Management Practice

3. Supply

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MPiE

Course

Literature for the course:

Eisner, Howard. *Essentials of project and systems engineering management*. John Wiley & Sons, 2008.

Learning objective for this session:

- Able to define logistics and supply chain
- Able to state factors that influence the supply chain
- Able to provide a mathematical model for queuing
- Able to apply a model of queuing on to a problem

Literature for this session:

- Wagner, Stephan M., and Nikrouz Neshat. "Assessing the vulnerability of supply chains using graph theory." *International Journal of Production Economics* 126.1 (2010): 121-129.
- Little, John DC, and Stephen C. Graves. "Little's law." *Building intuition*. Springer, Boston, MA, 2008. 81-100.

Intro

Supply chain

The sequence of activities that take a product from a raw material to a consumable good.

50-70% The percentage of a company's profits that can be eaten up by supply chain and logistics costs.[1]

Supplier

A person or group in the supply chain that provides the materials, goods, or services needed to create a product.

From 10 to 10,000 The number of suppliers in a supply chain can vary greatly. A major retailer may have thousands, while a small mom-and-pop shop could have just a few.

Distributor

Companies who deliver goods or services to places where they are stored or sold, like warehouses, stores, or directly to customers.

$4 Billion USD

Projected increase in revenues from digital music distribution from 2015 to 2020. In the era of digital supply chains, distributors deliver more than just physical goods.[5]

Supply chain management (SCM)

Oversight of the manufacturing, distribution, and transportation of a product from raw material to finished good.

$10 Billion USD

Loss in revenue caused by Typhoon Halong in 2014, which severely disrupted supply chains in Southeast Asia. Managing disruptions is a top priority for supply chain managers.[2]

Inventory

Materials, parts, or finished products that are stored until ready for use. Suppliers stock inventories of raw materials to send to buyers. Retailers keep inventories of ready-to-sell products on hand.

95% The accuracy level of retailers' inventory data when they use item-level tagging (such as RFID tags) to track their merchandise. Tagging helps retailers know precisely what they have and where it's located.[6]

Logistics

Logistics ensure that a product moves efficiently through the supply chain – making sure that everything is at the right place at the right time.

37 Cents USD Total logistics cost of delivering a $3.60 box of cereal. The U.S. net retail profit is about 5 cents.[3]

Manufacturer

A maker of products. Manufacturers assemble, refine, or otherwise transform materials into a developed product.

$1.40 USD The amount added to the U.S. economy for every $1.00 spent in manufacturing – the highest multiplier effect of any economic sector. The manufacturing industry is a critical part of a national economy.[4]

Visibility

Knowing where products are located, the ability to monitor order progress, and the ability to anticipate unplanned events in the supply chain.[7]

96% Percentage of electronics manufacturers who said that lack of visibility increases risks in the supply chain – like long lead times, extra shipping time, and difficulty managing their capacity.[8]

Sources. 1: Paul Myerson: Introduction to Supply Chain and Logistics Management Made Easy, April 2015 2: Supply Management: The top five supply chain disruptions of 2014, 2015 3: Project44: Global Supply Chain Statistics, 2015 4: National Association of Manufacturers: Top 20 Facts About Manufacturing, 2015 5: Statista: Global digital music industry revenue 2015-2020, 2016 6: GS1 US: RFID is Gaining Traction, 2015 7: Red Prairie: The Struggle for Visibility in Global Supply Chains, 2011 8: Jabil: 2015 Supply Chain Trends [Infographic]

Operations Management of Logistics and Supply Chain

- Organizations adopt numerous business improvement methodologies to improve business performance.

- Logistics and supply chain management are regarded to be the crucial factor for the companies to obtain competitive edge.

Source: Operations Management of Logistics and Supply Chain, 2014

Logistics as process

- Logistics is the **process** of planning, implementing, and controlling the efficient, effective **flow and storage of goods**, **services**, and related **information** from point of origin to point of consumption for the purpose of conforming to customer requirements

Source: Council of Supply Chain Management Professionals

Logistics management

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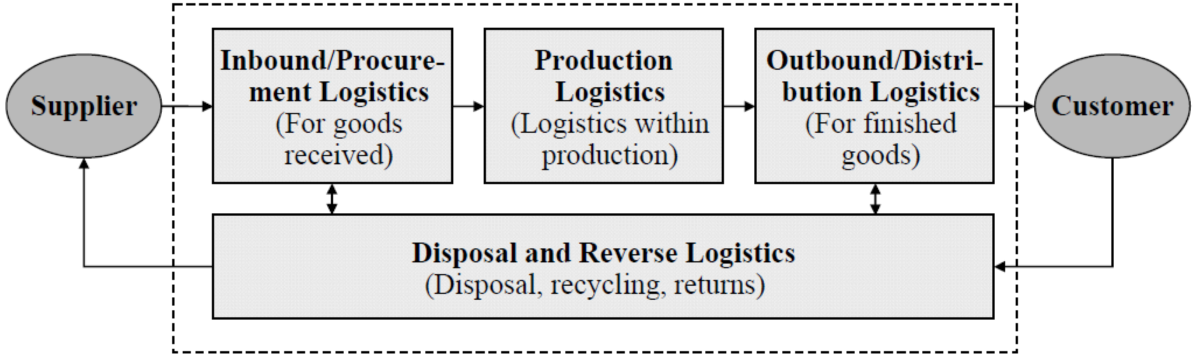
- Logistics is the management of **the flow of goods** between the point of origin and the point of consumption in order to meet some requirements, for example, of customers or corporations.
- The resources managed in logistics can include **physical items, such as food, materials, animals, equipment, and liquids, as well as abstract items, such as time, information, particles, and energy**.
- The logistics of physical items usually involves the integration of information flow, material handling, production, packaging, inventory, transportation, warehousing, and often security.

Source: Operations Management of Logistics and Supply Chain, 2014

Logistics

Logistics can be differentiated into :

1. Inbound logistics for purchased goods
2. Production logistics in production
3. Distribution logistics for finished goods
4. Disposal and reverse logistics for recycled, returned or disposed goods



Source: Corsten & Gössinger 2001

Supply chain

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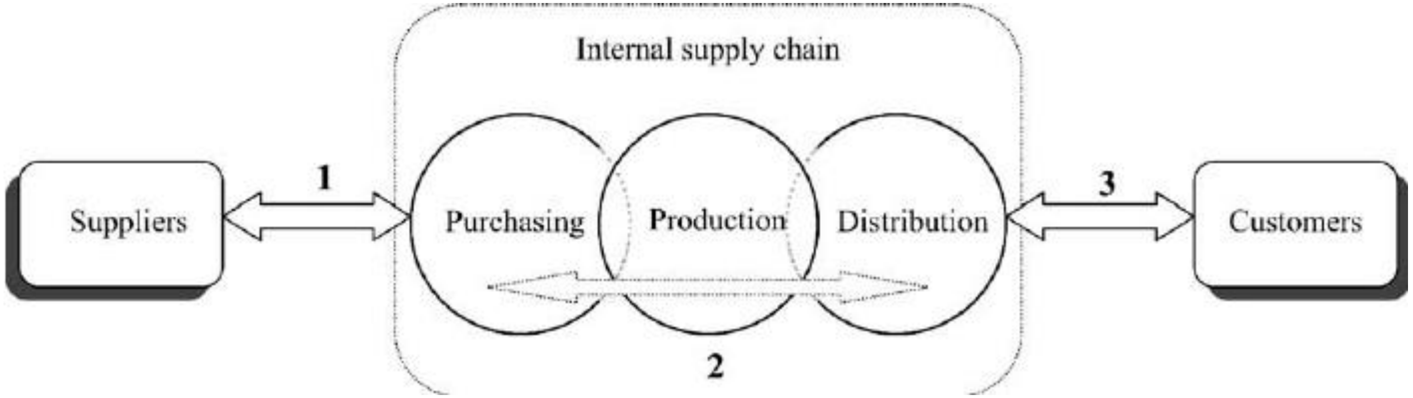
- Both supply chain and logistics are relevant to the **product circulation** during its whole life cycle, and both have been regarded as the central unit for competitive analysis.

- Supply chain can be seen as a broader concept with a wider range, as it can involve **network sourcing, supply pipeline management**, **value chain management and value stream management**.

Source: Operations Management of Logistics and Supply Chain, 2014

Supply chain - Internal



Understanding the supply chain is essential, so mapping out any uncertainties greatly helps in the management.

Source: Chen & Paulray (2004)

Uncertainty defined in scientific literature

Uncertainty in the supply chain can come from:

1. Supplier uncertainty, arising from on-time performance, average lateness and degree of inconsistency

2. Manufacturing uncertainty, arising from e.g. process performance, machine breakdown, supply chain performance.

3. Customer or demand uncertainty, arising from e.g. forecasting errors, irregular orders.

Environmental uncertainty

1. Supply uncertainty includes indicators that represent quality, timeliness and the inspection requirements of the suppliers.
2. Demand uncertainty is measured in terms of fluctuations and variations in demand.
3. Technology uncertainty measures the extent of technological changes evident within the industry.

Source: Chen & Paulray (2004)

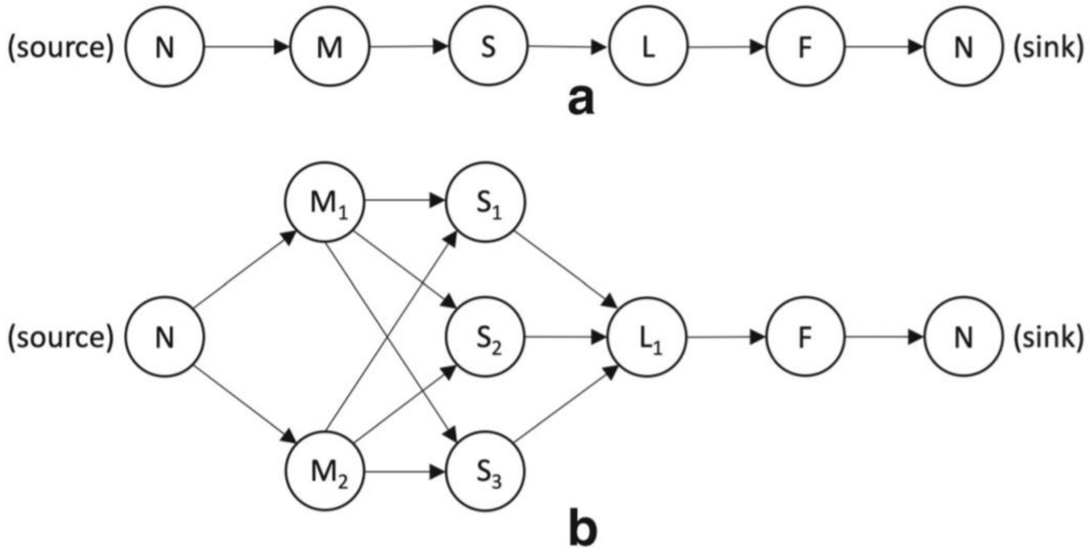
Need-driven supply chain

Customer focus

- Level of importance given to customers in the execution of strategic planning, quality initiatives, product customization and responsiveness.
- In general, the more attention a company pays to researching its customer base in order to identify customer needs, the more rewarding the exchange transaction in the supply chain will be for that company.
- Despite the use of the latest process improvement techniques and capable management, a firm's neglect of its customers may lead to disaster. A need-driven approach to the supply-chain is therefore very suitable.

Source: Chen & Paulray (2004), (Carson et al., 1998); (Kordupleski et al., 1993)

Need-driven approach



Need analysis and filtering as a network. (**a**) The vertex N contains a set of needs that flow through stages of market analyses M, stakeholder analyses S, and landscape analyses L to reach a filtered state F that yields a set of final needs. (**b**) The vertex for market analyses can be further seperated, with M_1 taking a top-down approach and M_2 a bottom-up. Stakeholder analyses can be split into in-depth interviews or re-immersions S_1, shorter interviews or phone calls S_2, and online research S_3. L_1 represents a single approach to landscape analyses to be conducted, but others could be added

Source: Soliman et al (2020)

Top management support

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- Research has shown that top management must be aware of the competitive benefits that can be derived from the impact of **strategic purchasing and information technology** on effective supply relationships.

- Top management support can be characterized in terms of **time and resources contributed by the top management to strategic purchasing, supplier relationship development and adoption of advanced information technology**.

Source: Hahn et al. (1990), Monczka et al. (1993), Krause and Ellram (1997)

Competitive priorities

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- Competitive priorities are used to describe manufacturers' choice of manufacturing tasks or key competitive capabilities, which are broadly expressed in terms of low cost, flexibility, quality, and delivery.

- This provides the following dimensions for competitive priorities:

- Quality
- Lead-time
- Cost
- Flexibility

Source: Skinner (1969), Hayes and Wheelwright (1984)

Competitive priorities

Dimensions of quality:

- Performance - the primary operating characteristics.
- Features - optional extras (the "bells" and "whistles").
- Reliability - likelihood of breakdown.
- Conformance - conformance to specification.
- Technical durability - length of time before the product becomes obsolete.
- Serviceability - ease of service
- Aesthetics - look, smell, feel, taste.
- Perceived quality - reputation.
- Value for money.

Competitive priorities

Dimensions of time:

- Manufacturing lead time.
- Due date performance.
- Rate of product introduction.
- Delivery lead time.
- Frequency of delivery.

Competitive priorities

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Dimensions of price and cost:

- Manufacturing cost.
- Value added.
- Selling price.
- Running cost - cost of keeping the product running.
- Service cost - cost of servicing the product.
- Profit.

Competitive priorities

Dimensions of flexibility

- Material quality - ability to cope with incoming materials of varying quality.
- Output quality - ability to satisfy demand for products of varying quality.
- New product - ability to cope with the introduction of new products.
- Modification - ability to modify existing products.
- Deliverability - ability to change delivery schedules.
- Volume - ability to accept varying demand volumes.
- Product mix - ability to cope with changes in the product mix.
- Resource mix - ability to cope with changes in the resource mix.

Information technology to improve competitive priorities

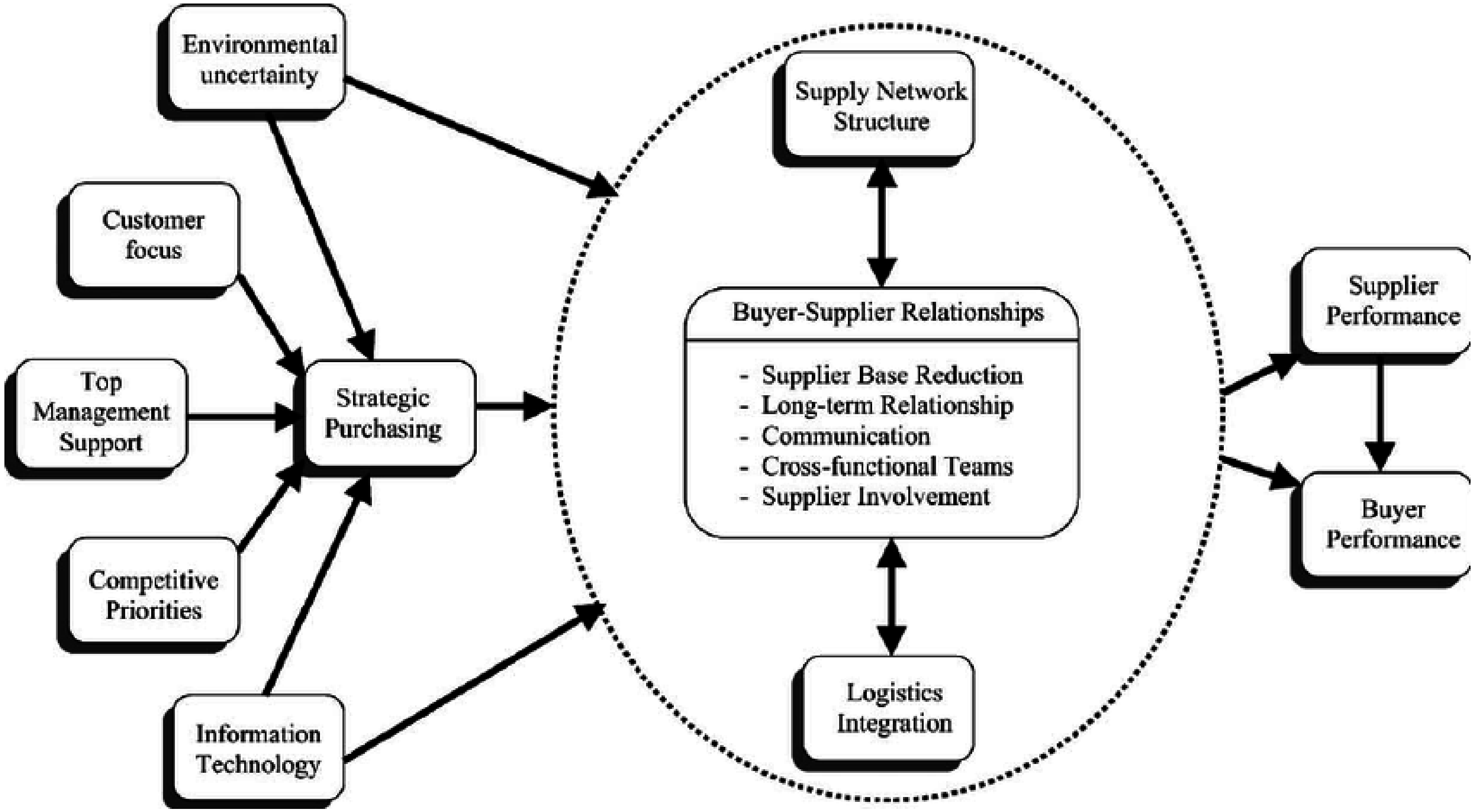
- The term “information technology” includes computers, ancillary equipment (including imaging peripherals, input, output, and storage devices necessary for security and surveillance), peripheral equipment designed to be controlled by the central processing unit of a computer, software, firmware and similar procedures, services (including support services), and related resources.

- It is captured as the presence of electronic transactions and communication in various forms between the supply chain partners

- It requires the ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged (**interoperability**).

Source: Greis and Kasarda (1997), Carr and Pearson (1999), HIMSS 2010, Federal Register

Supply chain – Theory based on literature



Source: Chen & Paulray (2004)

Supply chain management (SCM)

The term SCM has been used to explain the **planning and control** of materials and information flows as well as the logistics activities not only internally within a company but also externally between companies.

The concept of Supply Chain Management (SCM) is based on two key ideas:

- The first is that practically every product that reaches an end user represents the **cumulative effort** of multiple organizations. These organizations are referred to collectively as the supply chain.
- The second idea is that while supply chains have existed for a long time, most organizations have only paid attention to what was happening within their own company. The **entire chain of activities** that ultimately delivered products to the final customer was often not well understood let alone managed. The result was disjointed and often ineffective supply chains.

Source: NC State University; (Cooper et al., 1997b; Fisher, 1997)

Supply chain management (SCM)

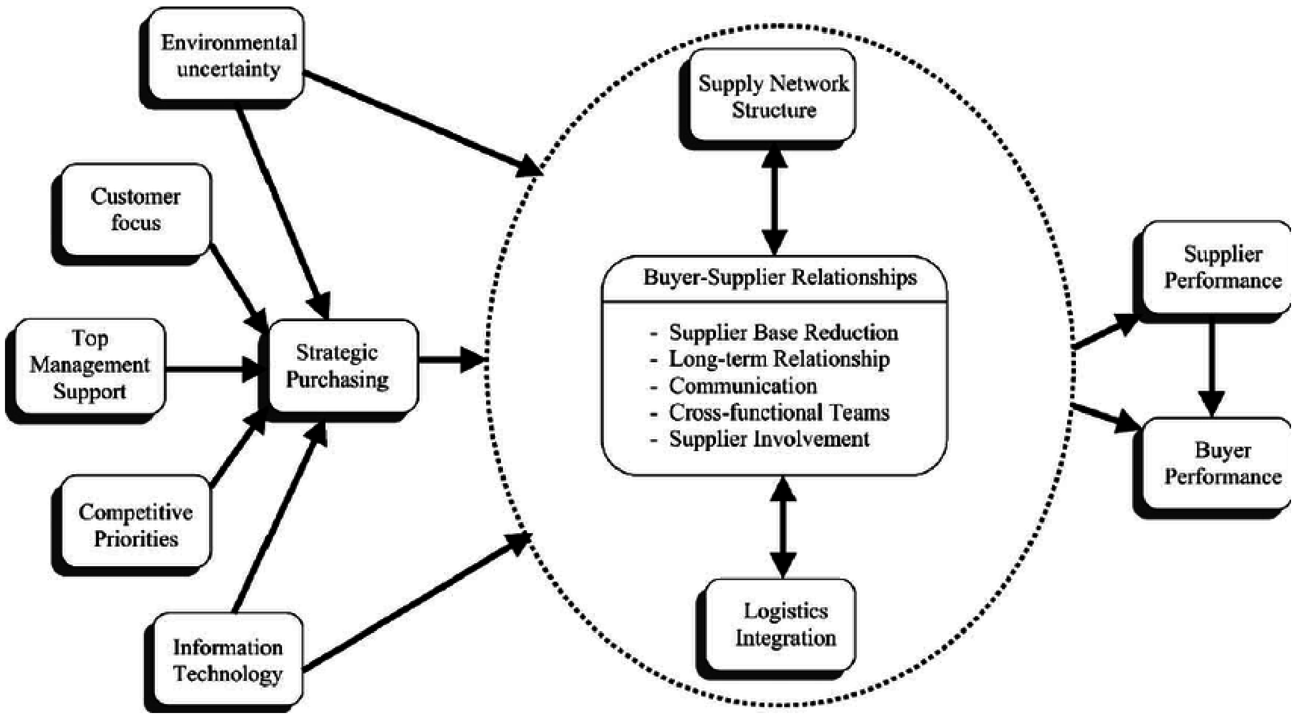
- The organizations that make up the supply chain are “linked” together through physical flows and information flows.
- **Physical flows** involve the transformation, movement, and storage of goods and materials. They are the most visible piece of the supply chain.
- **Information flows** allow the various supply chain partners to coordinate their long-term plans, and to control the day-to-day flow of goods and materials up and down the supply chain.

Source: NC State University

Supply chain

- Think about the supply chain factors.

- What do you "purchase"?
- What do you "produce"?
- What do you "distribute"?



An important practical factor is queuing

- Both logistics and supply chains are affected by queuing.
- Queuing is the amount of time a person, signal, or item spends before being attended to, or before value adding work is performed to or on it.
- It has been suggested that in many factories queue time makes up the majority of the total lead time.

Source: businessdictionary, 2017

Queuing

- A queuing system consists of discrete objects we call **items** that "arrive" at some rate into the system. Within the system the items may form one or multiple queues and eventually receive “service” and exit.
- Items in the system might be in queue, service or both.

- We don’t assume FIFO (first-in and first-out), so we consider the whole system as a queue plus service.

Source: doi: 10.1007/978-0-387-73699-0

Queuing

Little's Law (essentially a mathematical Theorem) asserts that the time average number of items in a queueing system (L) is equal to the product of the average rate at which items arrive per unit time and enter the system (λ) AND the average waiting time of a item (W).

$$L = \lambda W$$

Source: doi: 10.1007/978-0-387-73699-0

Queuing

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Little's Law asserts that the time-average number of items in a queueing system (L) is equal to the product of the average rate at which items arrive per unit time and enter the system (λ), as well as the average waiting time of a item (W).

$$L = \lambda W$$

This requires a stationarity assumptions of the underlying stochastic processes.

Source: doi: 10.1007/978-0-387-73699-0

Example

- The number of items in the queuing system over time *n(t), which is known*
- Time period (*T*) starts at 3 and ends at 20 days
- *N(T)* is number of cumulative **arrivals**
- Arrival rate during *T*

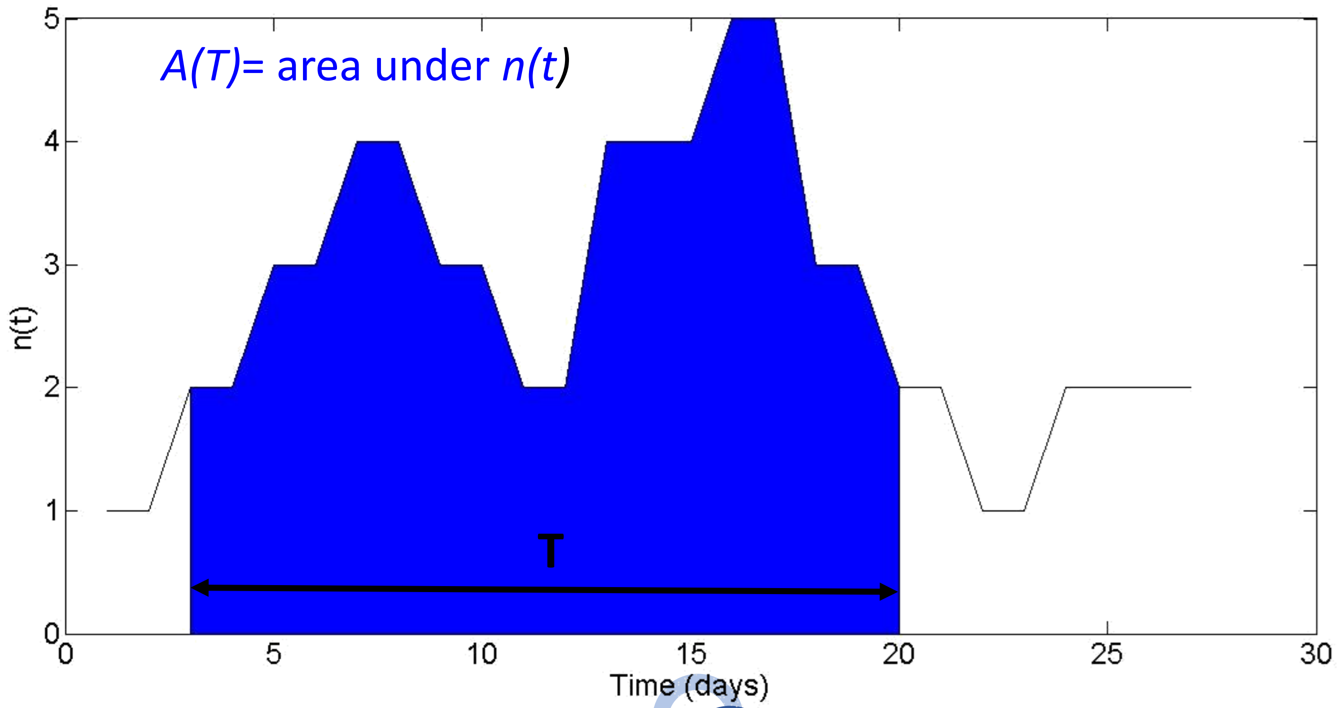
$\lambda(T)=N(T)/T \approx 0.3$

- Average queue length during T

$L(T)=A(T)/T \approx 3.3$

- Average waiting time during T

$W(T)=A(T)/N(T) \approx 11.2$



Example

- The number of items in the queuing system over time *n(t), which is known*
- Time period (*T*) starts at 3 and ends at 20 days
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- Average queue length during T

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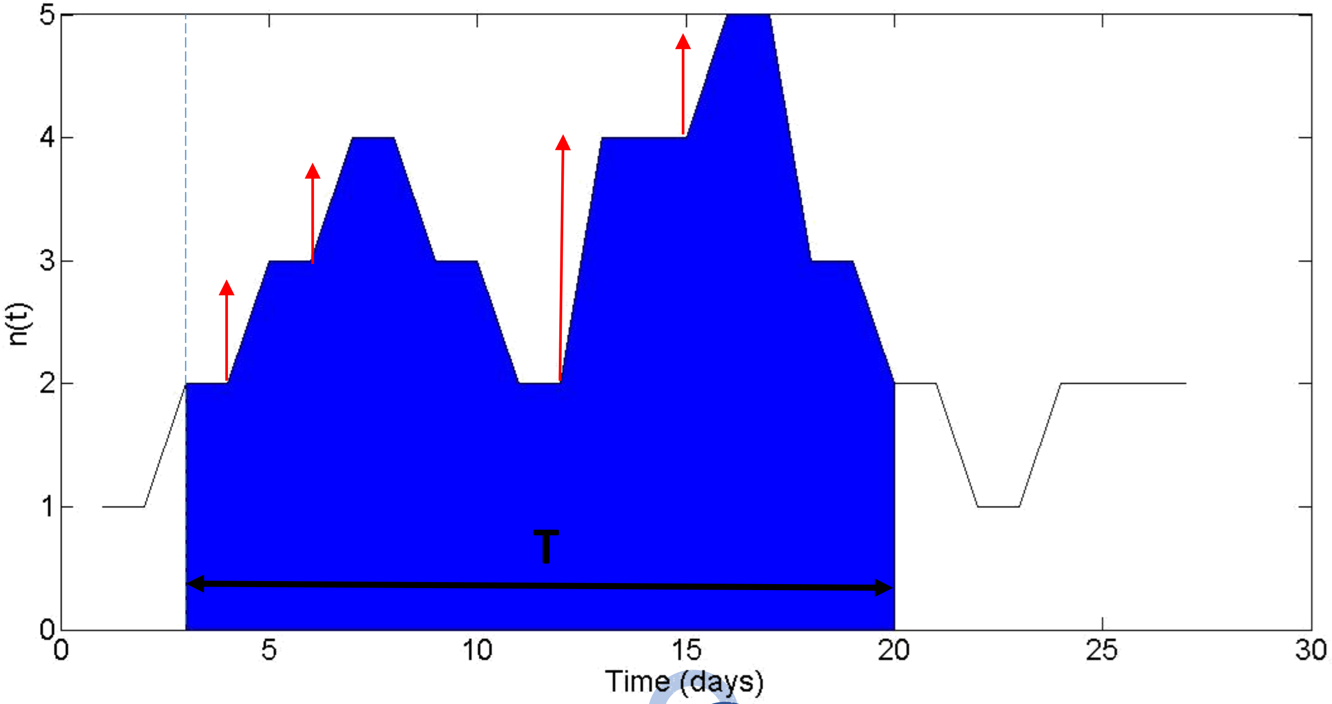
- Average waiting time during T

$W(T)=A(T)/N(T) \approx 11.2$

Assume this to be baseline



Example 2

- The number of items in the queuing system over time *n(t)*
- Time period (*T*) starts at 3 and ends at 20 days – **Unknown priors and *L(t)* is unknown**
- *N(T)* is number of cumulative **arrivals**
- **Arrival** rate during *T*

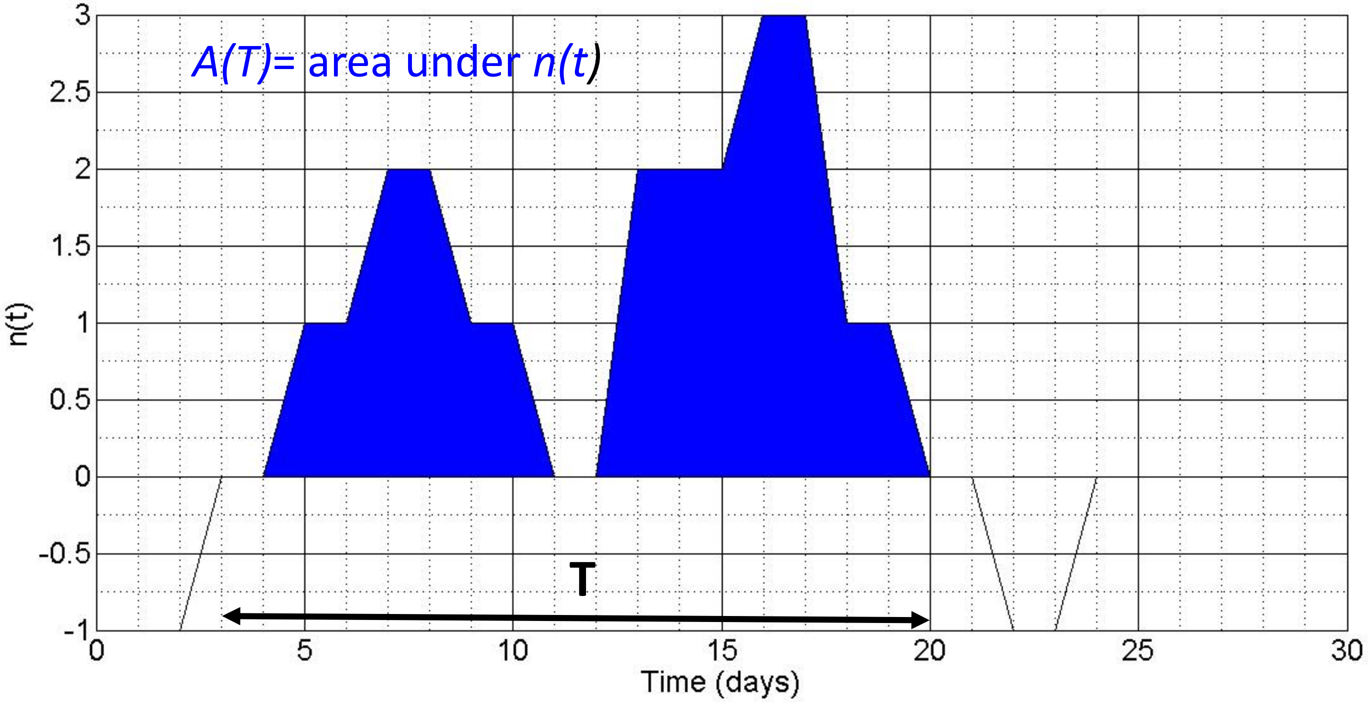
$\lambda(T)=N(T)/T \approx 0.3$

- Average queue length during T

$L(T)=A(T)/T \approx 1.3$

- Average waiting time during T

$W(T)=A(T)/N(T) \approx 4.4$



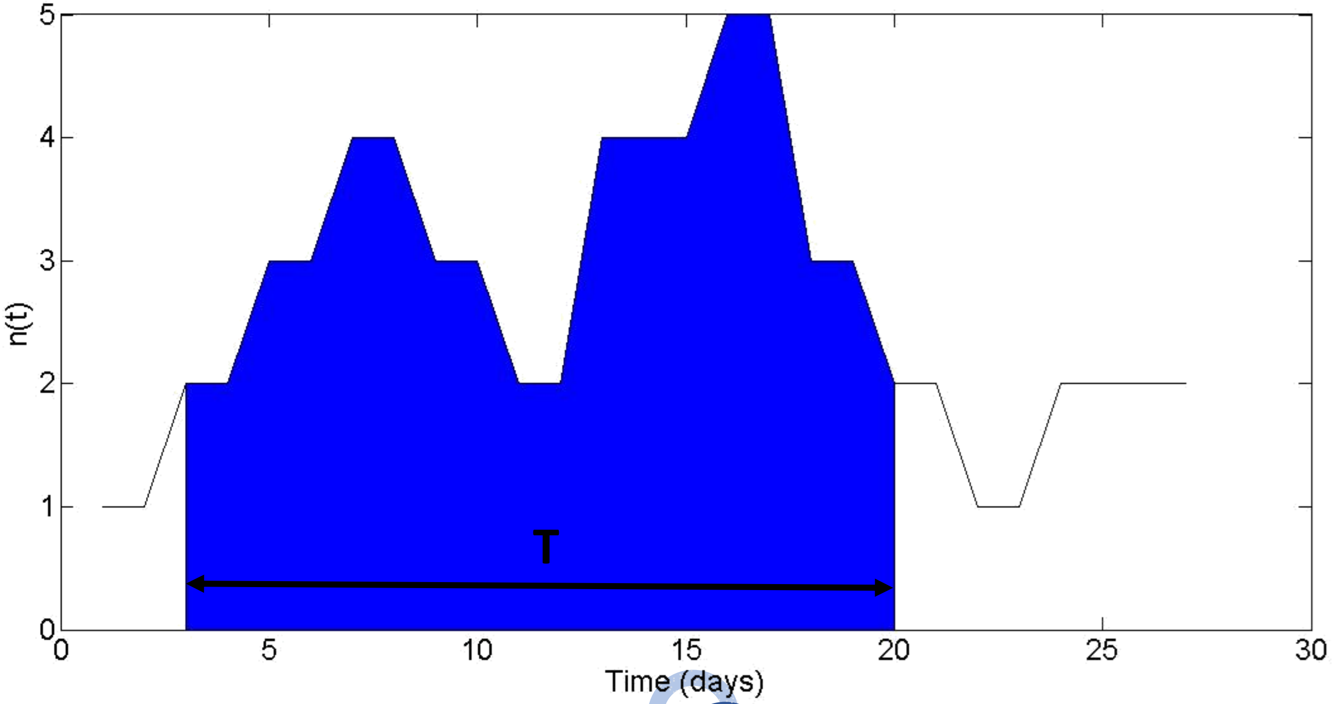
Queuing

- Keep in mind the stochastic nature (*{X(t)}* - random probability distribution)
- Keep in mind end effects (inclusion of waiting of items before *T* and exclusion of items arrived during *T* but not yet left)

$$\lim_{T\to\infty} L(T) = L$$

$$\lim_{T\to\infty} \lambda(T) = \lambda$$

$$\lim_{T\to\infty} W(T) = W$$

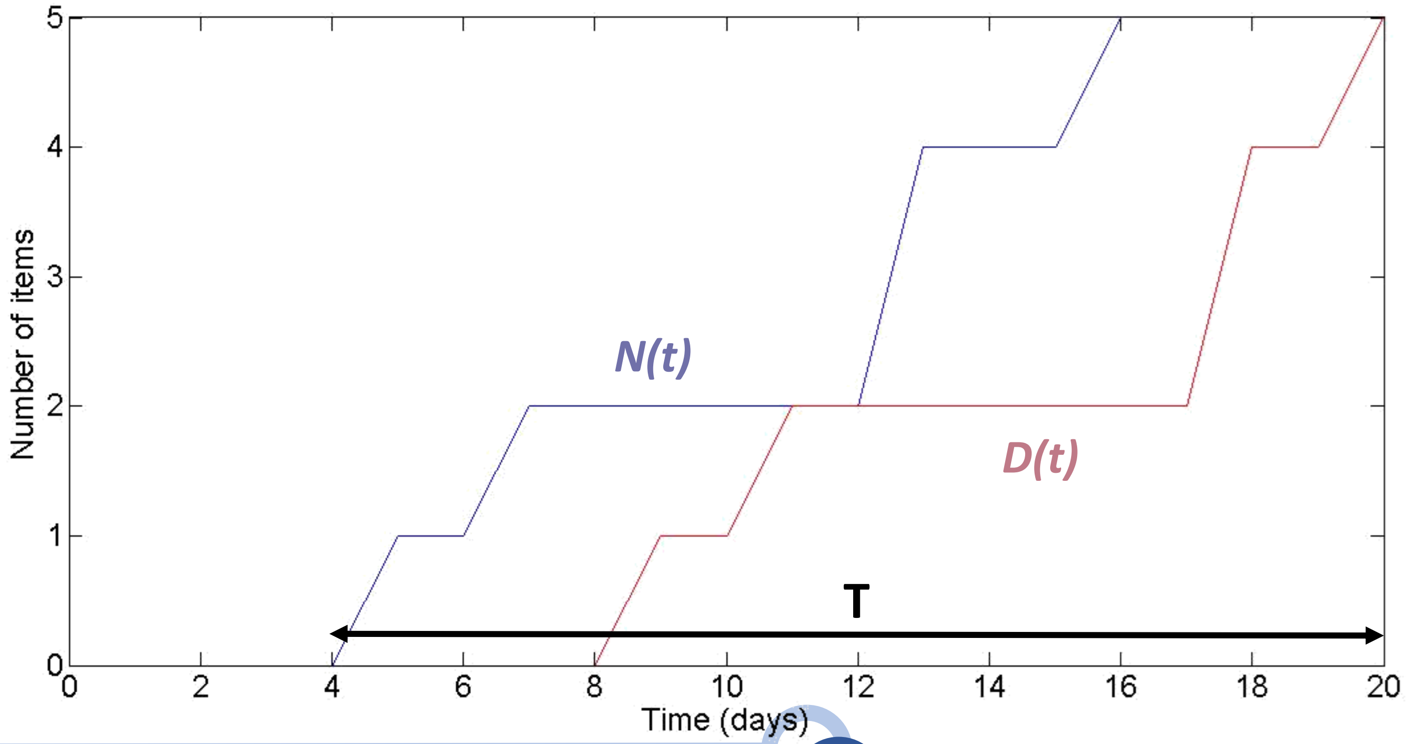


Queuing – average queue length

- *N(t)* is number of cumulative arrivals
- *D(t)* is number of cumulative departures

Based on N(t) and D(t), not on what is in the system

$$L = T^{-1} \int_{t_n=0}^{t_n=T} \left(N(t_n) - D(t_n)\right) dt_n$$



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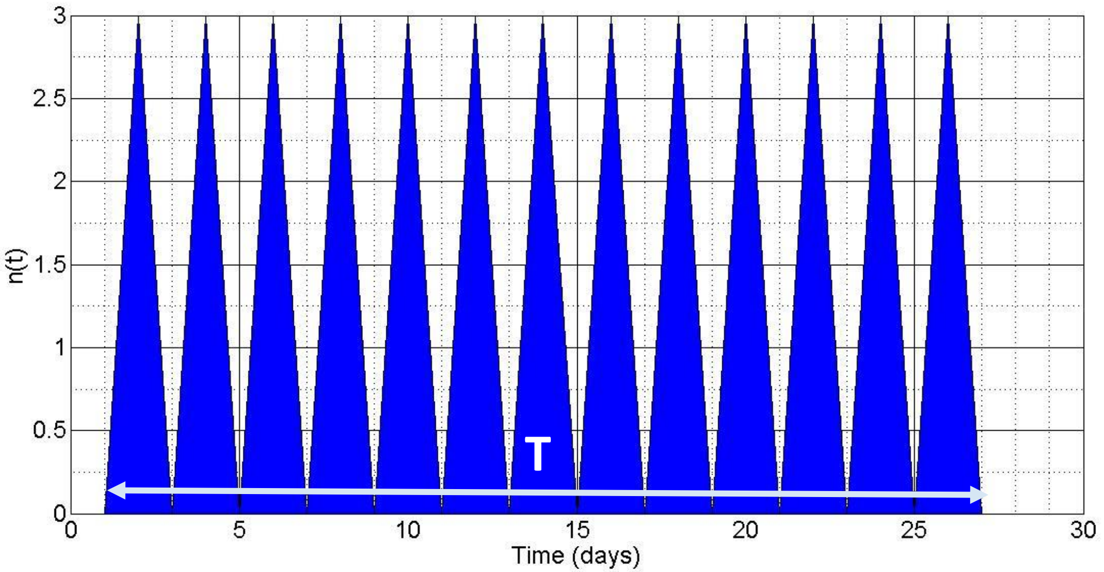
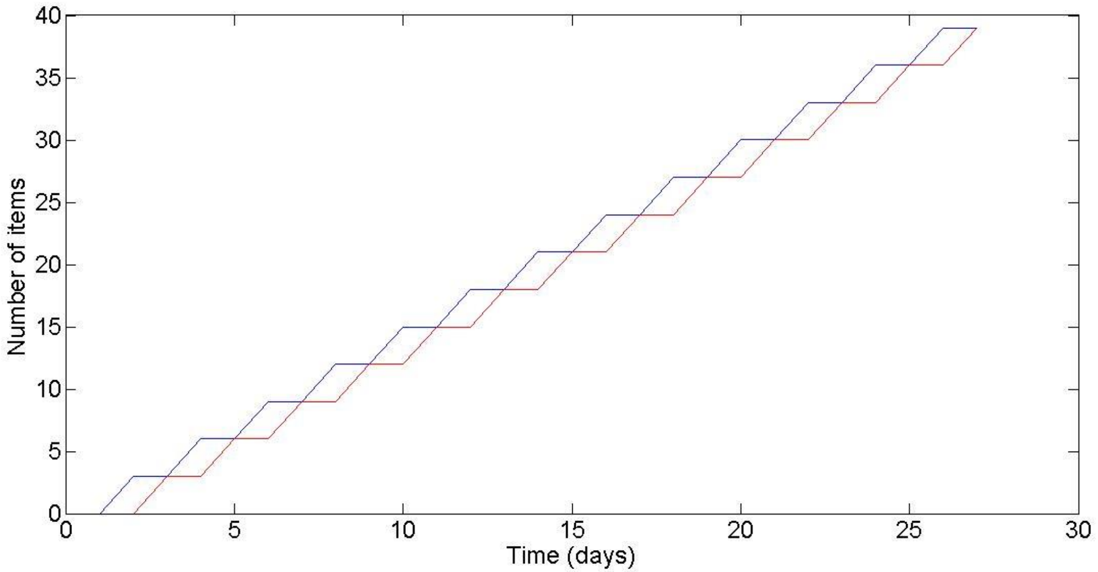
Queuing – average waiting time





Average waiting time during T

$$W(T) = N(T)^{-1}A(T) \;= 1$$
$$\lambda(T) = 1.5$$

Average waiting time during T

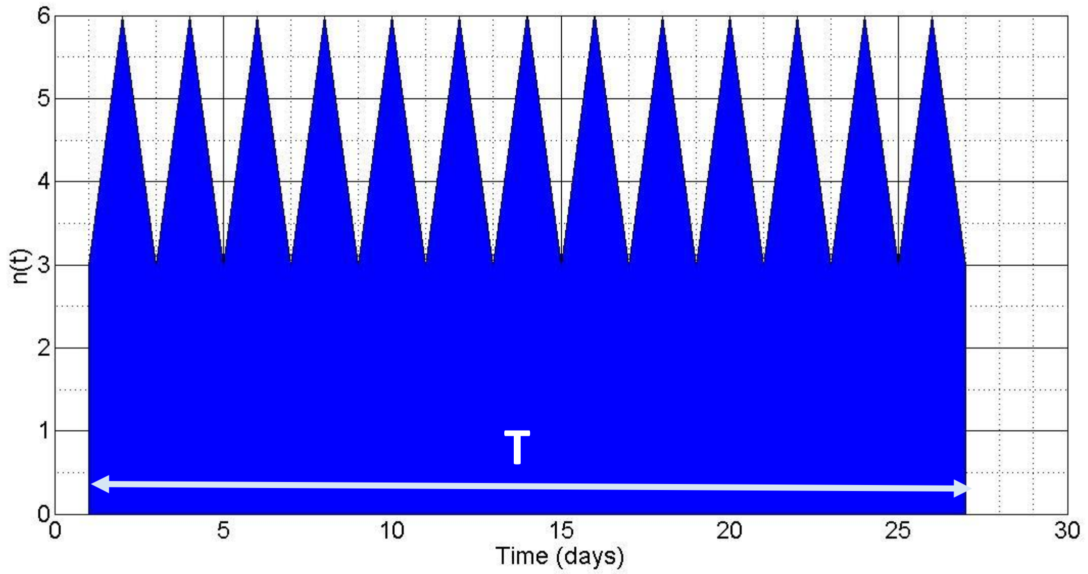
$$W(T) = N(T)^{-1}\int_{t_n=0}^{t_n=T}\big(N(t_n) - D(t_n)\big)dt_n = 1$$

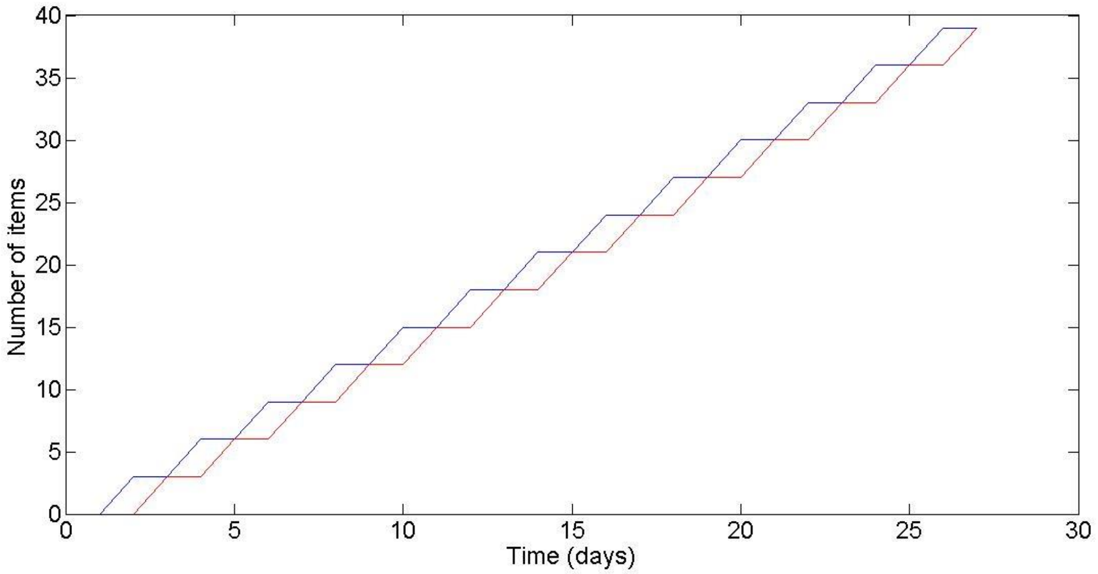
$$\lambda(T) = 1.5$$

Queuing – average waiting time

Effect of offset

A queue may never go to zero in *[0 T]* and *n(0)>0* as well as *n(T)>0*





Average waiting time during *T*

$$W(T) = N(T)^{-1}A(T) = 3$$
$$\lambda(T) = 1.5$$

Average waiting time during *T*

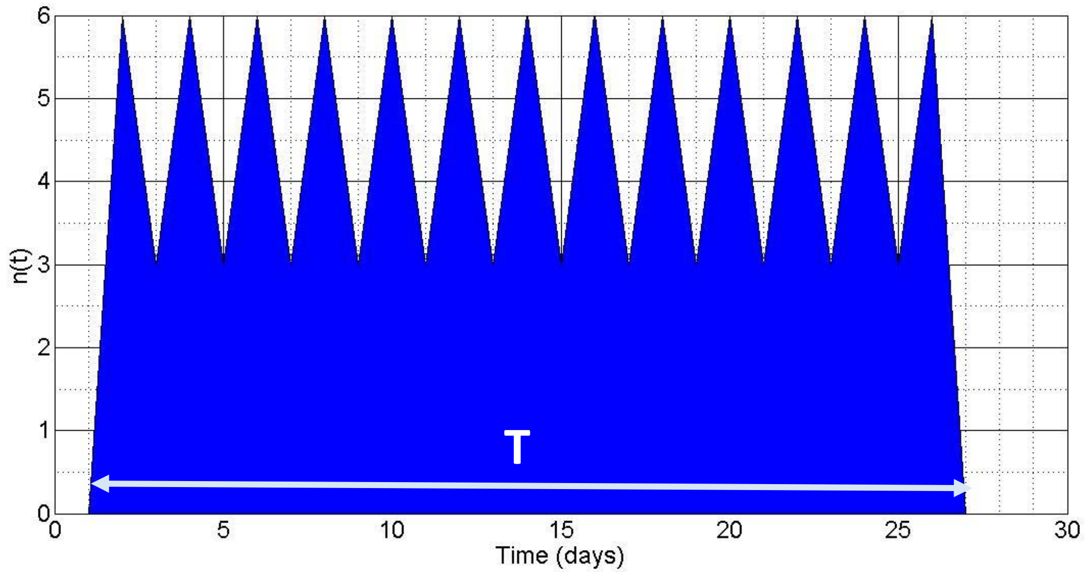
$$W(T) = N(T)^{-1}\int_{t_n=0}^{t_n=T}\big(N(t_n) - D(t_n)\big)dt_n = 1$$

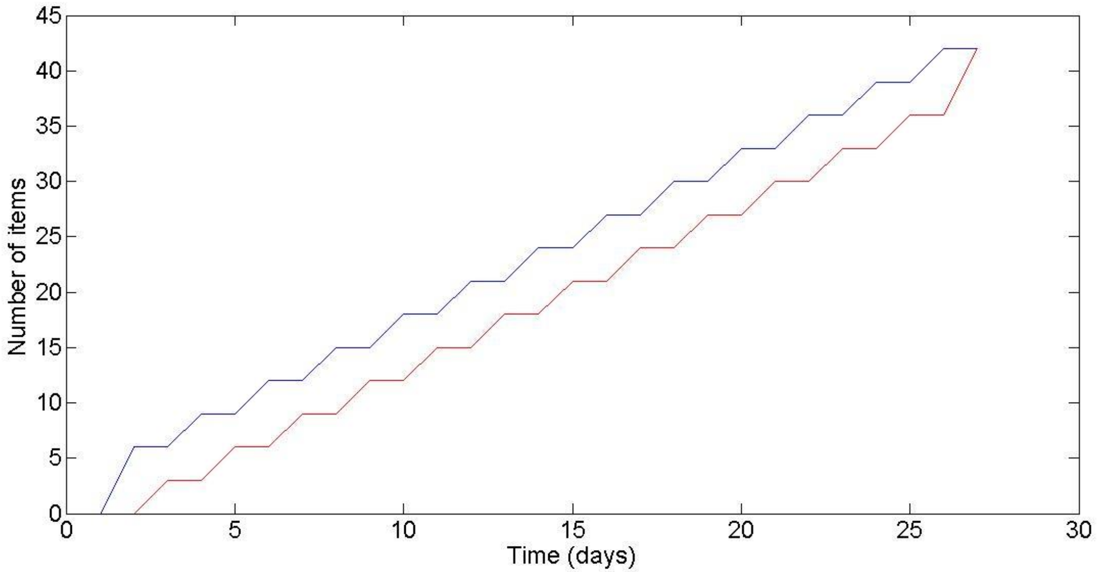
$$\lambda(T) = 1.5$$

Queuing – average waiting time

Effect of offset

A queue may never go to zero in *[0 T]* and *n(0)>0* as well as *n(T)>0*





Average waiting time during *T*

$$W(T) = N(T)^{-1}A(T) = 2.7143$$
$$\lambda(T) = 1.6154$$

Average waiting time during *T*

$$W(T) = N(T)^{-1}\int_{t_n=0}^{t_n=T}\left(N(t_n) - D(t_n)\right)dt_n = 2.7143$$

$$\lambda(T) = 1.6154$$

Queuing in Operations Management

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- *TH* =Throughput, the average output of a production process (machine, workstation, line, plant) per unit time
- *WIP* = Work In Process, the inventory between the start and end points of a product routing
- CT = Cycle Time (or flow time), the average time from release of a job at the beginning of the routing until it reaches an inventory point at the end of the routing (that is, the time the part spends as *WIP).*

$$\overset{\lambda}{TH} = \frac{\overset{L}{WIP}}{\underset{W}{CT}}$$

Source: doi: 10.1007/978-0-387-73699-0

Queuing in supply

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- If we take inventory (*I*) and keep throughput (*TH*) and cycle time (*CT*) we obtain

$$TH = \frac{I}{CT}$$

- Throughput is the rate at which an item is received and is sold out of stock

Kendall's notation for queues

Arrival distr.

Poisson – Markovian (M)

Service time distr.

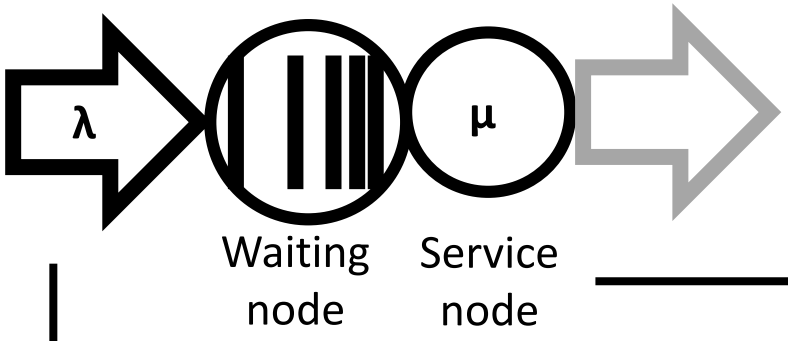
Poisson – Markovian (M)

Server number

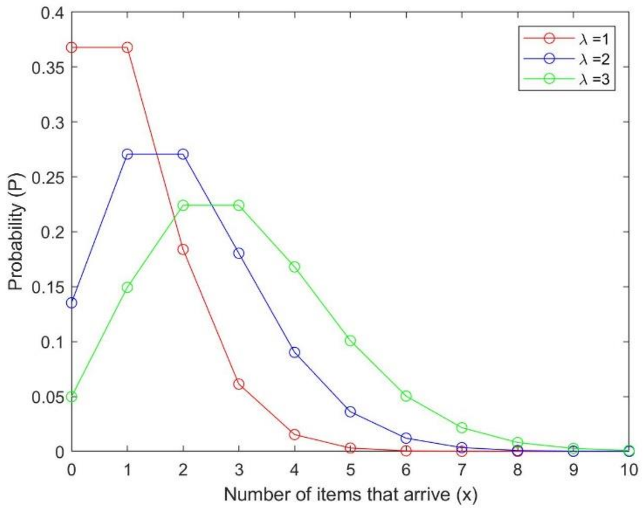
Number of servers (1)

M/M/1 queue

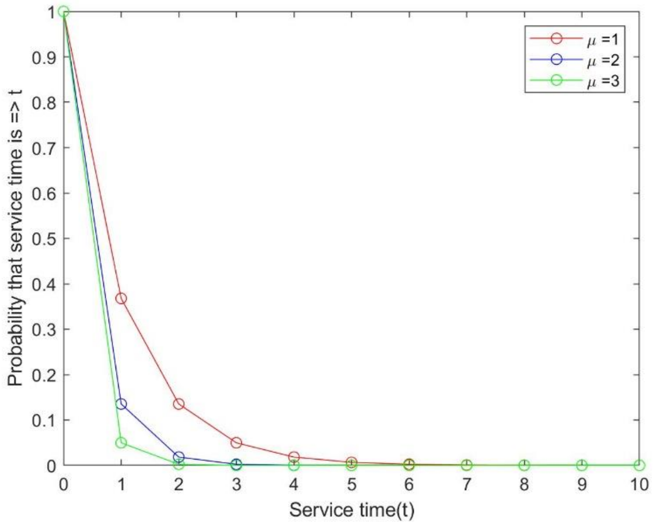
Single waiting area, where arriving follows a Poisson point process and a simple service distribution that follows the exponential distribution.



$$P(x) = \frac{e^{-\lambda}\lambda^{x}}{x!}$$



Discrete contribution



$$P(t) = e^{-\mu t}$$

M/M/1 queue

A *M/M/1* queue is one in which there is one ”machine” and both the inter-arrival time and service time are exponentially distributed.

The average utilization of the system (ρ) is given by:

$$\rho = \frac{\lambda}{\mu}$$

with μ being the mean service rate ($\frac{1}{T_{service}}$)and λ is mean arrival rate, ρ is also known as traffic intensity.

The mean number of items in the **queue** (L_q) is given by

$$L_q = \frac{\rho^2}{1-\rho} = \frac{\lambda^2}{\mu(\mu-\lambda)}$$

Thus, the wait in the **queue** (W_q) is

$$W_q = \frac{L_q}{\lambda} = W - \frac{1}{\mu} = \frac{\lambda}{\mu(\mu-\lambda)}$$

Recap: An exponential distribution with a mean of $\frac{1}{\lambda}$ has a variance of $\frac{1}{\lambda^2}$

The mean number of items in the **system** is given by

$$L = L_q + \frac{\lambda}{\mu}$$

The mean time an item spends in the **system** is

$$W = W_q + \frac{1}{\mu}$$

Queuing theory

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- Queuing theory is mathematical method of analysing the congestions and delays of waiting
- Define a waiting/queuing problem when a team of max 4 technicians have to attend to 30 users.
- For example think about managing the evaluation of information “sets” handed out (arrival / departure)

Questions?

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