Cost-benefit analysis for the 
“Intelligent Vessel”: The case of the ATOMOS IV project

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ATOMOS IV project

• “Advanced Technologies to Optimize Maritime Operational Safety: Intelligent Vessel”
• Contract No. 1999-CM.10540 (DG-TREN, 5th FP)
• Duration: 1999-2003
• 12 partners from 8 EU countries
Previous related projects

• ATOMOS
• ATOMOS II
• DISC (Demonstrators for Integrated Ship Control)
• DISC II/ATOMOS III
ATOMOS IV partners

- FORCE-DMI (DK) -Coordinator
- Lloyds Register of Shipping (UK)
- STN Atlas (D)
- Lyngsoe Marine (DK)
- Logimatic A/S (DK)
- National Technical University of Athens (GR)
- D’ Appolonia SpA (I)
- CETEMAR (E)
- ISSUS (D)
- TNO (NL)
- Swedish Maritime Administration (S)
- Aalborg University (DK)
Main Objectives

• Bring the benefits of advanced computer and control technology to the European fleet.
• Perform a trial retrofit of an advanced control system on a trial vessel.
• Perform a full verification and validation of the retrofit.
• Perform a full evaluation of the retrofit from a safety and cost-benefit viewpoint.
Other aspects

- Compliance to SOLAS V/15 (bridge and navigation equipment design and procedures)
- Human-centered development for ship control centers and interfaces
- Risk-based development applying safety assessment techniques
- Principles-based assessment for programmable systems
- Computer-based training tools
Rationale

ATOMOS-type technologies would

- reduce manning and other costs
- increase EU ship and fleet competitiveness
- reduce risk of accidents and pollution
- increase maritime safety
Possible contexts

- **Newbuilding**: Build a new ship based on ‘ATOMOS platform’
- **Retrofit**: Convert an existing ship by implementing the ‘ATOMOS platform’

**Focus of ATOMOS IV project**: Retrofit
ATOMOS IV project retrofit

- Implemented on “Frej”, a Swedish ice-breaker
- Vessel to be equipped with all necessary hardware and software
- ATOMOS bridge and integrated ship control
- Extensive tests and sea trials conducted
- Full verification, validation and evaluation
- Final demonstration (the ‘big switch’)
Retrofit Strategy Tool (RTS)

- Helps ship owner assess if retrofit is worth pursuing
- Goes over complete list of retrofit equipment
- Evaluates all costs and benefits from retrofit
- General context: applies to any ship, provided data is available
Cost-benefit issues in RST

• Compare original ship to converted (ATOMOS) ship
• Evaluate all cost and benefit components
• Use appropriate cost-benefit criteria
• Perform sensitivity analysis
• Draw conclusions
Cost benefit contexts in ATOMOS IV

- Specific: just for the ‘Frej’
- Generic: for any ship type
Main Criterion: Net Present Value (NPV)

\[
NPV = \sum_{n=1}^{RFL} \left( \frac{B_{CRn} + B_{MNTn} + B_{INSn} + B_{FUEn} - C_{TRAN} - C_{OTHn}}{(1 + i)^n} \right) - \left( C_{ATT} + C_{NAT} + C_{CAB} + C_{EXT} \right)
\]

Benefits:
- Manning
- Maintenance
- Insurance
- Fuel
- Safety

Initial Costs:
- ATOMOS Platform
- Non-ATOMOS Equipment
- Cabling
- Extra

Recurring Costs (for year “n”):
Training, Maintenance, Upgrading, Service
Cost Benefit Components (RST)

**Costs**

- ATOMOS Platform
- Non-ATOMOS Equipment
- Cabling
- Extra

**Benefits**

- Manning
- Safety
- Maintenance
- Insurance
- Fuel
ATOMOS Platform

Navigation Equipment / Bridge Systems

Alarm Monitoring and Control Systems

Software
## ATOMOS Platform Cost

<table>
<thead>
<tr>
<th>Category</th>
<th>PURCH. (euros)</th>
<th>INSTAL. (euros)</th>
<th>TRAIN. (euros)</th>
<th>OPER. (euros)</th>
<th>MAINT (euros)</th>
<th>UPGR. (euros)</th>
<th>SERV. (euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAVIGATION EQUIPMENT</td>
<td>345,970</td>
<td>14,300</td>
<td>6,700</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>24,800</td>
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<tr>
<td>ALARM MONITORING and CONTROL</td>
<td>283,500</td>
<td>168,500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOFTWARE</td>
<td>21,756</td>
<td>154,743</td>
<td>4,597</td>
<td>2,758</td>
<td></td>
<td></td>
<td>919</td>
</tr>
<tr>
<td>EXTRA</td>
<td>8,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL/ Category</td>
<td>659,226</td>
<td>337,543</td>
<td>11,297</td>
<td>2,758</td>
<td></td>
<td></td>
<td>919</td>
</tr>
<tr>
<td>TOTAL</td>
<td>996,769</td>
<td></td>
<td>11,297</td>
<td></td>
<td></td>
<td></td>
<td>28,477</td>
</tr>
</tbody>
</table>
Non – ATOMOS Equipment

- Navigation
- Communication
- Maneuvering
- Alarm /Control
- Propulsion
- Other

Question – Answer Query
Cabling Cost

ATOMOS BOX

ATOMOS Platform Centre

Vertical length

Longitudinal length

Transverse length
Maximum Transverse and Vertical cable length: \( B + D + (n-2) \times H + H/2 \)

Minimum Transverse and Vertical cable length \( H/2 \)

- \( L_{BR} \): Distance from stern to Platform centre
- \( L_{AT} \): Distance from stern to ATOMOS Box

Longitudinal cable length = \( |L_{AT} - L_{BR}| \)
Extra Costs

\[ C_{\text{EXTRA}} = T_R \times (C_{OP} + C_{\text{RET}}) + T_{TR} \times (C_{TR} + C_{OP}) \]

- **\( T_R \):** time duration of ATOMOS retrofit
- **\( C_{\text{RET}} \):** vessel's operational cost per unit time during retrofit
- **\( T_{TR} \):** travel time to the shipyard
- **\( C_{TR} \):** vessel’s operational cost per unit time during voyage to the shipyard
- **\( C_{OP} \):** vessel’s opportunity cost (lost income) per unit time
Manning cost reduction: most important benefit

• Compare conventional crew with ATOMOS vessel crew

• Question: What is the crew composition of an ATOMOS-type vessel?

• No previous results available

• Developed ‘crew synthesis tool’
Manning: Crew Synthesis Tool

- Indicative Vessel’s Crew Synthesis Estimation
- Possible Modification by the Ship Owner
- Reasonable Results (Classification)
- Operational Approach

Input: Database (480 Records: 60 vessels)

Output: Set of Derived Rules and Trees
Automation levels

L0 : Manual
L1 : Remote Monitoring
L2 : UMS
L3 : Automation of Individual Systems
L4 : CCS
L5 : Interconnected System
L6 : IBS – as defined by IEC (1999)
L7 : Watch 1 (ATOMOS vessel)
5 Major Greek Shipping companies - Interviews

Flags: Greek, Panama, Liberia, Malta, Norway

4 Automation Levels Selected: L0, L2, L4, L7

14 Selected Vessels
Crew Synthesis Tool (3)

Data Mining Techniques

Class Approximation with Classification Trees

Y : Dependent Variables

Crew Number per Rank

X₁, X₂... Xₘ : Independent Variables

- Automation / Integration Levels
- Ship Types
- GRT
- BHP
Manning: Illustrative Example

Calculations for Able Bodies

Rule-Leaf 7:

if

AUTOMATION LEVEL is L5 or L6
GRT > 3435
GRT <= 8500

then

AB = 2
Illustrative Example (2)

Sub-Tree: Graphical View

AUTOMATION LEVEL in [L6-L7]

AUTOMATION LEVEL = L6

GRT <= 4450

NO SECOND OFFICERS

GRT > 4450

1 SECOND OFFICER
# Cross Validation Test (1)

## Test Results:

<table>
<thead>
<tr>
<th>TYPE</th>
<th>FLAG</th>
<th>LEVEL</th>
<th>REAL</th>
<th>PRED</th>
<th>DIFF</th>
<th>% DIFF</th>
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</thead>
<tbody>
<tr>
<td>TANKER</td>
<td>UK</td>
<td>UMS</td>
<td>12</td>
<td>11</td>
<td>-1</td>
<td>-8.3</td>
</tr>
<tr>
<td>GC</td>
<td>Cyprus</td>
<td>CONV</td>
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<td>22</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>TANKER</td>
<td>Portugal</td>
<td>CONV</td>
<td>26</td>
<td>27</td>
<td>1</td>
<td>3.8</td>
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<tr>
<td>TANKER</td>
<td>Italy</td>
<td>CONV</td>
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<td>23</td>
<td>3</td>
<td>15.0</td>
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<tr>
<td>RORO</td>
<td>Sweden</td>
<td>CONV</td>
<td>20</td>
<td>21</td>
<td>1</td>
<td>5.0</td>
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<tr>
<td>BC</td>
<td>Spain</td>
<td>CONV</td>
<td>24</td>
<td>25</td>
<td>1</td>
<td>4.2</td>
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<tr>
<td>GC</td>
<td>Netherlands</td>
<td>CCS</td>
<td>7</td>
<td>8</td>
<td>1</td>
<td>14.3</td>
</tr>
<tr>
<td>GC</td>
<td>UK</td>
<td>CONV</td>
<td>23</td>
<td>22</td>
<td>-1</td>
<td>-4.3</td>
</tr>
<tr>
<td>CONT</td>
<td>Denmark</td>
<td>UMS</td>
<td>17</td>
<td>19</td>
<td>2</td>
<td>11.8</td>
</tr>
<tr>
<td>CONT</td>
<td>Denmark</td>
<td>UMS</td>
<td>17</td>
<td>19</td>
<td>2</td>
<td>11.8</td>
</tr>
<tr>
<td>RORO</td>
<td>Cyprus</td>
<td>CCS</td>
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<td>11</td>
<td>-1</td>
<td>-8.3</td>
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<tr>
<td>TANKER</td>
<td>France</td>
<td>CONV</td>
<td>21</td>
<td>24</td>
<td>3</td>
<td>14.3</td>
</tr>
<tr>
<td>BC</td>
<td>Italy</td>
<td>CONV</td>
<td>22</td>
<td>25</td>
<td>3</td>
<td>13.7</td>
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<tr>
<td>TANKER</td>
<td>Spain</td>
<td>UMS</td>
<td>17</td>
<td>19</td>
<td>2</td>
<td>11.8</td>
</tr>
</tbody>
</table>
## Cross Validation Test (2)

### Case Driven Results (Container, Danish Flag):

<table>
<thead>
<tr>
<th></th>
<th>UMS REAL</th>
<th>UMS PRED</th>
<th>CCS PRED</th>
<th>ATOMOS PRED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>17</td>
<td>19</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td><strong>Captain</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Chief Officer (Mate)</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>2nd Officer</strong></td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>3rd Deck Officer</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Chief Engineer</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>2nd Engineer</strong></td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>3rd Engineer</strong></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Electrician</strong></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Bosun</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Deck or Able Body</strong></td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td><strong>Wiper / Oiler</strong></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Cook</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Steward</strong></td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
**Illustrative Example (1)**

<table>
<thead>
<tr>
<th>Vessel’s Type</th>
<th>Tanker</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWT</td>
<td>90,000 t</td>
</tr>
<tr>
<td>GRT</td>
<td>39,283 t</td>
</tr>
<tr>
<td>L</td>
<td>205 m</td>
</tr>
<tr>
<td>B (Breadth)</td>
<td>37 m</td>
</tr>
<tr>
<td>D</td>
<td>21.5 m</td>
</tr>
<tr>
<td>BHP</td>
<td>16,681</td>
</tr>
</tbody>
</table>

**4-Parts Calculations**
## Illustrative Example (2)

<table>
<thead>
<tr>
<th>Cost Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATOMOS Cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annual Operating Cost: € 28,477</td>
</tr>
<tr>
<td></td>
<td>Purchase/Installation: € 996,769</td>
</tr>
<tr>
<td></td>
<td>Training: € 11,297</td>
</tr>
<tr>
<td>Non-ATOMOS Cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Value: € 77,257</td>
</tr>
<tr>
<td></td>
<td>Upper Value: € 226,842</td>
</tr>
<tr>
<td>Cabling Cost</td>
<td>€46,169</td>
</tr>
<tr>
<td>Extra Cost</td>
<td>€1,627,500</td>
</tr>
<tr>
<td>Benefits</td>
<td>Amount</td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Manning Benefits</td>
<td>€39,707 per month</td>
</tr>
<tr>
<td>Maintenance Benefits</td>
<td>€15,881 per year</td>
</tr>
<tr>
<td>Insurance benefits</td>
<td>€500 per year</td>
</tr>
<tr>
<td>Safety Benefits</td>
<td>€248,792</td>
</tr>
<tr>
<td>Fuel Benefits</td>
<td>0</td>
</tr>
</tbody>
</table>
Sample results

NPV - Lower Cost Level (Hellenic Flag)

NPV - Upper Cost Level (Hellenic Flag)

Lower Cost Level

Upper Cost Level
Conclusions (summary)

- Real-world retrofit a success
- Project objectives fully realized
- Significant benefits realized
Credits: NTUA ATOMOS team

- D. Lyridis
- N. Ventikos
- K. Dilzas
- P. Zacharioudakis
Coordinates for further info

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