Driven by IT: Innovations in Port Operations

Terminal Operation optimized by Emulation and Simulation Technology

Prof. Dr.-Ing. Holger Schütt

October 27th 2010
Agenda

- Institute of Shipping Economics and Logistics
- Terminal planning and operation supported by simulation/emulation technology
Institute of Shipping Economics and Logistics

ISL Bremen, Universitaetsallee

ISL Bremerhaven, t.i.m.e.Port II
# Short Profile

<table>
<thead>
<tr>
<th>Legal Form</th>
<th>Independent, private non-profit foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our Philosophy</td>
<td>Research based consultancy institute</td>
</tr>
<tr>
<td>Founded in</td>
<td>1954</td>
</tr>
<tr>
<td>Locations</td>
<td>Bremen, Bremerhaven</td>
</tr>
<tr>
<td>Capacity</td>
<td>60 permanent staff members</td>
</tr>
<tr>
<td>Directorate</td>
<td><strong>Prof. Dr. Hans-Dietrich Haasis</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Prof. Dr. Manfred Zachcial</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Prof. Dr. Frank Arendt</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Prof. Dr. Burkhard Lemper</strong></td>
</tr>
<tr>
<td>Board of Trustees</td>
<td>Decision makers from industry, science and politics</td>
</tr>
<tr>
<td>Scientific Advisory Board</td>
<td>Experts from transport industry, commerce and science</td>
</tr>
<tr>
<td>Sponsoring Body</td>
<td>Companies and individual members from the maritime industry</td>
</tr>
</tbody>
</table>
Information Logistics

Two special competence centers are located in Bremerhaven:

- **Auto-ID and Security in Container Transport**
- **Optimisation, Simulation and 3D-Visualisation of terminals**
Containerterminal

- Simulation*: SCUSY, CAPS und CRASY
  - Various operation systems, terminals of different sizes, strategies
  - worldwide Consulting
  - Sale of simulation tools
- Device-Emulator ViTO
  - Test bed for TOS (Terminal Operating System)
- Operations Research in logistics
  - Order distribution
  - Stowage planning
  - Pooling
- COSMA
  - Container Management System for small sized terminals
  - incl. Automation
Terminal planning and optimisation

Traffic
- traffic network
- lane allocation

Strategies (TOS)
- fine-tuning
- testing

Cost evaluation
- investment
- operation

Equipment
- technical data
- device requirement

Operation system
- type of equipment
- handshake

Layout
- terminal areas
- slot requirement

Terminal capacity
- quay side
- stacking area
- gate area
- intermodal yard

Quay crane
- productivity
- crane requirement

Saisonality

Annual workflow

level of detail
low

high
Simulation tools: Terminal Planning & Optimisation
Experiences with emulation technology

1989
- Development of SCUSY
  - Module based architecture
  - Layout editor, input module
  - Simulation module
  - Evaluation module

1991
- Head of division simulation at consultancy company within HHLA group
  - Emulation of high bay warehouse
  - Simulation/emulation support of automated CT Altenwerder/Germany (1999-2002, emulators still in use)

2003
- Concept of a SCUSY based emulation product
- Development of DeCoNet (comm. network)
- Eurogate group 1st client (for all terminals)
- Client may use ViTO
  - Configuration of terminal layout
  - Assignment of devices and jobs
- External emulators may be plugged to ViTO

Warsteiner yard/crane emulator
Siemens crane emulator
Update warehouse emulator DHL
ZPMC horizontal transp. emulator
Hinterland logistics

- **Goods flow simulation**
  - TRIPS (Port call strategies)
- **Hinterland terminal**
- **Simulation of logistic processes using standard tools**
  - Offshore wind farms
- **Operations Research in logistics**
  - E.g. warehousing
- **3D Visualisation**
  - Animation toolbox
- **Specific tools**
  - IYCAPS – Simulation of intermodal Yards
  - ATIS – **Auto**Terminal- Information and Management System
  - CRASY – Crane Simulation System
APM Terminals
ASEAN Terminals, Philippines
Bejaia Mediterranean Terminal, Algeria
Centerm Terminal, Vancouver, Canada
Contship, La Spezia, Italy
CSX, Jacksonville, USA
DP World Terminal Antwerp, Europe
DP World, Australia
EUROGATE, Bremerhaven, Germany
EUROGATE, Hamburg, Germany
HHLA, Hamburg, Germany
HPA Hamburg Port Authority, Germany
HIT, Hong Kong
JadeWeserPort, Germany
Kalmar Industries, Finland
MCT, Gioia Tauro, Italy
MTL, Hong Kong
Nhava Sheva Terminal, India
Noell Crane Systems, Germany
NTB, Bremerhaven, Germany
P&O Headquarter, London, Europe
Port of Odessa, Ukraine
Port of Tacoma, USA
PORTEK International Ltd., Singapore
Ports America, North America
Red Sea Gateway Terminal, Jeddah, UAE
Sandwell Eng. Inc., Vancouver, Canada
SCT, Southampton, U.K.
TRP, Buenos Aires, Argentina
VTE, Genoa, Italy
Warsteiner Brewery, Germany
Simulation tools: Terminal Planning & Optimisation

- Crane Simulation System
- Simulation of Container Unit Handling System
- Capacity Planning System
  - CAPS
  - Spreadsheet
  - ConRoCAPS
  - IYCAPS
- Virtual Terminal Optimiser

Level of detail:
- Low
- High
### Data analysis

#### Throughput p.a.

<table>
<thead>
<tr>
<th></th>
<th>import TEU</th>
<th>export TEU</th>
<th>import boxes</th>
<th>export boxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>total</td>
<td>1,250,000</td>
<td>1,250,000</td>
<td>750,000</td>
<td>750,000</td>
</tr>
<tr>
<td>shortsea</td>
<td>25,000</td>
<td>25,000</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>transhipment</td>
<td>225,000</td>
<td>225,000</td>
<td>135,000</td>
<td>135,000</td>
</tr>
<tr>
<td>landside</td>
<td>800,000</td>
<td>800,000</td>
<td>480,000</td>
<td>480,000</td>
</tr>
<tr>
<td>gate</td>
<td>480,000</td>
<td>480,000</td>
<td>288,000</td>
<td>288,000</td>
</tr>
<tr>
<td>rail</td>
<td>320,000</td>
<td>320,000</td>
<td>192,000</td>
<td>192,000</td>
</tr>
</tbody>
</table>

#### Modal split

<table>
<thead>
<tr>
<th></th>
<th>import %</th>
<th>export %</th>
<th>shortsea %</th>
<th>transhipment %</th>
<th>landside %</th>
<th>gate %</th>
<th>rail %</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEU</td>
<td>50,00%</td>
<td>50,00%</td>
<td>2,00%</td>
<td>18,00%</td>
<td>82,00%</td>
<td>60,00%</td>
<td>40,00%</td>
</tr>
<tr>
<td>boxes</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
<td>135,000</td>
<td>480,000</td>
<td>288,000</td>
<td>192,000</td>
</tr>
<tr>
<td>share of 40' boxes</td>
<td>66,67%</td>
<td>66,67%</td>
<td>66,67%</td>
<td>66,67%</td>
<td>66,67%</td>
<td>66,67%</td>
<td>66,67%</td>
</tr>
</tbody>
</table>

#### Container flow p.a. total

- **TEU**: 225,000
- **MV**: 320,000
- **FV**: 480,000
- **Gate**: 480,000
- **Rail**: 320,000
- **FV**: 480,000
## Data analysis

### Container mix

<table>
<thead>
<tr>
<th></th>
<th>Import</th>
<th>Transhipment</th>
<th>Gate</th>
<th>Railway</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Empty</strong></td>
<td>3.45%</td>
<td>45.00%</td>
<td>45.00%</td>
<td></td>
</tr>
<tr>
<td><strong>Reefer</strong></td>
<td>8.00%</td>
<td>5.00%</td>
<td>5.00%</td>
<td></td>
</tr>
<tr>
<td><strong>Oversize</strong></td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><strong>Hazardous</strong></td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>88.55%</td>
<td>50.00%</td>
<td>50.00%</td>
<td></td>
</tr>
</tbody>
</table>

### Dwell time

<table>
<thead>
<tr>
<th></th>
<th>Import</th>
<th>Transhipment</th>
<th>Gate</th>
<th>Railway</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td>7.00</td>
<td>9.00</td>
<td>9.00</td>
<td></td>
</tr>
<tr>
<td><strong>Empty</strong></td>
<td>9.00</td>
<td>8.00</td>
<td>8.00</td>
<td></td>
</tr>
<tr>
<td><strong>Reefer</strong></td>
<td>7.00</td>
<td>9.00</td>
<td>9.00</td>
<td></td>
</tr>
<tr>
<td><strong>Oversize</strong></td>
<td>7.00</td>
<td>9.00</td>
<td>9.00</td>
<td></td>
</tr>
<tr>
<td><strong>Hazardous</strong></td>
<td>7.00</td>
<td>9.00</td>
<td>9.00</td>
<td></td>
</tr>
</tbody>
</table>

### Average utilization [TEU in terminal]

<table>
<thead>
<tr>
<th></th>
<th>Transhipment</th>
<th>Gate</th>
<th>Railway</th>
<th>Add. landside</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Empty</strong></td>
<td>3.820,99</td>
<td>5.917,81</td>
<td>3.945,21</td>
<td>0.00</td>
<td>27.283,00</td>
</tr>
<tr>
<td><strong>Reefer</strong></td>
<td>191,40</td>
<td>4.734,25</td>
<td>3.156,16</td>
<td>0.00</td>
<td>11.367,40</td>
</tr>
<tr>
<td><strong>Oversize</strong></td>
<td>345,21</td>
<td>591,78</td>
<td>394,52</td>
<td>0.00</td>
<td>2.728,77</td>
</tr>
<tr>
<td><strong>Hazardous</strong></td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
<td>0.00</td>
<td>0,00</td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
<td>0.00</td>
<td>0,00</td>
</tr>
</tbody>
</table>

MTY TEU in standard blocks: TEU

**Incl. MTY/standard**
Static view

→ no simulation needed
Terminal capacity

- 1,500 m quay length
- 24/7 operation
- Average vessel length 330 m (incl. safety distance)
- Average throughput per vessel 2,300 TEU
- Average service time 24 h

$\Rightarrow$ Theoretical capacity

$\left(\frac{1,500}{330}\right) \times 365 \times 2,300 \text{ TEU} \approx 3.8 \text{ MTEU pa} \ ???$

Static view is insufficient

$\Rightarrow$ Simulation is recommended
CAPS

*Tool for determination of the maximum possible throughput of a container terminal*

- Where is the **bottleneck** of the terminal? (Quay or stacking area)
- How much **throughput** does a terminal cope with the existing capacity?

Support and information concerning the questions

- **quay** utilisation
- no. of **cranes** required
- no. of **stacking slots** required
- **yard** utilisation
CAPS

Main modules

Input data
- Quay layout
- Yard data
  - no. of slots
  - dwell time
- Operation
  - Yearly throughput
  - Time variation curve
- Vessel types
- Vessel arrivals
- STS cranes

Simulation

Animation

Output data
- Vessels
- Operation times
- Waiting times
- Quay
  - Utilisation
- No. of STS cranes
- Area
  - Utilisation
  - Overrun of capacity

Analysis of the bottlenecks and definition of new scenarios for improvement
Capacity planning

What will be the result if an other vessel mix will arrive?

What's the impact of vessel's accuracy?

Terminal capacity : 2,85 MTEU pa

What will be the result if QC's productivity decreases from 30 to 27 mv/h?
Simulation cycle
Reuse existing simulation models for sensitivity analysis and for getting a better understanding of the real terminal
Simulation tools: Terminal planning and Optimisation

Simulation of Container Unit Handling System

Container Terminal
SCUSY

Tool for decision making processes on the strategic and design level

- planning of new terminals
- expansion or reorganisation of existing terminals

Support and information concerning the questions

- best type of equipment
- no. of facilities
- changes in layout
- test of different strategies for operation
Various layouts, which one is the best?
Layout definition
Complex operation → simulation is needed
Case study
Comparison of operation systems selected

equipment use

<table>
<thead>
<tr>
<th></th>
<th>RTG/TC</th>
<th>RMG/AGV auto</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of STSCs</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>No. of SCs</td>
<td>45</td>
<td>X</td>
</tr>
<tr>
<td>No. of TCs/AGVs</td>
<td>X</td>
<td>53</td>
</tr>
<tr>
<td>No. of RTGs/RMGs</td>
<td>X</td>
<td>25</td>
</tr>
<tr>
<td>STSC operation hours</td>
<td>1130</td>
<td>1074</td>
</tr>
<tr>
<td>SC operation hours</td>
<td>5016</td>
<td>X</td>
</tr>
<tr>
<td>TC/AGV operation hours</td>
<td>X</td>
<td>56</td>
</tr>
<tr>
<td>RTG/RMG operation hours</td>
<td>X</td>
<td>17</td>
</tr>
</tbody>
</table>

The decision from an economical view is supported based on operational costs and investment.

<table>
<thead>
<tr>
<th></th>
<th>RTG/TC</th>
<th>RMG/AGV auto</th>
</tr>
</thead>
<tbody>
<tr>
<td>average service time</td>
<td>12.5</td>
<td>10.5</td>
</tr>
<tr>
<td>aver. moves/hr (total)</td>
<td>128.0</td>
<td>152.0</td>
</tr>
<tr>
<td>aver. moves/hr per STSC</td>
<td>29.3</td>
<td>31.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>average service time</td>
<td>4.5</td>
<td>4.3</td>
</tr>
<tr>
<td>aver. moves/hr (total)</td>
<td>53.0</td>
<td>56.0</td>
</tr>
<tr>
<td>aver. moves/hr per STSC</td>
<td>21.3</td>
<td>21.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>average service time</td>
<td>8.8</td>
<td>8.0</td>
</tr>
<tr>
<td>aver. moves/hr (total)</td>
<td>57.0</td>
<td>62.33</td>
</tr>
<tr>
<td>aver. moves/hr per STSC</td>
<td>20.4</td>
<td>21.5</td>
</tr>
<tr>
<td>total berth operation time</td>
<td>218.0</td>
<td>195.0</td>
</tr>
<tr>
<td>costs per move [€]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

... But what are the ecological impacts of the terminal?
Ecological impact

device type definition

layout

simulation

state/time - per device - per sector

simulation interface

device noise parameter

EPSIC acoustic calculations

EPSIC output

formulas

climate corrections

terminal simulation

acoustic parameters

noise analysis
SCUSY-EPSIC

- Embedding an acoustic evaluation in the planning programme
- SCUSY to improve noise control regarding immission and emission in planning and reorganisation of Container terminals
Use the results of simulation for economic aspects as well as for ecologic aspects
Handshakes during discharging, Straddle

Straddle carrier 1o3

No further handshake required

1. QC → SC handshake with buffer
Handshakes during discharging, AGV

1. QC → AGV
direct handshake
no buffer

2. AGV → YG
direct handshake
no buffer
Example horizontal transport

1. QC $\rightarrow$ trolley
direct handshake
no buffer

2. Trolley $\rightarrow$ v-crane
   direct handshake
   no buffer

3. v-crane - trolley
   direct handshake
   no buffer

4. trolley - YG
   direct handshake
   no buffer
Direct handshake between devices requires synchronisation between devices

→ the more direct handshakes are required, the complexer the control software will be
Typical layout of automated terminals

What may be terminals total productivity?

Technical:
- QC: >40 mv/h
- AGV à 12 mv/h
- YG à 18 mv/h
Impacts to QC productivity

Technical P. (100%)

Achievable (80-90%)
stowage plan
Hatch cover m.

Real P. (50-80%)

Potential for optimisation
Increase no. of transport devices
Synchronise devices (TOS)
Decoupled handshake
Increase device utilisation
Short distance algorithms
Effective pre planning (yard and equipment)
...
Equipment and Control

- Central control instead of decentral intelligence
- Prevention of Collisions
- Direct handshake requires synchronisation

Terminal Operating Systems are getting more and more complex

Within the first step the development of the IT for the fully automated Terminal in Altenwerder had cost 26 M€

(Interview with IT Director Michael Busch, Logistik Heute, 7-8/2004)
Virtual Terminal Optimiser

Emulation
What is ViTO?

ViTO is more science based universal.

It is a virtual tool designed to be distributed open.

ViTO helps to plan, restructure or realize container terminals.
Emulation

Emulation definition:
A model that accepts the same inputs and produces the same outputs as a given system. IEEE 610.3-1989

Emulation main concept:
Use the same TOS and switch between real or virtual terminal.

TOS
Terminal Operating System

Real

Virtual

switch
Benefits vs. costs

Example for a study to optimise productivity

the study costs

some 80 T€

operational cost (incl. personal) of the terminal (2.7 MTEU throughput) are some 100 M€ p.a.

<table>
<thead>
<tr>
<th></th>
<th>QC</th>
<th>RTG</th>
<th>TC</th>
<th>FLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>14</td>
<td>50</td>
<td>60</td>
<td>13</td>
</tr>
<tr>
<td>Op. Hours</td>
<td>5.500</td>
<td>3.500</td>
<td>4.500</td>
<td>4.000</td>
</tr>
<tr>
<td>Fixcosts p.a</td>
<td>8.925.000 €</td>
<td>7.625.000 €</td>
<td>4.104.000 €</td>
<td>478.400 €</td>
</tr>
<tr>
<td>Op. costs p.a.</td>
<td>12.320.000 €</td>
<td>14.000.000 €</td>
<td>10.800.000 €</td>
<td>3.380.000 €</td>
</tr>
<tr>
<td>Personal costs</td>
<td>23.100.000 €</td>
<td>13.125.000 €</td>
<td>20.250.000 €</td>
<td>3.900.000 €</td>
</tr>
<tr>
<td>sum p.a.</td>
<td>44.345.000 €</td>
<td>34.750.000 €</td>
<td>35.154.000 €</td>
<td>7.758.400 €</td>
</tr>
<tr>
<td>total p.a.</td>
<td></td>
<td></td>
<td></td>
<td>122.007.400 €</td>
</tr>
</tbody>
</table>

1% increase in productivity leads to

some 1 M€ p.a.
Main fields of ViTO
what can you do with a virtual container terminal?

• Real-time 3D visualization of (planned and real) terminal operation
• Planning and Reorganisation of container terminals via simulation
• Development & testing of Terminal Operation Systems (TOS)
• Validating the TOS functionality e.g. alternative strategies
• On-the-job training of TOS
• and more 😊...
ViTO main modules
what programs can be used

- Project Manager
- 2D Terminal Editor
- 3D Terminal Viewer
- Input Module (base data)
- Simulation Module (SCUSY simulation)
- Emulation Manager (with more than 10 further emulators)
- Evaluation Module
- Utilities (such as vessel designer, check programs, ...)

Project Manager
Terminal Editor
Input Module
Simulation
Supported terminal areas
what can you design with ViTO?

- **Container stacks with single Containers**
  (real position, size and colour, more than 100,000 Ct's are no problem)
- **Internal and external traffic network with one-way roads**
- **Gates**
- **Truck interchanges**
- **Rail tracks**
- **Berth (Quay) areas**
- **Parking areas**
- **Other areas like warehouses, office buildings, ...**
  (import of own 3D models is possible (e.g. in 3ds format)

All supported areas in an unlimited quantity
Virtual Terminal Optimisation Tool

Terminal devices in the standard package
what can be moved with ViTO?

• **Quay Cranes** *(movement and collision)*
• **Straddle Carrier** *(collision control at handling areas)*
• **Forklifts and Reach Stackers**
• **External Trucks**
• **Vessels** *(import of real Baplie files possible)*
• **RMG and RTG** *
• **Terminal-Chassis and AVGs** *(collision control at handling areas)*
• **Other devices on request...**

All in an unlimited quantity and with customizable technical data & models *(e.g. 3ds format)*
Virtual Terminal Optimisation Tool

Individual features
what can additionally be done with ViTO?

- Interface to TOS
- Special logic of internal equipment handling (especially manned devices)
- Import of terminal layout (direct import or comparison between TOS and ViTO)
- Straddle Carrier, Terminal Chassis, AGVs: collision control in the traffic network
- Import of external device emulators (also written in other languages, e.g. Java)
- Other devices on request...
ViTO – Emulation architecture

ViTO Emulation System

Device Communication Network

- Quay Emulator
- Equipment Emulator
- Gate Emulator

3D realtime animation
Yard Emulator
and more...

online
offline

TOS
Terminal Operating System

Emulator

Gate Emulator

Yard dump
Rail moves
Quay moves
Internal moves

online
offline
ViTO – Virtual Container Terminal Optimising

Message exchange between clients = XML

See also:
ViTO Interface Specification
Example SC-Terminal
Example collision control
Emulation

Benefits using emulators

- Failures in the TOS are recognized before terminal implementation
- Increasing the availability and stability of terminal's modules
- Bottlenecks and design errors are discovered in an early phase
- Analyzing and evaluation of alternative strategies
- Check TOS updates without interrupting the operation
- Checks may be realized in wear-free and energy-saving manner
- Testing can be much faster (up to 100 times faster as in reality)
- 3D animation may be used for demonstration and training issues
- Cost efficient solution over time 😊
Innovative Solutions in maritime Logistics.

Institute of Shipping Economics and Logistics
schuett@isl.org

Universitaetsallee 11-13
28359 Bremen
Germany
Tel. +49/4 21/2 20 96-0
Fax +49/4 21/2 20 96-55

Barkhausenstrasse 2 (t.i.m.e.Port II)
27568 Bremerhaven
Germany
Tel. +49/4 71/30 98 38-0
Fax +49/4 71/30 98 38-55
Eco - PorTS

Port Traffic System
Forecast Shipping Traffic

Forecast of Throughput Development for Port of Hamburg for several Years
- Container
- Liquid Bulk
- Dry Bulk
- General Cargo
- Cruise/Passenger

Forecast of Fleet Development
- Handling percentage
- Number of units to be handled
- Multiple port calls
- Multiple cargotype mix

(Number of Ships)
Terminal Capacity Expansion

Planned Capacity 2015: 18.3 Mio TEU

- West-Expansion of CT Eurogate
- Port Expansion Moorburg
- CT Altenwerder
- CT Burchardkai
- CT Tollerort
- Areal Central Freeport

Existing

Expansion, Restructuring

Potential

Source: HPA 12  Fol.No.: 2444
Simulation/Animation

Ship-Traffic:
- Direct (Sea/ Kiel Canal, Kiel Canal/ Sea)
- Origin/ Elbe ports/ Destination
- Origin/ Hamburg/ Destination
Simulation/Animation: Port of Hamburg (Zoom)
Main Air-Emission in Maritime Transport

- Carbon Dioxide ($CO_2$)
- Sulphure Oxides ($SO_X$)
- Nitrogene Oxides ($NO_X$)
- Particulate Matter (PM)

Pictures: http://www.marinetalk.com/articles_marine_companies/art/Reducing_Air_Pollution_from_Ships.IMCO0133728IN.html
Greenhouse Gas Emission from Ships

Source: IMO, Prevention of Air Pollution from Ships – Report on the outcome of the IMO Study on Greenhouse Gas Emissions from Ships, MEPC 45/8, (2000), London, (Figure 3-9)
Main factors of influence (Air-Emission)

**VESSEL**
- Time per Segment Status
  - (Sea, Maneuver, Hotel)

**MAIN ENGINE**
- Installed KW
- Service speed RPM
- SFOC; FUEL-Type

**AUXILIARIES**
- Installed KW
- % of Power (Status)
- SFOC; FUEL-Type

**BOILER**
- % of Main Engine Power By Status
- SFOC; FUEL-Type

**FUEL**
- HFO / MDO / MGO
- Sulfure Content

**REDUCTION** (per Em.Group)
- % Share of Fleet
- % Share of Reduction
- AMP/Shore Side Electricity
- Berth-Time

**AIR-EMISSION**
- CO₂
- SOₓ
- NOₓ
- PM

"ENGINE LOAD"
- Real Speed
- Per Segment

RPM Rotations per minute
SFOC Specific fuel oil consumption
HFO Heavy fuel oil
MDO Marine diesel oil
MGO Marine gas oil
AMP Alternative maritime power
World wide marine engines details

- Selected View on Data collection from ISL-Engine Data-Base
Influence an Emission

- Reduction (Examples)

Modern Engines

After Treatments

AMP

Fuel
- Destilates
- Sulphur content

Pictures: Tiggers, Kay (Siemens AG Hamburg), Fuel Savings on Propulsion by Recovery of Thermal Energy -- the Most Efficient Opportunity to Protect the Environment

http://www.sjofartsdir.no/upload/18198/Viking%20Line%20Solstrand%20060307.pdf

www.sam-electronics.de; www.gauss.org;