Tacoma Narrows Bridge

Presented by: Ramez Mousa

Software Engineering 3J03

March 14, 2003

Agenda

- Background information
- The disaster
- Reasons for the disaster
- Stakeholders & their interest
- Ethical issues
- Actual consequences of the failure

Agenda (cont'd)

- Who was responsible
- Lessons learned
- Applications to SE systems
- Comparable situations in software
- Questions and answers (open discussion)

Background information

- Completed in 1940 as 3^{rd} longest suspension bridge [iii]
- Original proposal by Washington Department of Highways was rejected and viewed as too expensive [ii]
- Proposal of Leon Moisseiff was accepted [ii]
- Moisseiff developed “deflation theory” to justify his proposal [iii]

Background information (cont'd)

- Theory justified using small trusses which accounted for cost difference
- Continuous oscillations on the bridge
- Checking cables and other devices added [v]
- University of Washington contacted to study oscillations and eliminate them
- Suggested many recommendations, but disaster struck before implementing them [ii]

The disaster

- On Nov. 7, 1940, winds of about 60 km/h [i]
- Authorities closed it down
- University of Washington inspectors on site [i]
- Bridge twisted about its centerline
- Bridge twisted vigorously and finally collapsed

Clip 1: Tacoma Narrows Bridge before collapse [vii]

Reasons for the disaster

- Aerodynamic forces not taken into account [ii]
- Width to length ratio was too large [i]
- Bridge was too slender for its length
- Resonance caused by the wind was discredited [vi]
- Design was selected to reduce costs [iv]

Stakeholders & their interests

- Washington Toll Bridge Authority
  - Safety
  - Economics
- Engineers working on the project
  - Design the bridge according to specs
  - Ensure stability and safety of the bridge
  - Loyalty to their employers

Stakeholders & their interests (cont'd)

- Society
  - The need for a bridge
- Public Works Administration
  - Financed the bridge
- Leon Moisseiff
  - Ensure bridge complies with requirements, design supported with theory

Ethical Issues

- Consultant Theodore L. Condron raised many issues about the stability of bridge [ii]
- Concerned about width to length ratio
- Continued investigation
- Found supporting arguments for deflation theory, but these arguments did not account for vertical deflations [iii]

Ethical Issues (cont'd)

- Condron felt that he was the only one with doubts about deflation theory
- Due to Moissieff's very strong reputation, he finally gave in and agreed, however, he recommended increasing the bridge's width [ii]
- "In view of Mr. Moisseiff's ability and reputation, I hesitate to make any criticism ... however, the width of this bridge relative to the length of spans was open to criticism, particularly since it was without precedent" [iii]

Ethical Issues (cont'd)

- Had his recommendations been followed, the disaster would've been avoided [ii]
- Many conservative engineers have also suggested a wider, less flexible bridge [viii]
- Did Condron and the other engineers who had doubts voice their opinions properly?
- One's reputation should not be a factor in agreeing with them

Actual consequences

- 4 years of aerodynamic research [viii]
- Importance of aerodynamic on such structures [viii]
- Emergence of aerodynamics as an important part of the civil engineering curriculum
- Research on dynamic effects of wind on bridge [viii]

Actual consequences (cont'd)

- Special wind tunnel constructed [viii]
- Stability determination methods developed
- Testing structures is essential
- New bridge is a structure of unprecedented function and stability [viii]

Who was responsible

- Carmody Committee formed to investigate [iii]
- Should the designers/engineers be held responsible?
- Committee decided that several factors were not known to the engineers
- The Federal Works Agency reported that the design was most suitable for its use, economics and location [vi]

Who was responsible (cont'd)

- Several other engineers argued that they wouldn't have known the effects of aerodynamics [viii]
- Engineers did their best to save the bridge [v]
- Aerodynamic forces on bridges proved disastrous in the past, however it was not known that they may affect such a large structure [iii]
- This case represents a precedent

Lessons learned

- Need for aerodynamic testing [v]
- Theory must be backed up with data
- Must not go well beyond existing experience [ii]
- Criticisms from consulting engineers should be given consideration [ii]
- “Cheapest option may turn out to be most expensive” [v]

Application to SE systems

- Software systems must be built using both theory and data
- Using new, undeveloped ideas without a basis of experience should be overcome [ii]
- SE need to be more cautious and slow the progress down when necessary [ii]
- Introduction of software control into safety critical systems should be done cautiously [ii]

Comparable situations in software

- SE is a new field
- Not enough past experience and data to learn from
- Progress must be slower and more cautious
- In SE, a similar situation must be tested and verified in a much more complete manner

Comparable situations in software (cont'd)

- First develop theories, understand and record past data and experience and finally test the system to prove the model.
- Model and testing are key to developing successful software systems
- “Testing can show the presence of error but not their absence” [Dijkstra]

Photo 1: Tacoma Narrows Bridge during the collapse [i]

References

[i] Galloping Gertie, http://www.nwrain.net/~newtsuit/recoveries/narrows/narrows.htm

[ii] Holloway, Michael C. From Bridges and Rockets, Lessons for Software Systems, 17th International System Safety Conference, August 1999.

[iii] Scott, Richard. In the wake of Tacoma. ASCE Press; United States, 2001.

[iv] Smith, D. A Case Study and Analysis of the Tacoma Narrows Bridge Failure, http://cee.carleton.ca/Exhibits/Tacoma_Narrows/DSmith/photos.html

[v] Software Engineering: Tacoma Narrows, http://www2.vuw.ac.nz/staff/stephen_marshall/SE/Failures/SE_Tacoma.html

[vi] Tacoma Narrows Bridge, http://cems.alfred.edu/students/harttm/tacoma.html

[vii] Tacoma Narrows Bridge Disaster, http://www.enm.bris.ac.uk/research/nonlinear/tacoma/tacoma.html

[viii] Today's Tacoma Narrows Bridge, http://www.nwrain.net/~newtsuit/recoveries/narrows/cb.htm