Tema 4

Estudios de tráfico de buques

Versión 1.0

Diagrama de Flujo

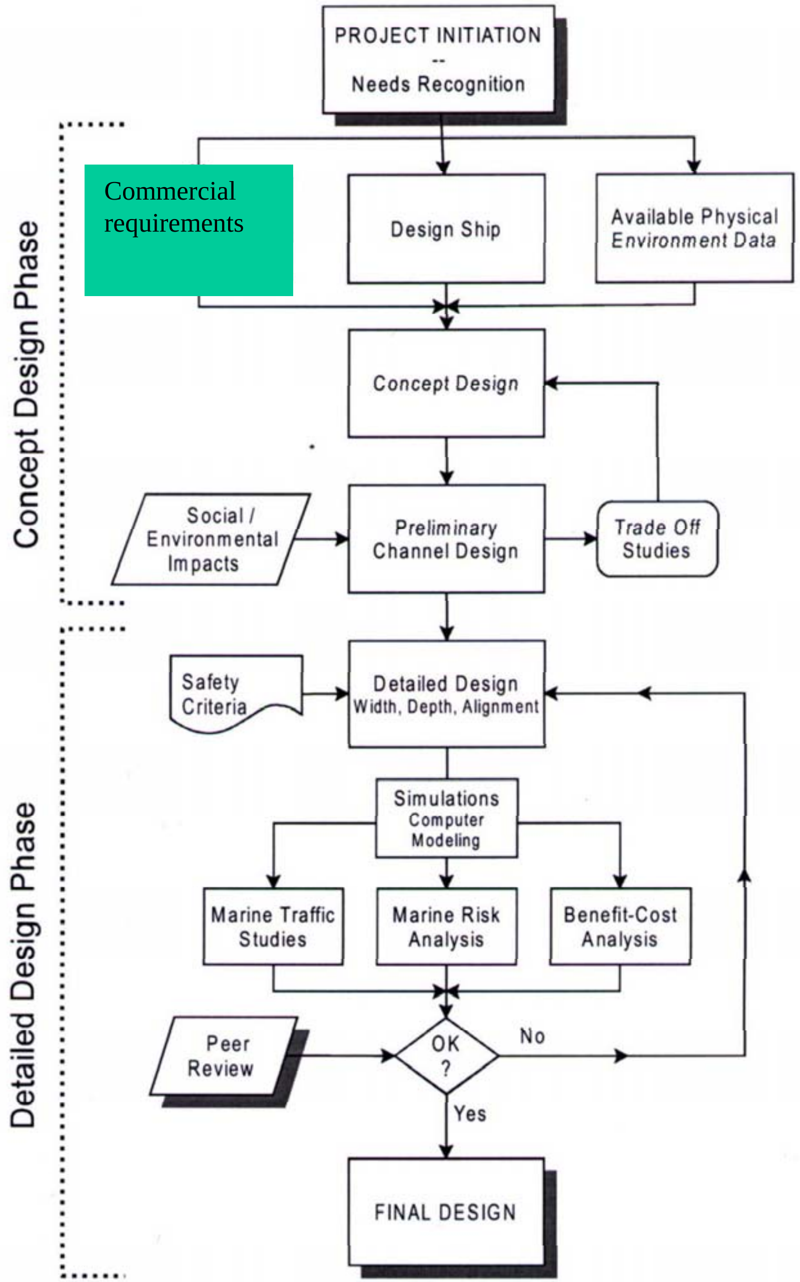


Figure 2.4. The Channel Design Process (after [4]).

Estudios de tráfico

- Estudio de mercado
  - El estudio de mercado estudia la evolución de las cargas
- Estudio de tráfico de buques

- Estudio de navegación (shipping) – Ver Tema 5
  - Estudia la evolución de las flotas de buques
- Determinación de capacidad del canal
  - Modelos
- Determinación de riesgos del sistema
  - Este tema se ve por separado al final del curso

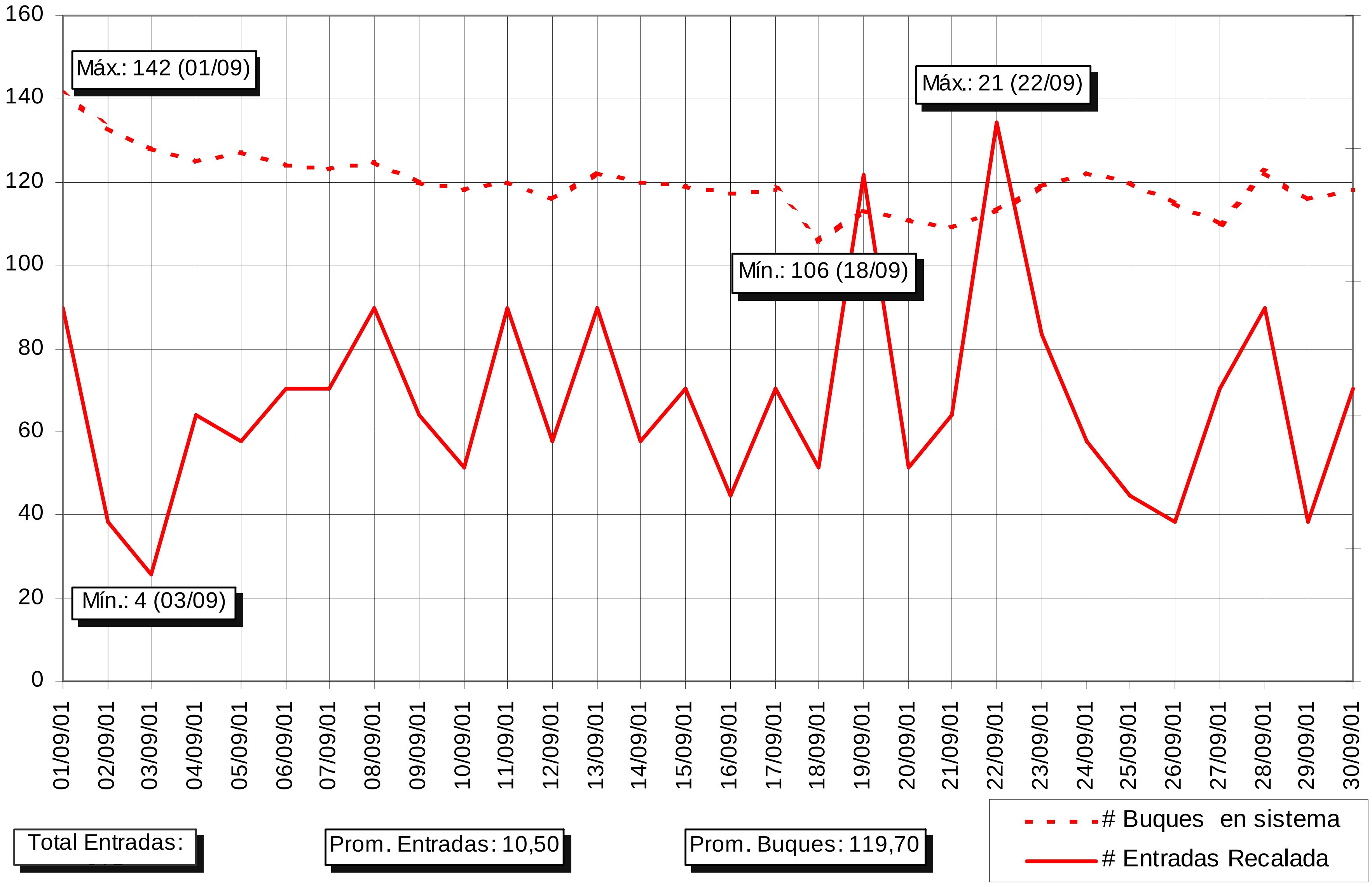
Estudio de mercado

- Estudia las cargas que se van a cargar a los buques
- Se utilizan los denominados modelos de transporte y asignación de cargas
- Determina tipo de carga y cantidad para cada uno de los puertos del sistema

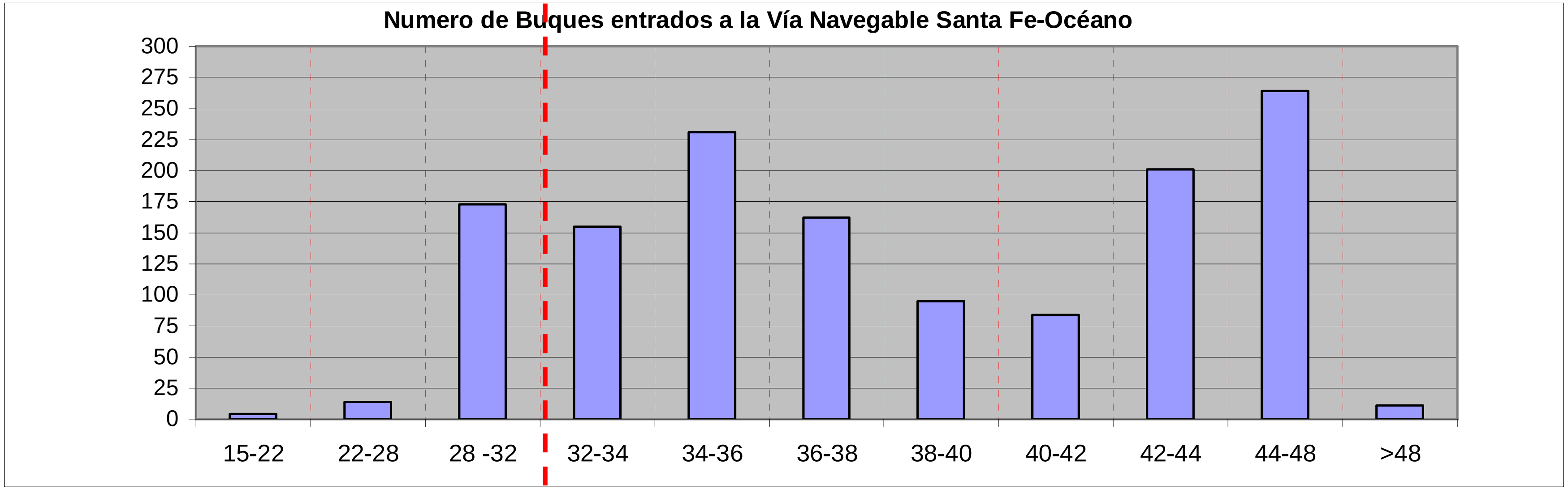
Estudio de tráfico de buques

- El estudio de tráfico debe dar la siguiente información
  - Cantidad y tipo de buques
  - Cargados o en lastre y en que dirección
  - Puertos que tocan
  - Tipo de carga
  - Obligación de cumplir horarios o no
  - Otras obligaciones
  - Proyecciones a 20 años basadas en estudios de transporte

Entradas y Buques en Sistema durante Septiembre 2001



Buques Graneleros - Año 2003											
Rango Calados	**15-22**	**22-28**	**28 -32**	**32-34**	**34-36**	**36-38**	**38-40**	**40-42**	**42-44**	**44-48**	**>48**
Buq. Entrados	4	14	173	155	231	162	95	84	201	264	11
Acumulado	4	18	191	346	577	739	834	918	1,119	1,383	1,394
< que cal (%)	***0.3%***	***1.3%***	***13.7%***	***24.8%***	***41.4%***	***53.0%***	***59.8%***	***65.9%***	***80.3%***	***99.2%***	***100.0%***



Determinación de la capacidad del canal

- Teoría de colas
- Modelos de simulación de tráfico de buques (Traffic flow simulation models)

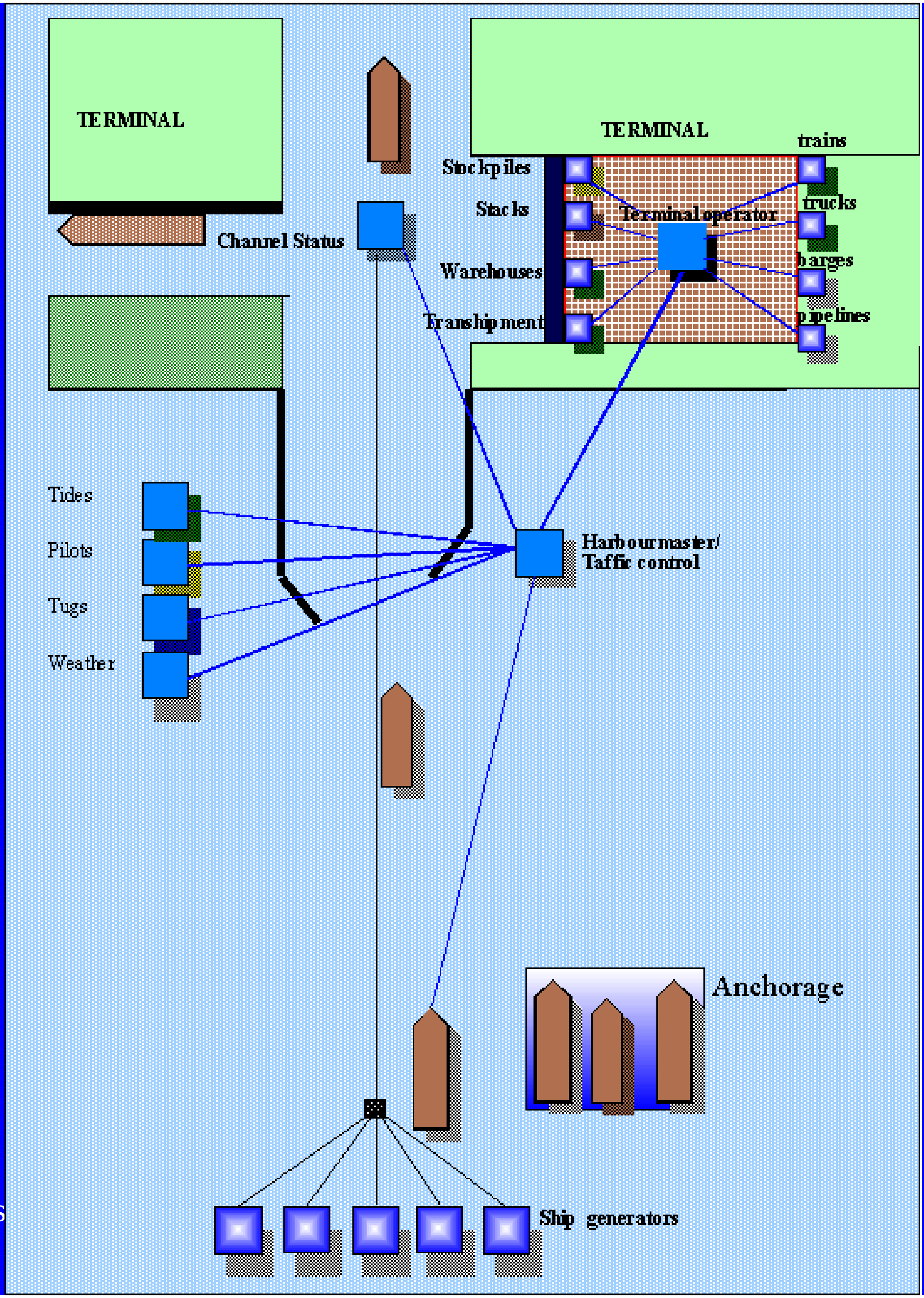
Questions to be answered

1 What is a service system

2 What do we want to know from the system

3 When do need information from the system

Question 1



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Question 1

WET INFRA STRUCTURE WITH:

1. Configuration (Anchorage, approach channel, turning basins, mooring basins, sail sections)

1. Tidal windows

2. Tugs and Pilots

3. Traffic situation

TERMINAL SYSTEMS WITH:

1. Quays or jetties
2. Quay cranes
3. Horizontal transport equipment
4. Storage facilities
5. Hinterland connections

Question 2

What do we want to know

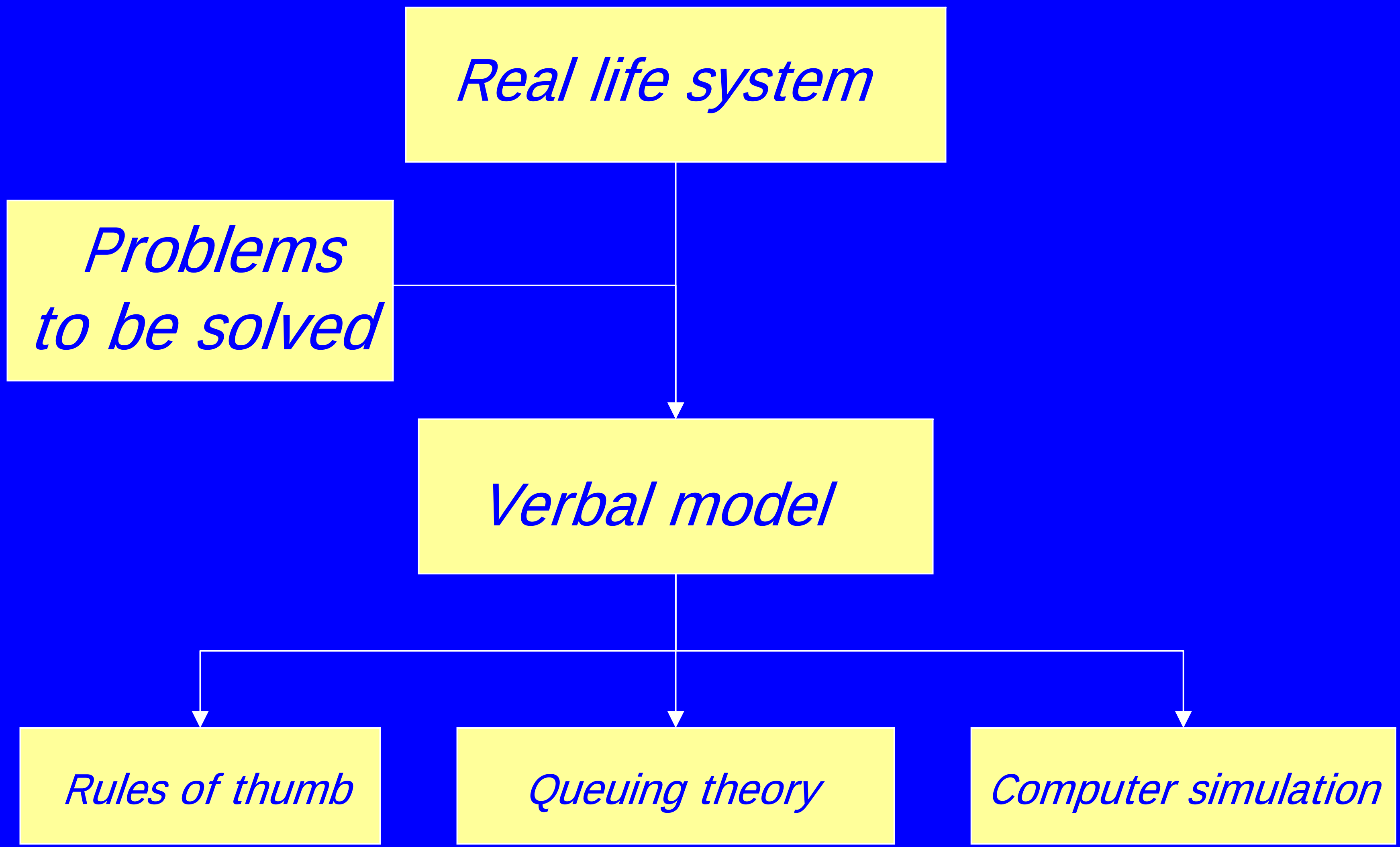
- Capacity versus service level (anchorage, dimensions infra structure, turnaround times, waiting times occupancies facilities)
- Safety versus facilities

Question **3**

When do we need this information

- bad functioning port
- predict and solve problems that may arise in the future
- check the design requirements

How to schematize a system to a model



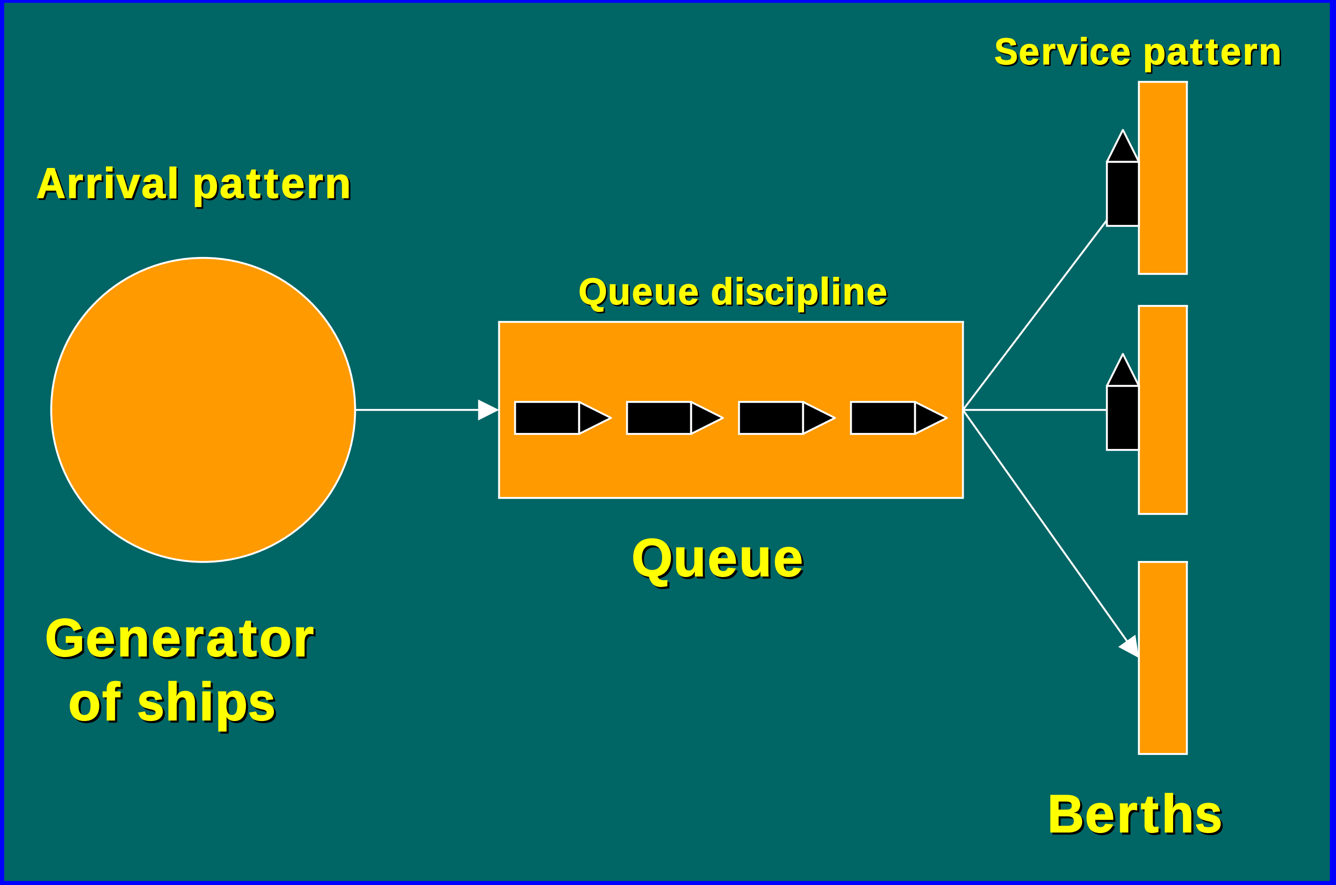
Modelo de simulación de tráfico

- El modelo puede ser **verbal**: Operaciones típicas Part V-5 pag 13
  - Muy buena descripción de como es la operación desde que sube el práctico hasta que atraca
- Modelo **parcial**
- El objeto de un modelo de simulación de flujo de tráfico es revelar si el canal propuesto con sus reglas operativas y condiciones ambientales puede manejar el volumen de tráfico existente y futuro y determinar las esperas de los buques y tiempos de operación. Se puede estimar la capacidad máxima del canal.

Componentes

- Un modelo de tráfico tiene las siguientes componentes
  - Función de arrivo de buques $F(t) = 1 - e^{-\mu t}$
  - Función de servicio Erlang – k (Ver documento adjunto **Erlang**)
  - Conditiones de marea
  - Conditiones ambientales
  - Tiempo de navegación

Simple system



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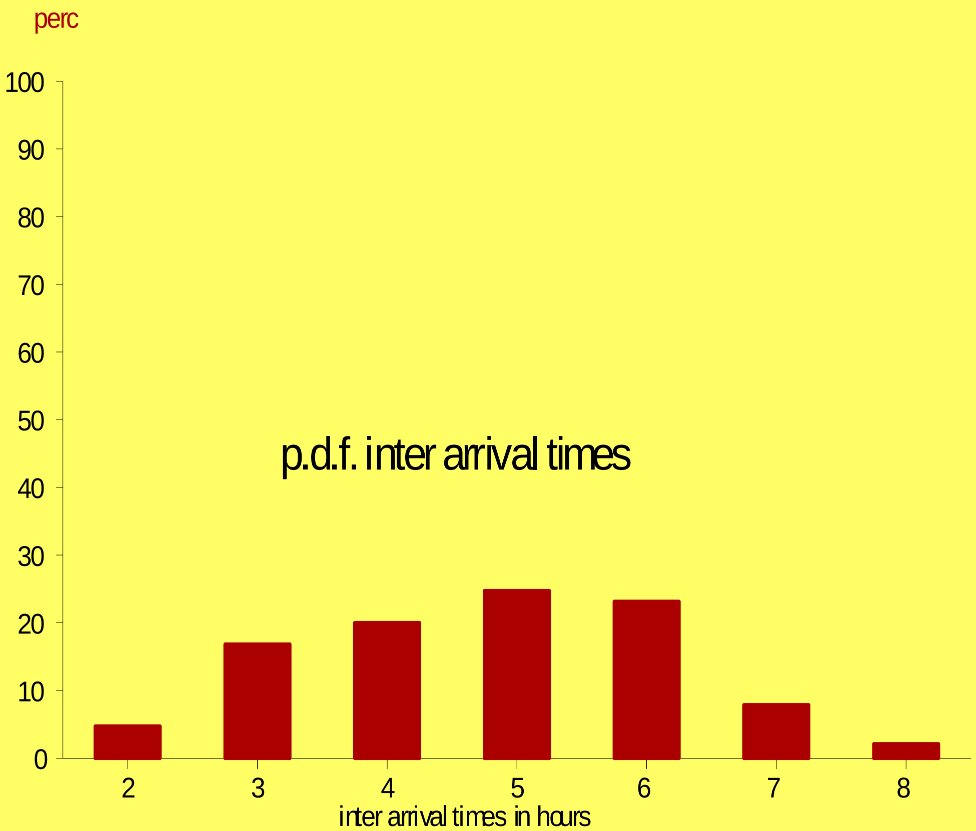
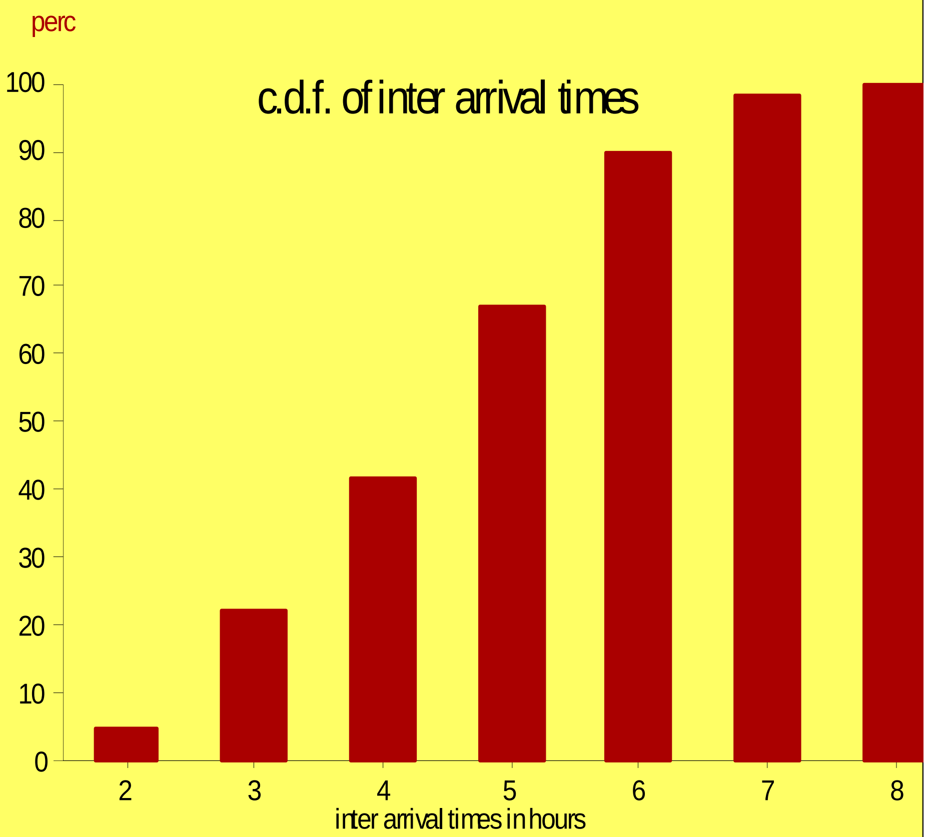
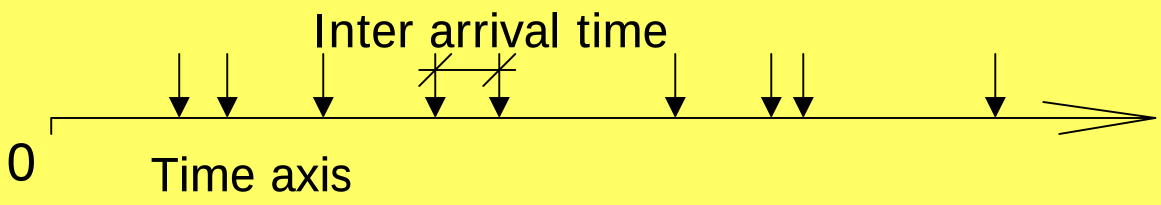
Teoría de colas

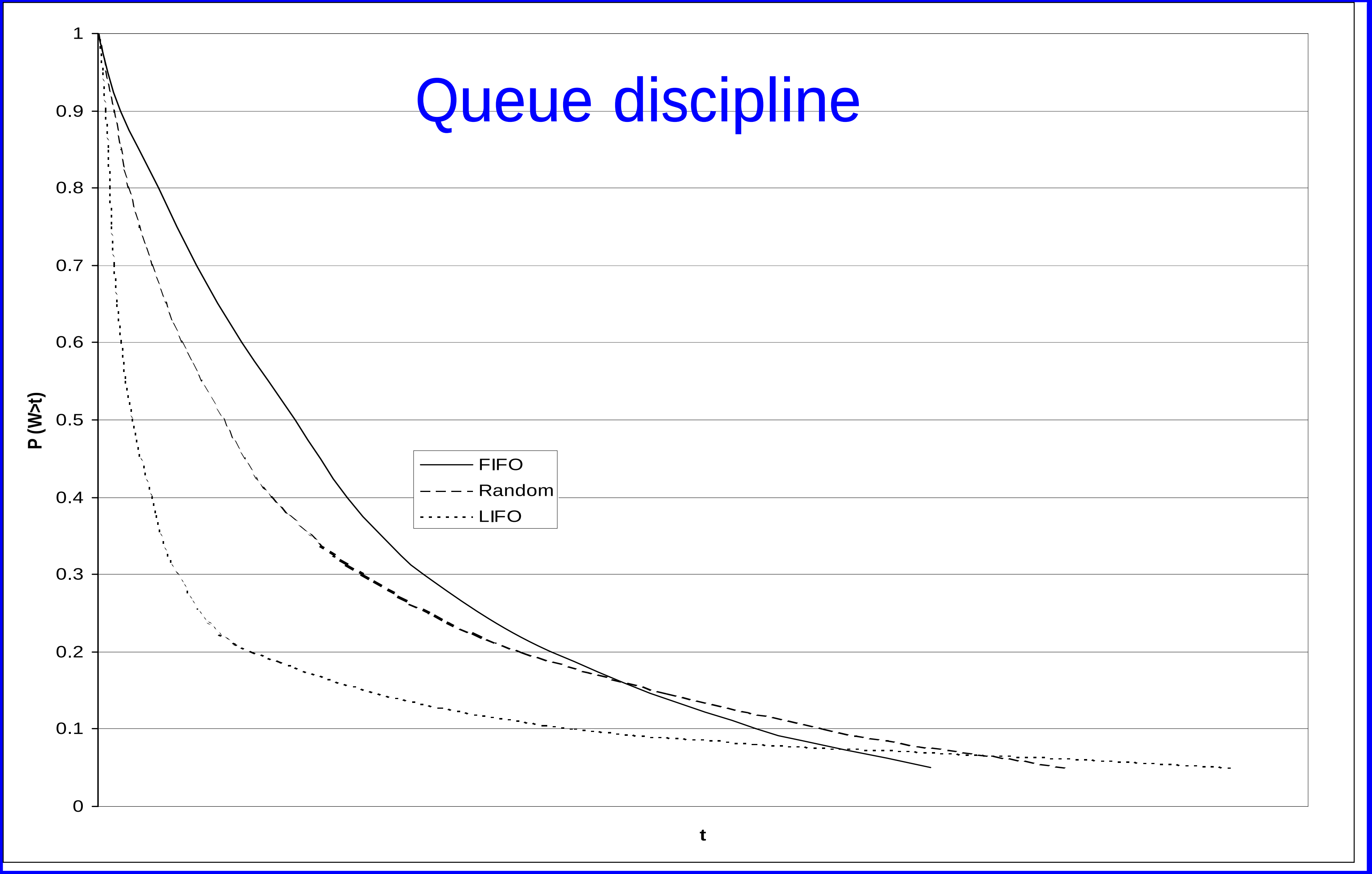
- Función de llegadas
- Función de servicio
- Factor de ocupación $\rho = \frac{\lambda}{\mu}$
- Fórmula de Inoue

Arrival pattern









Probability function waiting times for different queue disciplines

Erlang-k distribution

Agos

Notations

- Kendall notation: three part code

1 distribution function of inter arrival times

2 distribution function of service times

3 number of servicing point

- For example: M/E_k/n; M/M/n; M/D/n; D/M/n; G/M/n

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Input parameters queuing theory

- Distribution arrivals, with arrival rate λ and distribution function (M, E_k, D, G)
- Distribution service times with service rate per service point μ and distribution function (M, E_k, D, G)
- Number servers n
- Occupancy

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

$$\psi = \frac{\lambda}{\mu * n}$$

Output Queuing Theory

- W average waiting time client
- N_w average number of clients in the queue
- N_a average number of clients in the system
- T average turn around time
- P(0) chance zero clients in the sytem

M/Ek/1 Queuing system

Utilisation:

$$\rho = \frac{\lambda}{\mu} \qquad (5\text{-}34)$$

Number of ships in the system:

$$N_a = \rho + \frac{1+k}{2k} \cdot \frac{\rho^2}{1-\rho} \qquad (5\text{-}35)$$

Average number of ships in the queue:

$$N_w = \frac{1+k}{2k} \cdot \frac{\rho^2}{1-\rho} \qquad (5\text{-}36)$$

Chance the system is empty:

$$P(0) = 1-\rho \qquad (5\text{-}37)$$

Average waiting time:

$$W = \frac{1+k}{2k} \cdot \frac{\rho\mu^{-1}}{1-\rho} \qquad (5\text{-}38)$$

Average turnaround time:

$$T = \mu^{-1} + \frac{1+k}{2k} \cdot \frac{\rho\mu^{-1}}{1-\rho} \qquad (5\text{-}3$$

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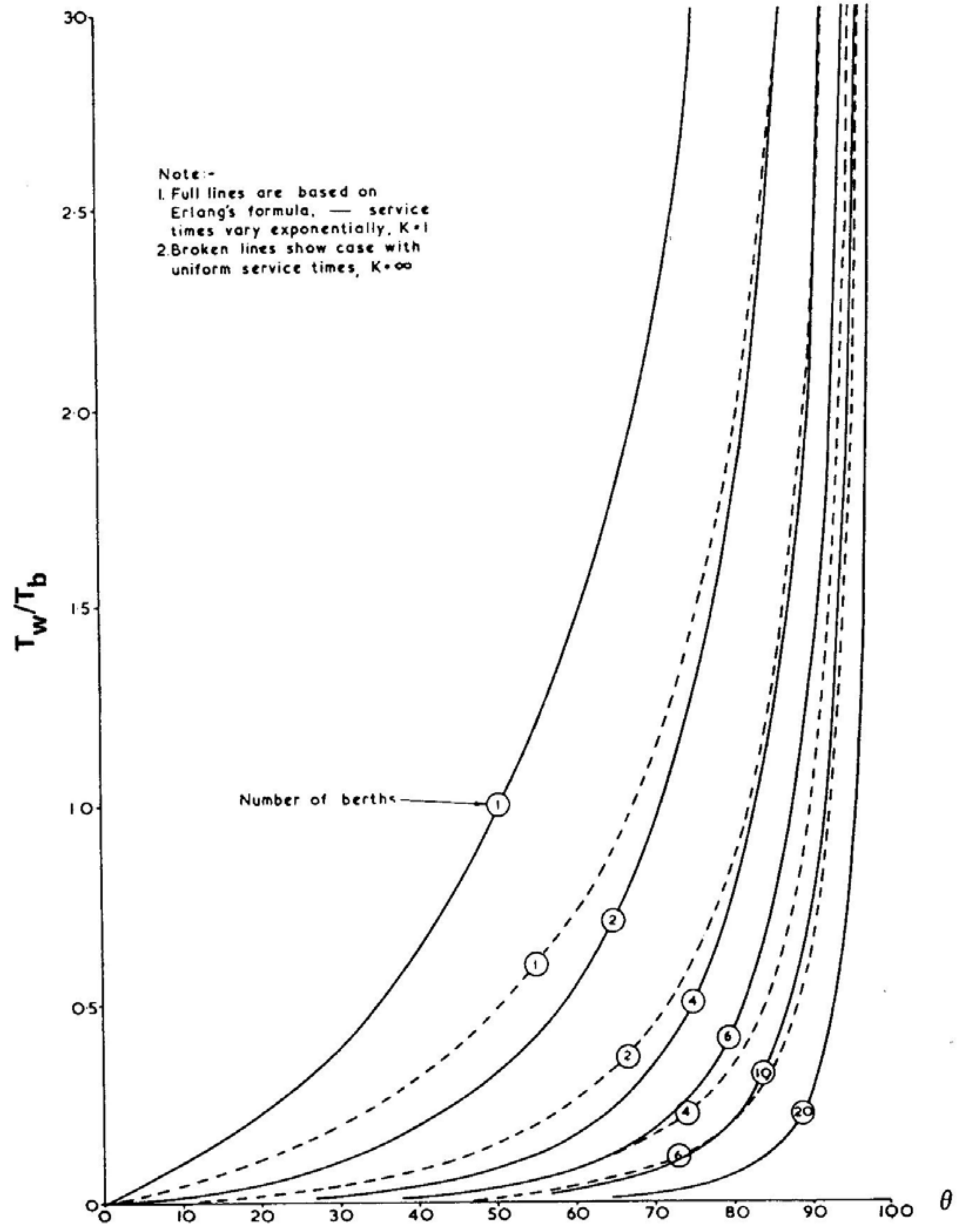

Figure 5.32. Relation between T_w/T_b *and* θ for various different numbers of berths.

TABLE I

Average waiting time of ships in the queue **M/M/n**
(In units of average service time)

utilisation (u)	number of servers (n) 1	2	3	4	5	6	7	8	9	10
0.1	0.1111	0.0101	0.0014	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.2	0.2500	0.0417	0.0103	0.0030	0.0010	0.0003	0.0001	0.0000	0.0000	0.0000
0.3	0.4286	0.0989	0.0333	0.0132	0.0058	0.0027	0.0013	0.0006	0.0003	0.0002
0.4	0.6667	0.1905	0.0784	0.0378	0.0199	0.0111	0.0064	0.0039	0.0024	0.0015
0.5	1.0000	0.3333	0.1579	0.0870	0.0521	0.0330	0.0218	0.0148	0.0102	0.0072
0.6	1.5000	0.5625	0.2956	0.1794	0.1181	0.0819	0.0589	0.0436	0.0330	0.0253
0.7	2.3333	0.9608	0.5470	0.3572	0.2519	0.1867	0.1432	0.1128	0.0906	0.0739
0.8	4.0000	1.7778	1.0787	0.7455	0.5541	0.4315	0.3471	0.2860	0.2401	0.2046
0.9	9.0000	4.2632	2.7235	1.9693	1.5250	1.2335	1.0285	0.8769	0.7606	0.6687

Average waiting time of ships in the queue **M/E$_2$/n**
(In units of average service time)

utilisation (u)	*number of servers (n)* 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.10	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.15	0.13	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.20	0.19	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.25	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.30	0.32	0.08	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.35	0.40	0.11	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.40	0.50	0.15	0.06	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.45	0.60	0.20	0.08	0.05	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.50	0.75	0.26	0.12	0.07	0.04	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
0.55	0.91	0.33	0.16	0.10	0.06	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00
0.60	1.13	0.43	0.23	0.14	0.09	0.06	0.05	0.03	0.03	0.02	0.02	0.01	0.01	0.01	
0.65	1.38	0.55	0.30	0.19	0.12	0.09	0.07	0.05	0.04	0.03	0.03	0.02	0.02	0.02	
0.70	1.75	0.73	0.42	0.27	0.19	0.14	0.11	0.09	0.07	0.06	0.05	0.04	0.03	0.03	
0.75	2.22	0.96	0.59	0.39	0.28	0.21	0.17	0.14	0.12	0.10	0.08	0.07	0.06	0.05	
0.80	3.00	1.34	0.82	0.57	0.42	0.33	0.27	0.22	0.18	0.16	0.13	0.11	0.10	0.09	
0.85	4.50	2.00	1.34	0.90	0.70	0.54	0.46	0.39	0.34	0.30	0.26	0.23	0.20	0.18	
0.90	6.75	3.14	2.01	1.45	1.12	0.91	0.76	0.65	0.56	0.50	0.45	0.40	0.36	0.33	

TABLE V

Average waiting time of ships in the queue **$E_2/E_2/n$**
(In units of average service time)

utilisation (u)	*number of servers (n)* 1	2	3	4	5	6	7	8	9	10
0.1	0.0166	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.2	0.0604	0.0065	0.0011	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.3	0.1310	0.0235	0.0062	0.0019	0.0007	0.0002	0.0001	0.0000	0.0000	0.0000
0.4	0.2355	0.0576	0.0205	0.0085	0.0039	0.0019	0.0009	0.0005	0.0003	0.0001
0.5	0.3904	0.1181	0.0512	0.0532	0.0142	0.0082	0.0050	0.0031	0.0020	0.0013
0.6	0.6306	0.2222	0.1103	0.0639	0.0400	0.0265	0.0182	0.0128	0.0093	0.0069
0.7	1.0391	0.4125	0.2275	0.1441	0.0988	0.0712	0.0532	0.0407	0.0319	0.0258
0.8	1.8653	0.8300	0.4600	0.3300	0.2300	0.1900	0.1400	0.1200	0.0900	0.0900
0.9	4.3590	2.0000	1.2000	0.9200	0.6500	0.5700	0.4400	0.4000	0.3200	0.3000

Determinación de la capacidad del canal

- Debe determinarse la capacidad del canal. Se determina mediante un modelo de simulación – Traffic flow simulation model
- Del estudio debe surgir si es suficiente un canal de una mano o es necesario uno de dos manos o si se puede solucionar con alternativas de cruce. Efectos económicos de esta decisión

Reglas

- Reach rules can be categorized as single vessel rules, multiple vessel rules, or tidal rules.
- Single vessel rules limit the movement of individual ships based on the physical limitations of the channel and the size of the ship. Size parameters restricting movements can include deadweight tonnage, length overall, draft, or beam. Other application of single vessel rules may limit sailing to daylight hours, or restrict movement based on a relationship between the vessel size and the physical dimensions of the channel.
- Multiple vessel rules restrict interactions of vessels, such as meeting, passing, or overtaking. As with the single vessel rules, these restrict movements based on physical characteristics of vessels or of the channel. These rules may also be set absolutely without any parameters of application, such that no vessels meet, pass or overtake within given reaches.

Reglas

- The third category of rules relate to movements with tide. In many ports vessel operators use the additional depth gained by tidal influence to increase the amount of cargo they can carry. Pilots associations develop rules to define the maximum draft, using tide, that vessels can sail in each reach. Tidal rules also govern sailing under current conditions, set in individual channel segments.

Modelo total

- Existen diferentes modelos de de simulación de tráfico
  - Simulación – Promodel
  - Gines – Bahia Blanca – Esta es una aplicación del modelo Promodel – Ver publicación adjunta **Modelo Gines**
- WAM – Ver presentación adjunta **WAM Model Everglades**
- R. Groenveld – Harborsim – Ver publicación adjunta **Simulation model Harborsim**
- NETS - HarborSym

NETS

- http://www.corpsnets.us/index.html
- The U.S. Army Corps of Engineers is committed to spending the nation's tax dollars wisely by investing in navigation projects that provide the best value for the dollar long term. The Navigation Economic Technologies (NETS) program supports this mission by developing independently-verified economic models, tools and techniques.
- Our web site is designed to provide the latest information on the NETS team, the issues we are addressing, the approaches we are using and the status of our activities. The NETS bookshelf contains final reports and policy guidelines, while the toolbox holds final instruments, models, etc. that result from our research. For regular updates on our progress, sign-up for ***NETS News***, a monthly e-newsletter delivered directly to your inbox.
- We must upgrade infrastructure to increase system capacity.

- **HarborSym: Simulation Model for Deep Draft Navigation Improvements**

  Fact Sheet
  Team
- Presentation by Shana Heisey Olig *(2 MB, ppt)*

  Presentation by David Moser, Keith Hofseth, Shana Heisey, Richard Males, and Cory Rogers *(5 MB, ppt)*

- Paper by David Moser, Keith Hofseth, Shana Heisey, Richard Males, Cory Rogers *(378 KB, pdf)*

  Paper by Shana Heisey *(735 KB, pdf)* Ver copia
  HarborSym Model (web link) De este sitio se puede bajar el modelo

Paper Shana Heisey

- Some nations are blessed with naturally deep water leading into their ports, requiring only minimal investments to maintain navigable channels for ocean-going vessels. Unfortunately, the United States is not such a nation.
- In 2002 the U.S. Army Corps of Engineers engaged in studies examining the benefits of improving different physical aspects of 19 individual coastal ports and an additional six Great Lakes deep draft harbors. Corps studies require examining not only the engineering feasibility of any improvement but also the economic efficiency of all possible alternatives.
- Navigation projects dealing with channel width related congestion are particularly difficult to analyze because delays occur as a result of the random interactions of vessels within the system.

Heisey (2)

- In an attempt to assist with these and future navigation studies, the Corps' Institute for Water Resources developed a simulation model, HarborSym, to track vessel movements within ports and to capture delay times associated with transit restrictions.
- HarborSym can also be used to evaluate the impacts of existing restrictions within the system, such as navigation rules.
- This can aid port authorities, governmental bodies, and other stakeholders in understanding congestion problems in their ports and also in identifying the areas of greatest economic impact, thus focusing investigations of harbor improvements. **Ver documento adjunto DePaape Willems Award Heisey**

Introduccion al modelo HarborSym

- HarborSym is designed as a planning level economic model, not a detailed operational tool. With user provided input data, such as the port layout, vessel calls, and the intricate set of transit rules, the model calculates vessel interactions within the harbor.
- Vessel call information includes the time vessels arrive at the system, which begins the calculations for an individual vessel call. When a ship arrives at the bar, the model calculates if it can proceed to its destination dock based upon the transit rules and all other vessels within the system.
- By determining what time the entering vessel will arrive and depart each reach, HarborSym predicts if there will be a rule conflict with any other vessel already moving through the simulation.
- If so, the entering vessel is forced to delay sailing until the conflict abates.

HarbourSym (2)

- Once a vessel is cleared to proceed to the dock, the model determines the amount of time it will spend at the dock based upon its total cargo and the dock-specific commodity exchange rate.
- After all necessary commodities are transferred and the ship is ready for departure, it begins the process of testing for rule conflicts again. When it can proceed through all channel segments required to reach the bar without any rule conflicts, the ship may exit the system.
- HarborSym can be a useful tool in determining which of the many rules within a port have the greatest impact on vessel movements.

Determinación de riesgos

- Este tema se ve por separado al final del curso
- Un análisis que puede realizarse mediante la aplicación de modelos de tráfico es determinar el riesgo de que ocurran accidentes durante la navegación
- Comparación de alternativas
- Influencia de las reglamentaciones
- Se evalúa el número de encuentros entre buques y el riesgo que se produzcan colisiones
- Se recomienda ampliar este tema con la publicación de R. Groenveld – Ëstimation of the nautical risk by using a low cost traffic flow simulation model”

Bibliografía

- Rink Groenveld – Capacity Analysis and Capacity Estimates of Port Systems – June 2004 – Apuntes para el curso dictado en la EGIP
- http://www.corpsnets.us/index.html Este es el sitio del programa NETS – Navigation Economic Technologies Program
- R. Groenveld – “Safety and capacity of wet infrastructure, Puerto América, Venezuela”- PIANC 2002, 30th International Navigation Congress, Sydney, 2002 – Ver archivo adjunto **Groenveld**
- Shana A. Heisey, “Determining economic efficiency in harbors **-** HarborSym, An Application” 2005 Depaepe-Willems contest submission – Ver archivo adjunto **Heisey**