, such as economic growth and sustainability, the optimal exploitation of exhaustible resources and net national income as a measure of sustainability. Special attention is paid to the existence of general equilibria in economies with an infinite dimensional commodity space, in view of the fact that sustainability extends to an infinite horizon. The problems mentioned are addressed by means of a large variety of mathematical tools such as game theory, functional analysis and optimal control theory.

## 9 Overview of scientific results

### Subprogramma Stochastic Operations Research

#### a) Queueing Theory

Most of the work in this area relates to queueing problems which can be described by random walks on an  $n$ -dimensional integer grid. A major effort has been the characterisation of the random walks which have an equilibrium distribution which can be written as a finite or countably infinite mixture of product-form solutions. For such cases also efficient numerical techniques have been developed. Typical queueing problems which belong to this class are the  $E_k/E_r/c$ -queue, the shortest-queue problem with 2 servers with several variants, some periodic queueing systems.

For queueing problems not fitting into this class, a general approximation procedure has been developed leading to sequences of upper and lower bounds in a systematic way. Typical applications of this approach are the shortest queue problem with more than 2 queues and the longest queue problem. This work is documented in 3 doctor's theses (one of these has been published in book form by Springer) and in many papers in scientific journals.

Part of this work is joint work with professor W.H.M. Zijm (UT).

#### b) Neural nets

The work on neural nets is joint work with professor E.H.L. Aarts (TUE and Philips Research). The basic goal of our work on neural nets is to explore the capabilities of neural nets for planning processes under uncertainty. The main inspiration in this respect stems from production planning problems with a rolling information horizon. The work in this area has led mainly to two types of results:

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- (i) results with respect to capabilities of neural nets for solving classification problems exactly; these results also comprise construction methods for neural nets which solve a particular classification problem exactly; this work has been published in a doctor's thesis and several papers in journals.
- (ii) a decomposition approach for production planning problems in which the uncertainty aspects are processed by a neural net and the detailed scheduling is executed algorithmically; this work will be documented in a forthcoming doctor's thesis and some journal papers; several papers in proceedings have appeared already.

c) Multi-echelon inventory systems

For multi-echelon inventory systems, control policies have been developed in order to minimize the total costs (holding costs and penalty costs).

An algorithm has been developed to determine the parameters of the control policies in every stockpoint.

In most analysis concerning multi-echelon systems it is assumed that the imbalance in a stockpoint does hardly have any effect on both the total costs and the attained customer service levels.

Research has been done to determine the impact of imbalance on the attained service levels, using the parameters of the control policies.

This work will be published in a forthcoming doctor's thesis. Several papers have been published in proceedings and scientific journals. Also a monograph on inventory systems is in preparation.

d) Real-time performance of data bases

This work is based on cooperation with Dr. P.D.V. van der Stok (TUE) and is executed in the form of a double STW-project.

The aim of the project is to achieve that the real-time performance of a database system can already be judged in the design phase, so that later disappointment is prevented.

The performance measure for a real-time database is the percentage of transactions that meets its deadline. This percentage can be increased by allowing transactions to be executed in parallel. However, then a transaction scheduler is needed to preserve the consistency of the database.

Two schedulers, Single Queue Static Locking and Optimistic Concurrency Control, were analysed using stochastic models. The result for both schedulers is a good approximation for the transaction response time distribution, so for the probability that a transaction meets its deadline.

The project is halfway now and will lead to one doctor's thesis on our side and several papers in journals and proceedings.

e) Decision support systems

Several activities fall under this heading:

- (i) the use of Petri Nets for specification was investigated in cooperation with professor K.M. van Hee and led to a doctor's thesis and some papers, mainly in proceedings.
- (ii) the development of decision support systems based on mathematical programming models was investigated in cooperation with a group of Polish colleagues led by professor A.P. Wierzbicki (T.U. Warsaw). Applications mainly regarded environmental problems at the International Institute for Applied Systems Analysis (IIASA) at Laxenburg, Austria.  
An edited volume on the topic is in preparation and several workshops have been organised.
- (iii) a new version of the manpower planning package FORMASY has been developed; applications have been executed in government and industry.

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- (iv) a package for the analysis of conventional order picking has been developed for a company.
- (v) a package for supporting inventory management (IMES) has been developed and is used in several places.

f) Miscellaneous Mathematical topics

- (i) A method for fitting discrete distributions on the first two moments has been developed. It is used for analysing periodic queueing systems and also in the order-picking package (cf. e (iv)). A journal paper has been published on the topic.
- (ii) Fluid flow analyses have been used for evaluation of traffic shapers in ATM-communication networks (in cooperation with Dr. J.L. van den Berg of KPN) and are used for evaluating highly integrated video signal processors (in cooperation with Dr. P. van der Wolf of Philips). On the first topic a paper has appeared. Also research has been done on the change of traffic streams in an ATM network due to interference with other streams.  
On this topic two papers appeared.
- (iii) Perturbation analysis of inventory systems has been used to obtain estimates of derivatives of important performance indicators from one simulation run (in cooperation with Dr. S. Uryasev and professor Y. Ermoliev from IIASA). A paper has been submitted to a journal.
- (iv) Further a lot of work is being done on the modelling and analysis of various problems in the area of production and inventory control. This research is leading to a series of papers that will be submitted for publication.

Subprogramme Mathematical Economics

a) general equilibrium theory

The work in this field has concentrated on economies with an infinite-dimensional commodity space, brought about by an infinite time domain, differentiated commodities or a continuum of possible states, for example. The approach taken in this project is the so-called truncation approach. It departs from the existence of equilibria in the finite-dimensional analogue of the original economy and subsequently applies a limit argument to establish an equilibrium in the limiting economy. This way of attack has proven very useful for a number of interesting models. The work has led to three articles in international economic journals and work in progress is promising. Results have been presented at numerous conferences with an international audience.

b) market equilibrium on the oil market

The oil market is frequently modelled as being supplied by a cartel (OPEC) and a large number of fringe suppliers. This gives rise to a von Stackelberg differential game. The literature has provided a solution to this game in an open loop setting. Groot (Free University) Withagen and de Zeeuw (Tilburg University) have shown that this solution was wrongly calculated. This result was published in an outstanding journal. During the period under consideration much attention was paid to the feedback von Stackelberg equilibrium concept applied to the model. For 15 years this has been an open problem in the literature, which was shortly solved by the three authors already mentioned.

c) national income accounting and sustainability

Currently there is an interesting debate on Net National Income as a possible indicator for sustainable development. This is not just a matter of accounting; the debate has its roots in fundamental economic theory. We have succeeded to make an important contribution to the debate, applying optimal control theory to an economy aiming at welfare maximization over time. Some important results will be

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published in scientific journals. The research has also had its impact on a report on this issue to be delivered to the Central Committee of Statistics (in Dutch).

d) transition from dirty to clean technology

This theme deals with the question what instruments should be used to provide incentives to firms to make a transition from a polluting technology to an environmentally friendly (but possibly more expensive) technology. The sensitivity of the outcome for the modelling of the assimilative capacity of nature is also subject to study. This gives rise to irreversibilities, non-convexities and non-differentiabilities, and hence to rather complicated mathematical problems. The research was carried out in cooperation with M. Toman, at that time member of the staff of the Council Economic Advisers (of president Clinton). A paper was finished and presented on several scientific occasions. Presently a new research grant is submitted to the Environmental Protection Agency in order to continue and extend the research.

## 10 Programme development

The reorganisation of the Department of Mathematics and Computing Science has disastrous consequences for the research programme in Mathematical Economics. The Eindhoven University has decided that the program in Mathematical Economics has to stop because it is not in the center of the future research programme in Mathematics.

We want to stress that this decision has not at all been based on doubts about the quality of the research.

The programme in Stochastic Operations Research will be continued with participation in the Research Schools BETA (Business Engineering and Technology Application) and Stieltjes. The major change is the fact that the 0.2-appointment of Prof. De Kok ends October 1, 1996.

New activities comprise a project on queueing analysis for situations where each activity requires at least two resources and a project on more advanced order-picking strategies. The latter project will be proposed to STW for financial support.

## 11 Societal/technological relevance

a) The aim of the programme is to work in pure as well as applied mathematics. There are two types of stimuli for directing research. One is of a purely mathematical nature, the other stems from applications. For the more applied research the stimulus originates from business and industrial processes, computer and communication systems and in a variety of natural and social sciences. Typical subjects are the design of logistic control systems and the design of communication systems. There are many intensive contacts with industry and other organisations outside the TUE.

The research effort is divided between the pure research school Stieltjes and the applied school BETA, with the larger part in BETA. Further, the researchers in the programme participate in 'second phase' designer programmes: Mathematics in Industry and Logistic Control Systems.

b) Sustainable development is the key issue in the objectives of Eindhoven University of Technology. Eindhoven University also explicitly states that economics plays a crucial role in sustainable development. Large part of the research programme in mathematical economics deals with questions

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such as the optimal transition to a clean technology, the conditions that have to be imposed on technology in order to reach sustainable development etc. Hence, with some care one could say that this programme is relevant from the perspective of society as well as technology.

## 12 Other indications for quality and reputation

### Subprogramme Stochastic Operations Research

#### Prof.dr. A.G. de Kok

- Board member of the Netherlands Society for Statistics and Operations Research
- Certified Fellow in Production and Inventory Management (CFPIM) of the American Production and Inventory Control Society (APICS)
- Member of the Scientific Council of Research Institute BETA
- Associate Editor of Management Science

#### Prof.dr. J. Wessels (selection)

- Leader of the project 'Methodology of Decision Analysis' of IIASA, Laxenburg, Austria
- Editor 'Statistics and Decisions'
- Editor 'Nieuw Archief voor Wiskunde'
- Member Advisory Board 'Operations Research Spektrum'
- Member Editorial Board 'Mathematics of Industrial Systems'
- Member of the preparatory committee European Research Institute 'EURANDOM'
- President of the Netherlands Society for Statistics and Operations Research
- Member of the Board of the Dutch 'AIO-Network Mathematics of Operations Research'
- Member of the Board of the Stan Ackermans Institute
- Chairman of the programme committee "Mathematics in Industry"
- Vice-chairman of the programme committee "Logistics Control Systems"
- Member of the Board of the Stieltjes Institute
- Member of the Presidium of the Science Committee of the Stieltjes Institute
- Member of the Science Committee of the Cooperation Center of Eindhoven and Tilburg Universities
- Chairman of the programme committee of the Designers Course Mathematics in Industry
- Member of the Board of the Research Institute BETA
- Member of the Scientific Council of the Research Institute BETA.

#### Subsidies

Apart from external funding of several doctoral projects, as mentioned before, the following subsidies were obtained within the IIASA-framework:

- subsequent projects on decision support for environmental problems have been financed by the Environmental Agency of Japan
- a project on the use of neural nets for processing remote sensing data has been financed by the Austrian Ministry of Science.

### Subprogramme Mathematical Economics

#### Dr. J.H. van Geldrop

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- External Fellow Tinbergen Institute

Dr. C.A.A.M. Withagen

- Member Central Bureau of Statistics committee on "Monetizing environmental losses"

- External Fellow Tinbergen Institute

- Member Program Committee 1996 meeting of the European Association of Environmental and Resource Economists (Lisbon)

### 13 Five key publications

#### Subprogramme Stochastic Operations Research

- 1 P.J. Zwietering, E.H.L. Aarts and J. Wessels (1992). Exact classification with two-layered perceptrons. *Int. Journal of Neural Systems* 3, 143-156.
- 2 I. Adan, J. Wessels and W.H.M. Zijm (1993). A compensation approach for two-dimensional Markov processes. *Advances in Applied Probability* 25, 783-817.
- 3 I. Adan, G.J. van Houtum and J. van der Wal (1994). Upper and lower bounds for the waiting time in the symmetric shortest queue system. *Annals of Operat. Research* 48, 197-217.
- 4 J. van Geldrop and C. Withagen (1994). General equilibrium in a economy with exhaustible resources and an unbounded horizon. *Journal of Economic Dynamics and Control* 18, 1011-1037.
- 5 I.J.B.F. Adan, M.J.A. van Eenige and J.A.C. Resing (1995). Fitting discrete distributions on the first two moments. *Probability in the Engineering and Informational Sciences* 9, 623-632.

### 14 Dissertations

**category 1:** doctorate from the own institution, preparation within the own institution

#### 1991

Adan, I.J.B.F.:

A compensation approach for queueing problems.

Promotors: prof.dr. J. Wessels and prof.dr. W.H.M. Zijm.

Eindhoven, 1991, pp. 179.

#### 1992

Aalst, W.M.P. van der:

Timed coloured Petri nets and Their application to logistics.

Promotors: prof.dr. J. Wessels and prof. K.M. van Hee.

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Eindhoven, 1992, pp. 276.

Pijnenburg, M.J.P.:  
 Reliability analysis of a repairable dependent parallel system.  
 Promotors: prof.dr. P.C. Sander and prof.dr. J. Wessels.  
 Eindhoven, 1992, pp. 210.

## 1994

Zwietering, P.J.:  
 The complexity of Multi-Layered Perceptrons.  
 Promotors: prof.dr. J. Wessels, prof.dr. E.H.L. Aarts.  
 Eindhoven, 1994, pp. 223. I

## 1995

Houtum, G.J. van:  
 New Approaches or multi-dimensional queueing systems.  
 Promotors: prof.dr. J. Wessels, prof.dr. W.H.M. Zijm.  
 Eindhoven, 1995, pp. 203.

**category 2:** doctorate from the own institution, preparation outside the own institution

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**category 3:** doctorate from other institution, preparation within the own institution

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**category 4:** doctorate from other institution, supervision partly within the own institution

### Subprogramme b)

Dr. J.H. van Geldrop acted as co-promotor with

'Adjustment processes for exchange economies and noncooperative games', A. van den Elzen,  
 Tilburg University, July 1991

'Static and dynamic aspects of general disequilibrium theory', P. Herings, Tilburg University, June 1995.

## 15 Scientific publications

### Subprogramme 1

#### 1991

#### International journals

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Adan, I.J.B.F.; Wessels, J.; Zijm, W.H.M.:  
Analysis of the asymmetric shortest queue problem.  
Queueing Systems, vol. 8, 1991, pp. 1-58.

Adan, I.J.B.F.; Wessels, J.; Zijm, W.H.M.:  
Analysis of the asymmetric shortest queue problem with threshold jockeying.  
Stochastic Models, vol. 7, 1991, pp. 615-627.

Dekkers, A.; Aarts, E.H.L.:  
Global Optimization by Simulated Annealing.  
Mathematical Programming, 50, 1991, pp. 376-393.

Houtum, G.J. van; Zijm, W.H.M.:  
Computational procedures for stochastic multi-echelon production systems.  
International Journal of Production Economics, 23, 1991, pp. 223-237.

Kraaij, M.W.I. van; Venema, W.Z.; Wessels, J.:  
Support for problem solving in manpower planning problems.  
Methods of Operations Research 64, 1991, pp. 519-528.

Willekens, E.; Resnick, S.I.:  
Moving averages with random coefficients and random coefficient autoregressive models.  
Stochastic Models 7, 1991, pp. 511-525.

Zwietering, P.J.; Aarts, E.H.L.:  
Parallel Boltzmann Machines: a Mathematical Model.  
Journal of Parallel and Distributed Computing, 13, 1991, 65-75.

Zwietering, P.J.; Aarts, E.H.L.; Wessels, J.:  
The design and complexity of exact multi-layered perceptrons.  
International Journal of Neural Systems, vol. 2, 3, 1991, pp. 185-199.

### **Refereed contributions to international conferences**

Aalst, W.M.P. van der; Waltmans, A.W.:  
Modelling logistic systems with EXSPECT.  
H.G. Sol, K.M. van Hee (eds), Dynamic Modelling of Information Systems. Elsevier Science Publishers, North-Holland, 1991, pp. 269-288.

Adan, I.J.B.F.; Wessels, J.; Zijm, W.H.M.:  
Flexible assembly and shortest queue problems.  
G. Fandel, G. Zaepfel (eds): Modern production concepts. Theory and applications, Springer-Verlag, Berlin, 1991, pp. 644-659.

Korst, J.H.M.; Aarts, E.H.L.; Lenstra, J.K.; Wessels, J.:  
Periodic multiprocessor scheduling.  
E.H.L. Aarts, J. van Leeuwen, M. Rem (eds.), PARLE '91, Parallel Architectures and Languages Europe, vol.

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I. Springer-Verlag, Berlin, (LNCS), 1991, pp. 166-178.

Zwietering, P.J.; Kraaij, M.J.A.L. van; Aarts, E.H.L.; Wessels, J.:  
Neural Networks and Production Planning.  
Proceedings Neuro-Nimes Conference, 1991, pp. 356-369. (best paper award).

## 1992

### International journals

Heijden, M.C. van der; Kok, A.G. de:  
Customer Waiting Times in a (R,S) Inventory System with Compound Poisson Demand.  
Zeitschrift für Operations Research, 36, 1992, pp. 315-332.

Zwietering, P.J.; Aarts, E.H.L.; Wessels, J.:  
Exact classification with two-layered perceptrons.  
International Journal of Neural Systems 3, no. 2, 1992, pp. 143-156.

### Refereed contributions to international journals

Aalst, W.M.P. van der;  
Logistics: a Systems Oriented Approach.  
Proceedings of the third International Working Conference on Dynamic Modelling of Information Systems,  
Noordwijkerhout, June 1992, pp. 169-189.

Aalst, W.M.P. van der:  
Modelling and Analysis of Complex Logistic Systems.  
Proceedings of the IFIP WG 5.7 Working Conference on Integration in Production Management Systems,  
Eindhoven, August 1992, pp. 203-218.

## 1993

Adan, I.J.B.F.; Wessels, J.; Zijm, W.H.M.:  
The effect of varying routing probability in two parallel queues with dynamic routing under a threshold-type scheduling.  
IEICE Transaction on Communication, Vol. E76B, 1993, pp. 29-31.

Adan, I.J.B.F.; Wessels, J.; Zijm, W.H.M.:  
Analysing multiprogramming queues by generating functions.  
SIAM Journal on Applied Mathematics, Vol. 53, 1993, pp. 1123-1131.

Adan, I.J.B.F.; Houtum, G.J. van; Wessels, J.; Zijm, W.H.M.:  
A compensation procedure for multiprogramming queues.  
OR Spektrum, Vol. 15, 1993, pp. 95-106.

Adan, I.J.B.F.; Wessels, J.; Zijm, W.H.M.:

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Matrix-geometric analysis of the shortest queue problem with threshold jockeying.  
Operations Research Letters, Vol. 13, 1993, pp. 107-112.

Adan, I.J.B.F.; Wessels, J.; Zijm, W.H.M.:  
A compensation approach for two-dimensional Markov processes.  
Adv. Appl. Prob. Vol. 25, 1993, pp. 783-817.

Boxma, O.J.; Houtum, G.J. van:  
The compensation approach applied to a 2x2 switch.  
Probab. Engineer. Inform. Sci. vol. 7, 1993, pp. 471-493.

Resing, J.A.C.:  
Polling systems and multitype branching processes.  
Queueing Systems 13, 1993, pp. 409-426.

Zwietering, P.J.; Aarts, E.H.L.; Wessels, J.:  
The construction of minimal multilayered perceptrons: a case study for sorting.  
Neurocomputing 5, 1993, pp. 197-210.

#### **Refereed contributions to international journals**

Aarts, E.H.L.; Stehouwer, H.P.:  
Neural networks and the traveling salesman problem.  
Proceedings of the International Conference on Neural Networks, Amsterdam, 1993, pp. 950-956.

Aarts, E.H.L.; Zwietering, P.J.; Wessels, J.:  
The applicability of neural networks for decision support.  
Proceedings of the EUFIT93, Verlag der Augustinus Buchhandlung, Aachen, 1993, pp. 379-386.

Adan, I.J.B.F.; Wessels, J.:  
Product forms as a solution base for queueing systems.  
Operations Research Proceedings 1992, Springer-Verlag, Berlin, 1993, pp. 316-323.

Braker, J.G.; Resing, J.A.C.:  
On a generalized asymptoticity problem in max algebra.  
Discrete Event Systems: Modeling and Control, S. Balemi, P. Kozak, R. Smedinga (eds.), Birkhauser Verlag  
Basel, 1993, pp. 125-139.

Houtum, G.J. van; Adan, I.J.B.F.; Wessels, J.; Zijm, W.H.M.:  
The compensation approach for three or more dimensional random walks.  
Operations Research Proceedings 1992, Springer Verlag, Berlin, 1993, pp. 342-349.

Kok, A.G. de:  
Demand management in a multi-stage distribution chain.  
Proceedings 4th International Production Management Conference, London, 1993, pp. 183-198.

Kok, A.G. de:

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Global production and distribution in a consumer electronics company.  
 Proceedings Symposium on Globalization of Operations Management, Washington, 1993, pp. 11.

Wessels, J.:  
 Decision systems: the relation between problem specification and mathematical analysis.  
 User-oriented methodology and techniques of decision analysis and support;  
 J. Wessels and A.P. Wierzbicki (eds.), LNEMS 397 Springer-Verlag, Berlin, 1993, pp. 2-20.

### **(Contributions to) books**

Wessels, J.; Wierzbicki, A.P. eds.:  
 User-oriented methodology and techniques of decision analysis and support.  
 Springer-Verlag, Berlin, Lecture Note in Economics and Mathematical Systems no. 397, 1993, pp. 296.

## **1994**

### **International journals**

Adan, I.J.B.F.; Houtum, G.J. van; Wal, J. van der:  
 Upper and lower bounds for the waiting time in the symmetric shortest queue system.  
 Annals of Operations Research, Vol. 48, 1994, pp. 197-217.

Boxma, O.J.; Resing, J.A.C.:  
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University	:	Eindhoven University of Technology
Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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University	:	Eindhoven University of Technology
Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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University	:	Eindhoven University of Technology
Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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## **16 Professional Publications and Reports**

### **Subprogramme 1**

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University	:	Eindhoven University of Technology
Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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## 1991

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University	:	Eindhoven University of Technology
Programme	:	Stochastic Operations Research (including Mathematical Economics)
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University	:	Eindhoven University of Technology
Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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University	:	Eindhoven University of Technology
Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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## **Subprogramme 2**

### **1991**

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Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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## 1993

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University	:	Eindhoven University of Technology
Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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**Designs, software, etc.**

## Subprogramme 1

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University	:	Eindhoven University of Technology
Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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## Software

Venema, W.Z.:

TCP-wrappers (diverse versies): een eenvoudig gereedschap voor het bewaken van de toegang tot UNIX systemen.

Logdaemon (meerder versies): verbeterde bescherming van UNIX systemen door middel van niet afluisterbare wachtwoorden en verbeterde logging van pogingen tot toegang.

Satan: netwerk security audit tool, ontwikkeld in samenwerking met Dan Farmer.

FORMASY, a new version of the manpower policy package based on NetScape.

## Designs

### (Mathematics in Industry)

Meuwissen, J.E.P.:

Computer aided design.

September 1992, supervisor: prof.dr. E.H.L. Aarts and ir. P.J. Zwietering.

Everdij, M.H.C.:

Judging the stability of train timetables.

September 1994, supervisor: dr.ir. J. van der Wal.

### (Logistics Control Systems)

Langenhoff, L.J.G.:

Emergence shipments for service parts at Océ-Van der Grinten.

April 1991, supervisor: prof.dr. J. Wessels.

Nieuweboer, Z.P.L.:

Afstemming Verkoop/Productie in de semi proces-industrie.

April 1991, supervisor: prof.dr. J. Wessels.

Bevelander, L.:

Logistiek beheersplan voor de zakgoed-verlading bij Meneba B.V.

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Programme	:	Stochastic Operations Research (including Mathematical Economics)
Research director	:	prof.dr. J. Wessels

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