Contribution of STAMP to the Risk Management of CO$_2$ Capture, Transport and Storage Projects

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MINES ParisTech, CRC

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Contents

1. Research Question
2. Context
   - CTSC, Climate Change, Risks & Risk Management
3. Proposed Methodology & Application
4. Conclusions
Research Question

Is the safety control structure of CTSC projects effective enough?
In which context and why some CTSC projects are more successful than others?

A systemic approach is proposed for Risk Management of CTSC projects.
CTSC & Climate Change (1/2)

- Research Question
- Context
- Proposed methodology & Application
- Conclusions

Atmospheric CO₂ concentrations (ppm)

Global temperature anomaly (°C)

Year

[GCCSI, 2011]
Objective: halving the emissions by 2050 (compared to the current amount ~ 390 ppm)
CTSC Technology

[IPCC, 2005]
CTSC Projects Current Status

[Figure: Bar chart showing the status of projects across different countries.]

Most (10/16) of the operational projects: EOR

[Jaleh SAMADI, March 28, 2013]
CTSC & Risks (1/2)

- **CO₂ Capture Risks:**
  - Vent gas
  - Liquid & solid wastes
  - Impurities such as H₂S, SOₓ, NOₓ, N₂, O₂, H₂O => Corrosion

- **CO₂ Transport Risks,** depends on:
  - Transportation mode
  - Local topography
  - Meteorological conditions
  - Population density

- **CO₂ Storage Risks:**
  - Local risks, e.g. human beings, animals & plants, and potable water sources
  - Global risks: CO₂ atmospheric release

- **Most significant issues:**
  - Leakage
  - Corrosion (Impurities)
It is essential to analyze the risks associated to CTSC whole chain.

Eight major risk categories are identified.

Long term reliability of the technology

Acceptability of CTSC projects
Requirement of a novel systemic approach

CTSC is a complex sociotechnical system

Complex System:
“composed of many parts that interact with and adapt each other.”
“the behavior cannot be adequately understood by only studying their component parts, because the behavior arises through the interactions among those parts.”

[IRGC, 2010]

A systemic approach is necessary to identify & analyze the risks affecting CTSC projects and their interconnections.
Proposed Methodology, Outline

1. Identifying major risks associated to CTSC (according to literature review, projects documentation and discussion with experts)
2. Assigning the risks to different CTSC subsystems and project phases
3. Defining the nature of risks and their consequences
4. Extracting the risks related to the very first phases of the project
5. Modeling the major risks using a systemic approach
6. Applying the systemic approach to model the safety control structure of different case studies

Jaleh SAMADI, March 28, 2013
1: Identifying major risks

- Identifying major risks associated to CTSC (according to literature review, projects documentation and discussion with experts)

### Overview of risks affecting CTSC project progress

<table>
<thead>
<tr>
<th>Risk</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project permits not obtained</td>
<td>1</td>
</tr>
<tr>
<td>Technology scale-up</td>
<td>2</td>
</tr>
<tr>
<td>Public Opposition</td>
<td>3</td>
</tr>
<tr>
<td>Lack of knowledge/qualified resources for operating the unit</td>
<td>4</td>
</tr>
<tr>
<td>Corrosion</td>
<td>5</td>
</tr>
<tr>
<td>Using the existing facilities (specially pipelines)</td>
<td>6</td>
</tr>
<tr>
<td>CO₂ out of specification</td>
<td>7</td>
</tr>
<tr>
<td>CO₂ plumes exceed the safe zone</td>
<td>8</td>
</tr>
<tr>
<td>Legal uncertainties</td>
<td>9</td>
</tr>
<tr>
<td>Safety related accident</td>
<td>10</td>
</tr>
<tr>
<td>Uncertainties in stakeholders requirements/perceptions - Communication problems</td>
<td>11</td>
</tr>
<tr>
<td>Public availability of sensitive information</td>
<td>12</td>
</tr>
<tr>
<td>Change in policies/priorities</td>
<td>13</td>
</tr>
<tr>
<td>Financial crisis impact on financial support of CCS projects</td>
<td>14</td>
</tr>
<tr>
<td>Unavailability of a monetary mechanism for CO₂</td>
<td>15</td>
</tr>
<tr>
<td>Construction field conditions</td>
<td>16</td>
</tr>
<tr>
<td>Geographical infrastructure</td>
<td>17</td>
</tr>
<tr>
<td>Proximity to other industrial plants</td>
<td>18</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>19</td>
</tr>
<tr>
<td>Maintenance and control procedures (including ESD system)</td>
<td>20</td>
</tr>
<tr>
<td>BLEVE</td>
<td>21</td>
</tr>
<tr>
<td>Lack of financial resources</td>
<td>22</td>
</tr>
<tr>
<td>Lack of political support</td>
<td>23</td>
</tr>
<tr>
<td>Phase change &amp; material problems</td>
<td>24</td>
</tr>
<tr>
<td>Lower Capture efficiency due to the upstream plant flexible operation</td>
<td>25</td>
</tr>
<tr>
<td>High cost of project</td>
<td>26</td>
</tr>
<tr>
<td>Lower Capture efficiency due to the upstream plant flexible operation</td>
<td>27</td>
</tr>
<tr>
<td>CO₂ leakage from compression unit</td>
<td>28</td>
</tr>
<tr>
<td>Pipeline construction</td>
<td>29</td>
</tr>
<tr>
<td>CO₂ leakage from pipeline</td>
<td>30</td>
</tr>
<tr>
<td>Unavailability of regulations regarding different types of storage (offshore/onshore)</td>
<td>31</td>
</tr>
<tr>
<td>Leakage through manmade pathways such as abandoned wells</td>
<td>32</td>
</tr>
<tr>
<td>Well integrity</td>
<td>33</td>
</tr>
<tr>
<td>Injectivity reduction over time</td>
<td>34</td>
</tr>
<tr>
<td>Uncertainties regarding the storage performance</td>
<td>35</td>
</tr>
<tr>
<td>CO₂ leakage from storage to the surface</td>
<td>36</td>
</tr>
<tr>
<td>Model and data issues</td>
<td>37</td>
</tr>
<tr>
<td>Uncertainties related to storage monitoring</td>
<td>38</td>
</tr>
<tr>
<td>Soil contamination</td>
<td>39</td>
</tr>
</tbody>
</table>

A list of 39 risks

Examples:

1. Project permits not obtained

3. Public Opposition

22. Lack of financial resources
2: Risks, CTSC subsystems & project phases

- Assigning the risks to different CTSC subsystems and project phases

<table>
<thead>
<tr>
<th>RISK</th>
<th>SUBSYSTEM</th>
<th>AFFECTED PROJECT PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example:</td>
<td>C</td>
<td>Opportunity</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>Definition and Planning</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>Engineering</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>Construction</td>
</tr>
<tr>
<td>Project permits not obtained</td>
<td></td>
<td>Operation (Injection of CO$_2$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-injection (Monitoring)</td>
</tr>
</tbody>
</table>

Example:
Project permits not obtained
### 3: Nature of Risks & Consequences

- Defining the nature of risks and their consequences

<table>
<thead>
<tr>
<th>RISK</th>
<th>SUBSYSTEM</th>
<th>RISK NATURE</th>
<th>NATURE OF CONSEQUENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>T</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>P</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>P/S</td>
<td>P/S</td>
<td></td>
</tr>
</tbody>
</table>

**Example:**

- Project permits not obtained

### Major risks affecting CTSC project progress (in the first phases)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project permits not obtained</td>
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<tr>
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<td>7</td>
<td>Public availability of sensitive information</td>
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<td>9</td>
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<td>10</td>
<td>Unavailability of a monetary mechanism for CO₂</td>
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<td>11</td>
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<tr>
<td>12</td>
<td>Lack of financial resources</td>
</tr>
<tr>
<td>13</td>
<td>Lack of political support</td>
</tr>
<tr>
<td>14</td>
<td>High cost of project</td>
</tr>
<tr>
<td>15</td>
<td>Unavailability of regulations regarding different types of storage (offshore/onshore)</td>
</tr>
<tr>
<td>16</td>
<td>Uncertainties regarding the storage performance (capacity/injectivity/containment)</td>
</tr>
<tr>
<td>17</td>
<td>Model and data issues</td>
</tr>
<tr>
<td>18</td>
<td>Uncertainties related to storage monitoring</td>
</tr>
</tbody>
</table>
5: Modeling the major risks/safety control structure

Objective: Modeling & Analyzing CTSC Safety Control Structure, using the concepts of STAMP & System Dynamics

1. Define the goal of safety structure
2. Determine system safety constraints
3. Develop the basic safety control structure
4. Specify responsible actors (controllers) for maintaining safety constraints
5. Identify required control actions for each controller
6. Define inadequate control actions leading to a hazardous state
7. System dynamics models, to understand the positive & negative feedbacks
8. Propose an improved safety control structure
Risk: Public opposition

Safety Constraints:
- Local population agreement should be assured.
- In case of opposition, measures should be in place to reduce the risk of project delay or cancellation.

Who is responsible for maintaining the safety constraint?
Project owner

Required Control Actions:
- Direct communication with the community from the initial phases of the project
- Giving information to the public in a less complicated manner (not too technical)
- Making the public trust them by highlighting the mutual benefits from the project development (including CTSC role in Climate Change mitigation)
- Making the public trust them by sharing the uncertainties and risks

(Examples of) Inadequate Control Actions leading to a hazardous state:
- Direct communication with the stakeholders is not provided.
- Communication with the stakeholders is performed indirectly (via media or third parties, for example).
- Direct communication with the stakeholders is provided too late.
- Project developers do not continue to directly communicate with the stakeholders during the life cycle of the project.
Example: Risk of Public Opposition (2/2)

- Knowledge about the risks and uncertainties
- Lessons learned from the project
- Public perception of climate change
- Effectiveness of communication with the public
- Trust between the public and other stakeholders
- Willingness to share the information with stakeholders
- Positive feedback from the history of the storage site
- Risk of CTSC project failure

Risk of public opposition
Rate of increase of public opposition
Willingness to share the information with stakeholders
Knowledge about the risks and uncertainties
Lessons learned from the project
Public perception of climate change
Trust between the public and other stakeholders
Positive feedback from the history of the storage site
Risk of CTSC project failure
Example of a regrouped model
6: Application for Case Studies

- Applying the systemic approach to model the safety control structure of different case studies

<table>
<thead>
<tr>
<th></th>
<th>Barendrecht</th>
<th>Lacq</th>
<th>Weyburn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current Status</strong></td>
<td>Cancelled (in detailed organization phase)</td>
<td>In operation</td>
<td>In operation</td>
</tr>
<tr>
<td><strong>Scale</strong></td>
<td>Demonstration</td>
<td>Pilot</td>
<td>LSIP</td>
</tr>
<tr>
<td><strong>CO₂ storage rate</strong></td>
<td>400,000 tonnes/year</td>
<td>60,000 tonnes/year</td>
<td>3 Mtpa</td>
</tr>
<tr>
<td><strong>Storage type</strong></td>
<td>Depleted gas field</td>
<td>Depleted gas field</td>
<td>EOR</td>
</tr>
<tr>
<td><strong>Country</strong></td>
<td>The Netherlands</td>
<td>France</td>
<td>The United States</td>
</tr>
<tr>
<td><strong>Major issues</strong></td>
<td>Public opposition</td>
<td>Technical challenges</td>
<td>- Public acceptance challenges</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- EOR as a long term storage option!</td>
</tr>
<tr>
<td><strong>Main objective</strong></td>
<td>Set down a foundation for CTSC LSIP in the Netherlands</td>
<td>Verify the feasibility of a CO₂ storage plant in France</td>
<td>Oil production increase</td>
</tr>
<tr>
<td><strong>Concerning Industry</strong></td>
<td>Oil &amp; Gas</td>
<td>Oil &amp; Gas</td>
<td>Oil &amp; Gas</td>
</tr>
</tbody>
</table>
Example: Barendrecht, Initial Model

1. Research Question
2. Context
3. Proposed methodology & Application
4. Conclusions

- National Government
  - Tender Offers
  - Tender Procedures
- Local Governments
  - Environmental Impact Analysis (EIA)
  - Procedures
- External Experts
  - Expertise Request
  - Expertise Report
- Project Developers
  - Information on the project
  - Reactions/Questions
- Media
- NGOs
- Local Population
- CTSC

Progress Reports, Lessons Learned, Incident/Accident Reports

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Example: Barendrecht, Improved Model

- Research Question
- Context
- Proposed methodology & Application
- Conclusions

1. National Government
   - Tender Offers
   - Environmental Permits
   - Procedures
   - Communicate with, on tender procedures

2. Local Governments
   - Tender Procedures
   - Environmental Impact Analysis (EIA)

3. External Experts
   - Expertise Request
   - Expertise Report

4. Project Developers
   - Information on the project
   - Reactions/Questions

5. Media
6. NGOs
7. Local Population
8. CTSC

- Progress Reports, Lessons Learned, Incident/Accident Reports
- Information on the project
- Delay removed

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Proposed Safety Control Structure

1. Research Question
2. Context
3. Proposed methodology & Application
4. Conclusions

- Global/National/Local Regulators
- Request for regulatory frameworks
- Regulatory frameworks

- Global Policy Makers (such as UNFCCC)
- Communication on regulatory frameworks
- Global policies & permitting procedures

- National Policy Makers
- Communication on global policies

- Local Policy Makers
- Communication on tender procedures

- External Investors (Banks or external industries)
- Communication on fund allocation

- Project Owner
- Expertise Report
- Expertise Request
- Information on the project

- External Experts
- Information on the project

- Media
- Information on the project

- NGOs
- Information on the project

- Local Population
- Information on the project

Design / Construction / Operation / Monitoring Procedures

Progress Reports, Lessons Learned, Incident/Accident Reports

Communication on project progress

Viewpoints on the project
Conclusions, Advantages of the Methodology

Overview:
- A novel methodology to model & analyze the risks & safety control structures
- Providing a means of decision making for CTSC projects development

Advantages:
- Presenting more comprehensive list and categories of risks
- Taking into account the complex network of risk interconnections by proposing a systemic modeling framework
- Underlining the significance of stakeholders role in the project success or failure
Many thanks for your attention

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