A Traffic Density Analysis of Proposed Ferry Service Expansions in San Francisco Bay Utilizing Maritime Simulation

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Rutgers University Presentation – August 13, 2004

Supporting Research Grants: WTA #02-112,
NSF Grants SES 0213627 & SES 0213700
THE RISK OF RIVER BOAT GAMBLING

A Risk Assessment in 1995 for the Port of New Orleans Port Authority

Joint Work:
The George Washington University
Rensselaer Polytechnic Institute

A Risk Assessment for
ADEC, APSC/SERVS,
PWS Regional Citizens Advisory Council,
US Coast Guard, PWS Shipping Companies

Joint Work:
Det Norske Veritas
The George Washington University
Rensselaer Polytechnic Institute

The stricken Exxon Valdez spilling oil
Washington State Department of Transportation

The George Washington University
Rensselaer Polytechnic Institute
Virginia Commonwealth University
Examples Risk Intervention Questions

• Port of New Orleans Risk Assessment:
  “Is it safer for a gambling boat to be underway or at the dock?”

• Prince William Sound Risk Assessment:
  “Should we tighten weather based closure restrictions for outbound tankers?”

• Washington State Ferry Risk Assessment:
  “Is it efficient (risk wise) to invest in addition survival craft capacity on Washington State Ferries?”
To relieve congestion on highways, the state of California is proposing to expand ferry operations on San Francisco (SF) Bay by:

- phasing in up to 100 ferries in addition to the 14 currently operating,
- extending the hours of operation of the ferries,
- increasing the number of crossings,
- employing some high-speed vessels.

San Francisco Bay Water Transit Authority (WTA) is tasked to investigate whether this can be done in a safe manner?
Three Future Ferry Service Scenarios

- Alternative 3: Enhanced Existing System (Least Aggressive Expansion)
- Alternative 2: Robust Water Transit System
- Alternative 1: Aggressive Water Transit System (Most Aggressive Expansion)

WTA asked us (GWU-VCU) to build a Maritime Simulation to help address the safety question.
Maritime System Simulation

1. Traffic Arrivals Simulation
2. Weather Simulation

Maritime System Simulation
Traffic Rules
Outline

• Building the Simulation (Modeling Traffic)
• Building the Simulation (Modeling Weather)
• Counting Interactions in a Maritime Simulation
• Results
  – Base Case
  – Alternatives 1, 2 and 3
Building a Base Case Simulation

• We Need:
  – Map of the study area
  – Ferry schedules and Ferry Routes
  – Traffic data from the VTS
  – Vessel track data from the VTS
  – Environmental data – wind, visibility.

• We need:
  – Small vessel data – Regatta Events
    (Particularly their locations in lat long coordinates)
Building the Simulation
(Modeling Traffic)
Map of the Study Area

- This map was creating by converting NOAA electronic charts to bitmap format and by connecting them together.
### Current and Future Ferry Schedules

- **Base Case** = Year 2000 Ferry Schedules (collected from Ferry Operators)
- **Spreadsheets for Alternatives 1, 2 and 3** were supplied by URS Corporation

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#### Alternative 3 - Enhanced (Existing) Water Transit System

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<th>Corridor</th>
<th>Route</th>
<th>Vessel Type</th>
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<th>Headways</th>
<th>Sailing Time</th>
<th>Idle Time</th>
<th>Deadhead Time</th>
<th>Weekday Trips</th>
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**DATE:** 9-Apr-02

*alternative 3-rev*
Ferry Schedules

- The spreadsheets were edited to match up with the routes in the simulation.

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</table>

- VBA programs were written to create arrivals databases suitable for the simulation program.
Ferry Routes Developed by URS Corporation
Piecing URS MAP on top of NOAA Collage
Other Large Maritime Traffic

- Detailed Vessel Arrival and Departure Data for Multiple Years from VTS San Francisco:
  - Vessel Class
  - Arrival Time into Study Area (Time, Day and Month)
  - Origin and Destination
  - Vessel Route (or Way Points)

- VTS Waypoints data
  - 2001 data was used as the primary source
  - Augmented by 2000 data
  - 99.5% of traffic could be matched to a waypoint defined route
  - Remaining 0.5% had missing departure and destination point information
Example of Vessel Routes (LPG Carriers)

- Routes like the one shown were created using waypoints data supplied by SF VTS
Regatta Events

• The USCG supplied their Marine Event List

<table>
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<tr>
<th>EVENT NUMBER</th>
<th>EVENT</th>
<th>LOCATION</th>
<th>Sailing_Area</th>
<th>DATE</th>
<th>Start_Time</th>
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Regatta Events

- The areas were matched up with maps supplied by Lieutenant Black and Stacey Shonk.
## Comparison WSF Simulation to SF Bay Simulation

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<tr>
<th>Washington State</th>
<th>San Francisco Bay</th>
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<tbody>
<tr>
<td>- 13 Ferry Routes</td>
<td>- 18 Ferry Routes (Base). 68 Ferry routes (Alternative 1)</td>
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<td>- 100 Routes for other VTS Traffic</td>
<td>- 6000 Routes for other VTS Traffic</td>
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<tr>
<td>- No Special Events</td>
<td>- 1000 Special Events</td>
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**COMPLEXITY DIFFERS BY ORDER OF MAGNITUDE!**
Kudos To SF VTS!

• Without their help, efficient and timely response to our repeated questions and data requests we would have been pulling our hair out.
Building the Simulation
(Modeling Restricted Visibility)
Environmental Data

- Study Area has been divided into five separate zones to determine visibility pattern.
- Divisions made based on differences in visibility pattern noted in the Coast Pilot and data availability.
- Sea Visibility is generated using meteorological model utilizing Water Temp and Air Temp.
Environmental Data - Wind

- Hourly Wind direction and Speed Data
  - Port Chicago 1/1998 – 12/2001
Environmental Data

• San Francisco International Airport
  – Hourly Air Temperature 1990-1995
  – Hourly Land Visibility 1990-1995
  – Hourly Dew Point 1990-1995
Sea Visibility Model

\[ W = \text{Water Surface Temperature (Celsius)} \]
\[ D = \text{Dewpoint Temperature (Celsius)} \]
\[ \Delta = W - D \]

\[
\begin{cases} 
\text{Good, } \Delta \leq 0^\circ \text{C} \\
\text{Bad, } \Delta > 0^\circ \text{C}
\end{cases}
\]

Good = More than 0.6 miles
Bad = Less than 0.6 miles

Environmental Data - VISIBILITY

• Hourly Air and Water Temperature Data

HOURLY DEW POINT DATA IS NOT AVAILABLE FOR THIS TIME PERIOD AND FOR THESE LOCATIONS!
Calculation of Dew Point Temp.

- Used SFO Dew Point Data:

  6 year averages of Dew points were calculated over the period from 1990-1995 per month and by an air temperature range of two degrees. These averages were used to convert 1998-2001 air temperature data to dew point data.

- For example: Average dew point for August was 13 in 1990-1995 when air temperature was between 14-16 degrees Celsius. An air temperature in August 1998 of 15 degrees would therefore be converted to a dew point of 13.
Visibility Model - Calibration

– To ensure the model more closely reflects restricted visibility conditions (mariners are required to use their fog signals) a calibration constant was be added for each month and location

\[
\text{Visibility} = \begin{cases} 
\text{Good,} & \Delta \leq k^\circ C \\
\text{Bad,} & \Delta > k^\circ C 
\end{cases}
\]
Calibrate to Sample Coast Pilot Data

Location Golden Gate:

- August: Fog signals operate 15-20% of the time in Golden Gate
- March and April, fog signals operate about 7-10% of the time.

WHAT ABOUT THE OTHER MONTHS?
WHAT ABOUT THE OTHER LOCATIONS?
Visibility Model Results

Visibility Pattern in: August  Location: Golden Gate
Average Bad Visibility: 19.89% of the time
Visibility Model

- To calibrate the percentage of times restricted visibility conditions occur within each location, information from the Coast Pilot 2000 was combined with expert judgment elicited using the Analytical Hierarchy Process technique.

Please compare the two locations in terms of the percentage of time that vessels operate in restricted visibility (i.e. vessels are required to use their fog signal) in the specified quarter.

<table>
<thead>
<tr>
<th>THIRD QUARTER: July - August - September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Left Hand Side More</td>
</tr>
<tr>
<td>1 Same amount of time</td>
</tr>
<tr>
<td>5 Five times more</td>
</tr>
<tr>
<td>7 Seven times more</td>
</tr>
<tr>
<td>9 Nine times or more</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
</tbody>
</table>
Visibility Model

- There was remarkable agreement between the VTS Operators and the SF Bar Pilots regarding visibility conditions at Golden Gate.

![Relative Comparison by Quarter: GOLDEN GATE](chart.png)
Visibility Model

• There was some level of disagreement regarding visibility conditions in the first quarter of the year.
## Visibility Model

- Estimated Percentages of Time that Restricted Visibility Occurs by Quarter and by Location

<table>
<thead>
<tr>
<th>Location</th>
<th>First Quarter J - F - M</th>
<th>Second Quarter A - M - J</th>
<th>Third Quarter J - A - S</th>
<th>Fourth Quarter O - N - D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golden Gate</td>
<td>5.17%</td>
<td>11.66%</td>
<td><strong>20.00%</strong></td>
<td>6.69%</td>
</tr>
<tr>
<td>San Pablo Bay</td>
<td>12.38%</td>
<td>6.17%</td>
<td>6.30%</td>
<td>9.62%</td>
</tr>
<tr>
<td>Alameda</td>
<td>7.49%</td>
<td>7.61%</td>
<td>10.61%</td>
<td>7.02%</td>
</tr>
<tr>
<td>South Bay</td>
<td>4.92%</td>
<td>5.00%</td>
<td>5.53%</td>
<td>4.74%</td>
</tr>
<tr>
<td>Grizzly Bay</td>
<td>14.40%</td>
<td>5.17%</td>
<td>5.34%</td>
<td>11.06%</td>
</tr>
</tbody>
</table>
Visibility Model Results – GOLDEN GATE 2000

Visibility Pattern in: January        Location: Golden Gate
Average Bad Visibility: 5.34% of the time

Visibility Pattern in: February        Location: Golden Gate
Average Bad Visibility: 5.90% of the time

Visibility Pattern in: March        Location: Golden Gate
Average Bad Visibility: 5.53% of the time

Visibility Pattern in: April        Location: Golden Gate
Average Bad Visibility: 12.04% of the time

Visibility Pattern in: May        Location: Golden Gate
Average Bad Visibility: 11.52% of the time

Visibility Pattern in: June        Location: Golden Gate
Average Bad Visibility: 12.83% of the time

Visibility Pattern in: July        Location: Golden Gate
Average Bad Visibility: 19.89% of the time

Visibility Pattern in: August        Location: Golden Gate
Average Bad Visibility: 19.89% of the time

Visibility Pattern in: September        Location: Golden Gate
Average Bad Visibility: 6.79% of the time

Visibility Pattern in: October        Location: Golden Gate
Average Bad Visibility: 8.62% of the time

Visibility Pattern in: November        Location: Golden Gate
Average Bad Visibility: 9.69%  of the time

Visibility Pattern in: December        Location: Golden Gate
Average Bad Visibility: 9.69%  of the time

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Locations in Visibility Model
Building the Simulation
(Counting Interactions)
Interacting Vessels
Risk During Interactions

- PWS = 5 minutes
- WSF = 2.5 minutes
- SF Bay = 1 minute
Simulation Counting - Crossing

Vessel

1/2 hour

1/2 mile

Vessel

Ferry

1 mile

1/2 mile

Ferry

1/2 mile
Simulation Counting - < 1/2 Mile

θ_{BACK} 

θ_{FRONT} 

θ_{FRONT}

Vessel 
Ferry

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Format of Output Results

% of Max Exposure

X%  Y%  Z%  Etc.
Simulation Analysis Results
(Base Case, Alternative 1,2,3)
## Overall Comparisons

<table>
<thead>
<tr>
<th></th>
<th># Ferry Transits</th>
<th># Grid Cells Covered</th>
<th># Interactions</th>
<th>% Base Case Interactions in 20% of Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base Case</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>97%</td>
</tr>
<tr>
<td><strong>Alternative 3</strong></td>
<td>365%</td>
<td>116%</td>
<td>624%</td>
<td>600%</td>
</tr>
<tr>
<td><strong>Alternative 2</strong></td>
<td>1228%</td>
<td>233%</td>
<td>4620%</td>
<td>4500%</td>
</tr>
<tr>
<td><strong>Alternative 1</strong></td>
<td>1559%</td>
<td>240%</td>
<td>8359%</td>
<td>8200%</td>
</tr>
</tbody>
</table>

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# Transits vs. # Interactions

SF Bay Maritime Simulation

% of Base Case Ferry Transits vs. % of Base Case Interactions
Base Case
Base Case

52.59% of Total Base Case Interactions
Alternative 3
Alternative 3

372.48% of Total Base Case Interactions
Alternative 2

Scenario: Alternative 2  Period: 2000

Date: 7 - 9 - 02

% of Max Exposure in:
Base Case
100 - 11140% 9.45 % 3.83
7.37 % 4.38
6.11 % 3.63
5.21 % 3.09
4.51 % 2.67
3.93 % 2.33
3.43 % 2.04
3.03 % 1.78
2.62 % 1.56
2.28 % 1.35
1.97 % 1.17
1.68 % 1.00
1.42 % 0.84
1.18 % 0.70
0.95 % 0.57
0.74 % 0.44
0.54 % 0.32
0.35 % 0.21
0.17 % 0.10
0.03 % 0.00

% of Base Case Grid Cells

Base Case  Alternative 2

Background map is composite of official National NOAA electronic charts.
Alternative 2

1,705.92% of Total Base Case Interactions
Alternative 1
Alternative 1

2.745.90% of Total Base Case Interactions
Base Case in Bad Visibility

6.57% of Total Base Case Interactions
Alternative 3 in Bad Visibility
Alternative 3 in Bad Visibility

57.92% of Total Base Case Interactions
## Comparisons: Restricted Visibility

<table>
<thead>
<tr>
<th></th>
<th># Ferry Transits</th>
<th># Grid Cells Covered</th>
<th># Interactions</th>
<th>% Base Case Interactions in Red Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>53%</td>
</tr>
<tr>
<td>Base Case - BVI</td>
<td></td>
<td>73%</td>
<td>16%</td>
<td>6.6%</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>365%</td>
<td>116%</td>
<td>624%</td>
<td>372%</td>
</tr>
<tr>
<td>Alternative 3 - BVI</td>
<td></td>
<td>91%</td>
<td>110%</td>
<td>58%</td>
</tr>
</tbody>
</table>

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Conclusion

The results seem to indicate that the safety levels currently enjoyed by the SF Bay ferry service cannot be maintained under the planned expansion scenarios without equally aggressive investment in risk intervention.
Recommendations

• Conduct Probabilistic Risk Assessment of SF Bay Ferry Service (i.e. analyze accident risk, not just interactions)

• Consider the Ferry Service as a Maritime Transportation System, not an individual collection of Ferry Routes
  a. Design a Ferry Route System (using traffic separation)
  b. Design a Ferry Schedules that distribute the arrivals and departures at major terminals

• Develop additional risk intervention measures that reduce the accident probability on a per interaction basis

• Test the effectiveness of these measures using the Maritime Extended Simulation Risk Model
Maritime Risk Assessment Links

- Maritime Risk Assessment Links
  - http://www.seas.gwu.edu/~dorpjr
  - http://www.people.vcu.edu/~jrmerric

- Available for downloading
  - Journal Papers, Proceedings, Reports
  - SF Bay Simulation Movies
QUESTIONS?