



# Innovation in IT Education - Foundation of Innovation

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# Outline

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- Origin of Queueing Theory
- Classifications of Queueing Systems
- Applications
- Solution Methods
- Software Support
- References

# Origin of Queueing Theory

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Agner Krarup Erlang, 1878-1929

- "The Theory of Probabilities and Telephone Conversations", Nyt Tidsskrift for Matematik B, vol 20, 1909.
- "Solution of some Problems in the Theory of Probabilities of Significance in Automatic Telephone Exchanges", Elektroteknikeren, vol 13, 1917.
- "The life and works of A.K. Erlang", E. Brockmeyer, H.L. Halstrom and Arns Jensen, Copenhagen: The Copenhagen Telephone Company, 1948.

## Queueing Theory Homepage

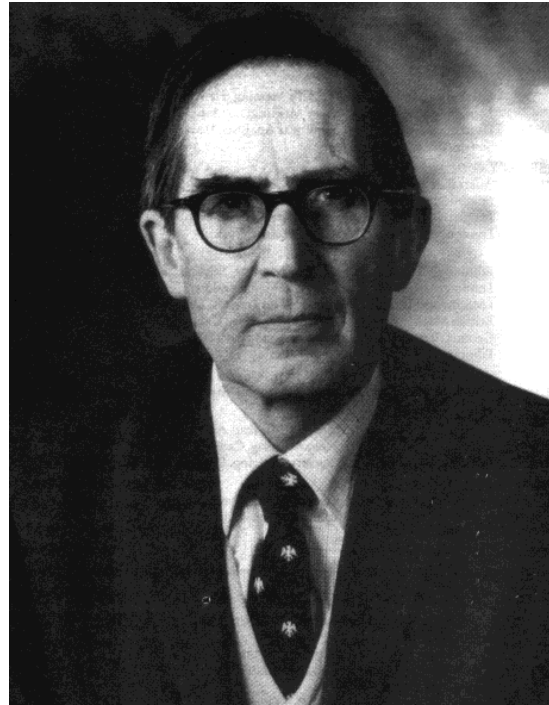
<http://web2.uwindsor.ca/math/hlynka/queue.html>

# Applications

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- Telephony, Call Centers
- Manufacturing
- Inventories
- Dams
- Supermarkets
- Computer and Communication Systems
- Sensor Networks, IoT
- Infocommunication Networks, Clouds
- Hospitals
- Many others

# Kendall's Notation



David G. Kendall, 1918-2007

$A/B/c/K/m/Z$

# Performance Metrics

- Utilizations
- Mean Number of Customers in the System / Queue
- Mean Response / Waiting Time
- Mean Busy Period Length of the Server
- Distribution of Response / Waiting Time
- Distribution of the Busy Period
- Distribution of Number of Customers Served during a Busy Period
- Distribution of Number of Retrials until Service Completion

# Solution Methodologies

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- Analytical
- Numerical
- Asymptotic
- Simulation
- Tool Supported Solutions



# Tool Supported Modeling

- University of Dortmund: *HIT, HiQPN, APNN*  
<http://ls4-www.informatik.uni-dortmund.de/tools.html/>
- University of Illinois at Urbana-Champaign: *MÖBIUS*  
<http://www.mobius.uiuc.edu/>
- University of Erlangen: *PEPSY, MOSEL*  
<http://www4.informatik.uni-erlangen.de/Projects/MOSEL/>
- University of Oxford: *PRISM*  
<http://www.prismmodelchecker.org/>

# Software and Information

<http://web2.uwindsor.ca/math/hlynka/qsoft.html>

<http://mason.gmu.edu/~jshortle/QtsPlus-4-0.zip>

## **QSA ( Queueing Systems Assistance)**

<https://qsa.inf.unideb.hu>

## **Lecture Notes**

[https://irh.inf.unideb.hu/~jsztrik/education/16/SOR\\_Main\\_Angol.pdf](https://irh.inf.unideb.hu/~jsztrik/education/16/SOR_Main_Angol.pdf)

[https://irh.inf.unideb.hu/~jsztrik/education/16/Queueing\\_Problems\\_Solutions\\_2021\\_Sztrik.pdf](https://irh.inf.unideb.hu/~jsztrik/education/16/Queueing_Problems_Solutions_2021_Sztrik.pdf)







# Introduction of QSA and Case Studies

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**QSA ( Queueing Systems Assistance)**

<https://qsa.inf.unideb.hu>






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-  GEBALI, F. *Analysis of Computer and Communication Networks*, Springer, 2008
-  KOUVATSOS, D. *Network Performance Engineering, A Handbook on Convergent Multi-Service Networks and Next Generation Internet*, Springer, 2011
-  MISIS, J., MISIC, V.B. *Performance Modeling and Analysis of Bluetooth Networks: Polling, Scheduling and Traffic Control*, Auerbach Publications, 2006

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for Your  
Attention*