Designing the Next Generation of Pit Emptying Technologies Using a Workshop Approach

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BMGF, UKZN, Mott MacDonald, Ashland Pumps, Univ. of Missouri, Practica, Carbyne, Netherlands Red Cross, FloHawks, AGI, Boeing, WFP, PID, MAWTS, Mveza, Jon Shaw and Assoc.
This is the problem

An estimated 1.77 billion people use pit latrines, many need to be emptied every 3-5 years.
How can we design a mechanical pit emptying device that is...

- Fast
- Reliable
- Safe
- Hygienic
- Robust
- Replaceable parts
- Can access all pits
- Can handle wet and dry pits
- Can handle trash
- Etc
- Etc

Meets specific requirements
Assemble ...

The Greatest Minds Ever
Assemble... A bunch of technical people with knowledge, experience, and interest ....

SMEs and non-SMEs, practitioners, researchers, engineers, optimists
What was different in this workshop?

• Visits to a variety of pits in Lusaka, Dar es Salaam, Durban, Bangalore to gain context of the challenge of emptying pits
• Experienced facilitator – Jon Shaw
Tremendous Insight No. 1

If we really want to solve a problem, we must:

Really harness the diversity of minds, experiences, and ideas of the right mix of people

Corollary:

The ways we do our normal work with other people (meetings, brainstorming) are probably not the most effective
Process matters!!!

• Problem Definition
  – Problem Statement
  – Scope
  – Inviolables

• Field Visits

• Review Pit Observation Sheets
Problem Definition - “I think the problem is...”

Technical:
There is currently no technical emptying solution that adequately mitigates the wide variety of trash and debris found in pits
Health and safety- pit emptying is often performed by hand
Pits can be difficult to access by mechanized means
Access to the pit
Water availability
Mechanized solutions to the FSM chain are too energy intensive (fuel, cost)
We’re trying to create one solution that works in every pit
Don’t have a solution to clear debris in an effective way
We don’t know what to do with sludge- there are limited options available for appropriate disposal of waste
We have to move sludge against gravity
Technical solutions are too big- difficult to design technical solutions that are small enough to access pits
Vibration can cause collapse of unlined pits

“Problem well stated is a problem half-solved.”
-Charles Kettering
Economics:
We don’t how to make pit emptying profitable/less expensive than digging new pit
Established mainstream industrial equipment is too expensive for certain entrepreneurial markets
Existing pumps are too expensive
We don’t understand the whole timing aspect of business process of emptying
We don’t understand market segmentation
Favorable financing is not available
Access to financing in developing countries is poor generally
Supply chain issues in developing countries
Lack of clarity as to who owns this problem (private sector? Public sector?)
The people that need this solution have little income
Availability of spare parts
Cost of importing parts
Availability of skills
The “do-nothing” or partial emptying solution is viable
Ambiguity in facility ownership
Enabling environment/regulations:
We don’t have all of the data around pit make-up/ a lot of the data is questionable
Sludge contains pathogens, is dangerous
Disposal sites are too far away too crowded or non-existent
We don’t have a safe, sustainable technical solution(s) that is supported by a viable business model in disadvantaged communities
Social/Cultural:
We’re trying to come up with a mechanical solution to a cultural problem
We don’t know how to overcome the social/cultural issues
People are not sufficiently concerned about the status quo hand emptying processes
We don’t understand how to influence private sector and authorities to change processes (moving from hand-emptying)
Not sufficient worker safety regulations in place
Pit emptiers are often the most vulnerable member of society
Do the people that would benefit understand the need

We don’t have sustainable technical solutions that protect public health and economically empty wet and dry urban pit latrines of various designs
Scope

What is in?
- Pit emptying and transport
- Dealing with trash in pits
- Ancillary existing pit modification

What is out?
- Treatment of faecal sludge
- New pit designs
- Availability of financing for operator and customer
- Regulatory environment
- Behavior change
Inviolates

What concepts, rules and processes specific to this problem are *considered* immovable, unchangeable or off-limits from change?

- How people defecate
- The location and legality of where people live
- Public and environmental health
- Health and safety of workers
- Dignity of people
Tremendous Insight No. 2

You have to agree on WHAT the problem is
Current State
– observations about pit latrines, nature of pit contents, current technologies

Current State/Level Setting Scorecard
- Objectives
- Deliverables
- Requirements
Idea Generation

**WHAT:** Identify all potential solutions

**HOW:** Use variety of IG techniques

**OUTPUT:** Catalog of solutions

- Brainstorming
- Group
- Systematic Inventive Thinking
- Concept mapping
- Structured group prompts
Idea Generation
Tremendous Insight No. 3

Brainstorming mantras

“Not a sprint, but a marathon, and it should HURT accordingly”

“Don’t own any one idea, own ALL the ideas”

“Beware structural fixedness”

“Applaud audaciousness, beware doubt”

“Use other ideas as springboards”
• Morphological chart – dealing with trash, pumping, safety, etc.

• Evaluation – each idea quickly described and rated as “feasible-infeasible”

• Sub Teams – pick from all the ideas, with focus areas, e.g., Universal solution, Lowest Cost, etc.
Team Name: The Dead Ringers

Emphasis: Universal Solution

Project Manager: Jamie

Team Members: Dale, Jason, Chris

Solution Elements:
- Wet/dry vac
- Lance + nozzle
- HP Pump
- Hose + valve
- Trolley
- Trailer
- [4 x 4 Horse]
- Pick, spade, cement
- Power Unit
- Elephant
- Funnel/cleanout

Equipment:
- Universal pit emptying solution to economically empty 95% of pits using proven technology that is easy to operate and maintain.

Pros:
- Off-the-shelf; easy to operate; unique; high costs; unskilled labour (local); low cost; scalable

Cons:
- Longer lead time; 100 motors; Heavy sludge + debris

Actions:
- Shopping list for Fri.
- Review JICUO data + JTR data
- Capex estimate
- Process map + timings

"OCTO PUS"

The PENGUIN
## Solution

### Components, costs, 40+ criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Estimate</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No. of workers</td>
<td>3</td>
<td></td>
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<tr>
<td>2. No. of parts</td>
<td>15</td>
<td></td>
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<tr>
<td>3. $ per unit emptied</td>
<td>21.5 USD / pit</td>
<td>1 hour per pit emptying</td>
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<tr>
<td></td>
<td>1.5 USD for fuel</td>
<td></td>
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<tr>
<td></td>
<td>10 USD for labor (3 trained operators)</td>
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<tr>
<td></td>
<td>10 USD for CAPEX amortized over 7 years &amp; financing 20% interest</td>
<td></td>
</tr>
<tr>
<td>4. Liters of fuel/ unit emptied</td>
<td>2 liters</td>
<td></td>
</tr>
<tr>
<td>5. Liter of water per unit emptied</td>
<td>5 gal</td>
<td></td>
</tr>
<tr>
<td>6. kW/liter of unit emptied</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7. No. of pits per day</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>8. Meters from pit horizontal</td>
<td>100 meters</td>
<td></td>
</tr>
<tr>
<td>9. Meters from pit vertical</td>
<td>40 meters</td>
<td></td>
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<tr>
<td>10. Number of minutes to set up</td>
<td>15 metric minutes</td>
<td>(estimate based on distance of 25 meters between pit to road)</td>
</tr>
<tr>
<td>11. Number of minutes for teardown</td>
<td>20 metric minutes</td>
<td></td>
</tr>
<tr>
<td>12. Number of operation steps</td>
<td>12 steps</td>
<td></td>
</tr>
<tr>
<td>13. Weight of unit in kg for RSU</td>
<td>1800 kg</td>
<td>empty weight</td>
</tr>
<tr>
<td>14. Weight of PSU</td>
<td>100 kg</td>
<td></td>
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<tr>
<td>15. Operation space required</td>
<td>2.9 X 2.9 m = &lt;9 m²</td>
<td></td>
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<tr>
<td>16. Number of COTS parts</td>
<td>~40% by value</td>
<td></td>
</tr>
<tr>
<td>17. % of COTS parts</td>
<td>see above</td>
<td></td>
</tr>
<tr>
<td>18. % of wear parts</td>
<td>~10%</td>
<td>hoses, chain saw blade, etc.</td>
</tr>
<tr>
<td>19. Capital Cost</td>
<td>36,200 USD</td>
<td></td>
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<tr>
<td>20. Unit Cost ($ per pit emptied per year)</td>
<td>40 metric hours</td>
<td>assumes the start is trained mechanic.</td>
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<tr>
<td>21. Hours of training for operations</td>
<td>24 metric hours</td>
<td></td>
</tr>
<tr>
<td>22. Hours of training for maintenance</td>
<td>24 metric hours</td>
<td></td>
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<tr>
<td>23. % of local manufacture</td>
<td>50%</td>
<td></td>
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<tr>
<td>24. Risk priority number</td>
<td>M</td>
<td></td>
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<tr>
<td>25. Cost of service delivery</td>
<td>M</td>
<td></td>
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<tr>
<td>26. Life expectancy in months</td>
<td></td>
<td></td>
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<tr>
<td>27. Minutes cleaning between operation</td>
<td></td>
<td></td>
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<tr>
<td>28. Skill level to operate</td>
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<tr>
<td>29. Max. depth capability (m)</td>
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<td></td>
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<td>30. Max. horizontal reach (m)</td>
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<tr>
<td>31. Mean time between failures</td>
<td></td>
<td></td>
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<tr>
<td>32. Likelihood of damaging unlined pits</td>
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<tr>
<td>33. Odor impact</td>
<td></td>
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<td>34. % of spillage per operation</td>
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<td>35. Time to gain access for emptying</td>
<td></td>
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<td>36. Min. hole size allowing access to</td>
<td></td>
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<td>37. Number of different content types addressed</td>
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<td>38. Range of solids content</td>
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<td>39. Propensity to clog</td>
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<td>40. Time to clear blockage (min)</td>
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<tr>
<td>41. Grams per contamination</td>
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<tr>
<td>42. Mean time between blockages</td>
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<tr>
<td>43. Emptying rate per second</td>
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<td>44. Human output per operation</td>
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<td>45. Min. residual operational depth</td>
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<tr>
<td>46. Operational noise levels (dB)</td>
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<td></td>
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<td>47. Particulate emissions per operations</td>
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<tr>
<td>48. Maintenance oil used for operation</td>
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- Evaluation/Prioritization

**Teamwork – Ranking of “mock-ups”**

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<thead>
<tr>
<th>$/m^3</th>
<th>CapX</th>
<th>Trash handling</th>
<th>Wet sludge removal rate</th>
<th>Dry sludge removal rate</th>
<th>Cleanliness</th>
<th>Technical risk</th>
<th>Ease of use</th>
<th>Avg</th>
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Lessons learned

• Value of innovation process tools and techniques

• Learning: challenges in pit emptying, variability, learning from each other

• A single pit emptying machine?

• Challenges: time for evaluation, review; follow-up and steps forward