Managing Software Development for Global Health

Richard Anderson
Outline

• PATH
• The Cold Chain
• National Vaccine Forecasting
• CCEM 1.0: In house development
• CCEM 2.1: Out sourcing
• Managing a software product
• Lessons learned
Today’s talk

- I’m spending my sabbatical working at a Global Health NGO in Seattle
- I’ve gotten sucked into a Microsoft Access software project
- The project made many of the classic software engineering mistakes and was in serious trouble
- Applying software industry best practices is leading to a positive outcome
Why this might be interesting

• **Programming in the real world:** much of the world’s software is written by people who don’t know what they are doing using tools like Microsoft Access

• **ICT4D:** improving the quality of software for global development could be Computer Sciences big contribution

• Software Engineering appears to be the key
PATH

• Seattle based NGO working in health technologies
• Founded 1977
  – Now working in 70 countries
• Program for Appropriate Technology in Health
PATH focus

• Solutions for emerging and epidemic diseases, like AIDS, tuberculosis, and malaria.
• Health technologies designed for low-resource settings, by the people who will use them.
• Safer childbirth and healthy children.
• Health equity for women, among the world’s most vulnerable—and influential—populations.
• The basic protection of vaccines for women and children around the world.
Technology Solutions
Primary areas of focus

• Immunization & vaccine technologies
• Diagnostic tests for diseases
• Reproductive health technologies
• Maternal & child health technologies
• Nutrition technologies
• Health Management Information Systems
Safe and Effective Immunization

Safe Vaccine

Safe Injection

Safe disposal
HEATmarker™
Vaccine vial monitors

Illustration of HEATmarker™ Color Change

- The square is lighter than the circle. If the expiry date is not passed, use the vaccine.
- The square is lighter than the circle. If the expiry date is not passed, use the vaccine. Soon!
- The square matches the circle. Do not use the vaccine. Inform your supervisor.
- The square is darker than the circle. Do not use the vaccine. Inform your supervisor.
Auto Disable Syringes

More than 5.4 billion distributed by 2005

Leads to medical waste problems
Removing the Danger of Contaminated Needles

Needle removal can (‘popper’)
• For luer-slip needles
• Reduces volume of ‘sharps’ waste
Expanding contraceptive choice

Reducing Sexually Transmitted Infections

Safe Pregnancy and Childbirth

Early Detection of Cancer
Q: I'm just curious - and this must be very hard as very practical, successful people to admit - but has there been an occasion where you've let some foundation money out the door and after a couple of years you would say, oh, that was pretty much a failure; that was wasted money; didn't work?

Melinda Gates: And sometimes you make a mistake where it's a fantastic investment but there's a little piece of it you didn't get right. So, a great example is rotavirus. We have, thank God, an amazing life-saving vaccine that's coming for kids. And it's actually being delivered now in Nicaragua; we're going to get it out in lots of places. It's a vaccine against diarrhea. . . . Well, unfortunately, the rotavirus packaging came out too large. We had these large boxes. Well, you can't carry large boxes of vials of vaccinations out into villages. That requires too much refrigeration.
Cold chain description

- Storage of vaccines from national level to point of delivery
- Manage vaccines for both immunization schedule and immunization campaigns
- Highly regulated
  - National health ministry
  - WHO / PAHO

- Facility hierarchy
  - National level store
    - Cold room
  - Regional
    - Cold room or refrigerator
  - District
    - Refrigerator
  - Health Center
    - Refrigerator
  - Health Post
    - Refrigerator or Cold box
## Vaccine Storage

<table>
<thead>
<tr>
<th>Vaccine</th>
<th>Primary vaccine store</th>
<th>Intermediate vaccine store</th>
<th>Health centre</th>
<th>Health post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Up to 6 Months</td>
<td>Region- up to 3 months</td>
<td>District- up to one month</td>
<td>Up to one month</td>
</tr>
<tr>
<td>OPV</td>
<td>-15°C to -25°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCG</td>
<td></td>
<td>2°C to +8°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measles, MR, MMR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YF</td>
<td></td>
<td>2°C to +8°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hib freeze-dried</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meningococcal A&amp;C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HepB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT, DTP, DTP Hep B</td>
<td></td>
<td>+2°C to +8°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hib liquid</td>
<td></td>
<td>+2°C to +8°C</td>
<td>+2°C to +8°C</td>
<td></td>
</tr>
<tr>
<td>Td</td>
<td></td>
<td>Never Freeze !</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TT</td>
<td></td>
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</tr>
</tbody>
</table>
Cold Chain
Cold Chain
Cold chain in Nicaragua

• 1350 refrigerators, including 250 solar.
• Vaccine distributed monthly to Pacific, once every three months in Caribbean
• Electric refrigerators considered reliable
• Problems with solar refrigerators
  – Primarily with solar generation
    • Batteries
    • Theft of panels
Cold chain management

• Basic problems
  – Keep track of nation’s inventory of refrigerators and cold rooms
  – Answer the question: do we have refrigerator storage capacity for vaccine schedule

• Extra credit
  – Model cold chain capacity over multiple years with additions and removal of equipment

• Out of scope
  – Tracking inventory of vaccines
  – Transit time for vaccines
Cold chain expertise

• Knowledge of the following domains
  – Refrigeration, logistics, vaccines, packaging, regulatory environment, health practices, national politics

• Plan nation wide vaccine distribution
  – Distribution, storage, delivery
  – Work with donors and international organizations

• Formalization of idea of a National Cold Chain
New Vaccines

• Higher cost vaccines
• Vaccine packaging
• Packaged with preservatives
• Global vaccine initiatives
  – GAVI: Global Alliance for Vaccines and Immunization
  – Gates Foundation: $10 billion commitment
Increased cost, increased volume

Sources: UNICEF Vaccine projection and PAHO Revolving Fund Vaccine Prices, 2009.
Old vs. New Vaccines

4,100 doses
Polio and Measles
$635

625 doses
Rotavirus
$4,687
CCEM Vision

• Capture expertise of cold chain experts in software
• Provide basic tool for analyzing a nation’s cold chain
• Enable countries to do their own cold chain analysis
• Model
  – Initial cold chain inventory
  – Inventory updates
  – Cold chain analysis
Cold Chain Equipment Management
CCEM

• Microsoft Access Application
  – 66 Tables
  – 204 Forms
Catalogs
Administrative Levels

<table>
<thead>
<tr>
<th>Health facility types</th>
<th>National Policy: Frequency of resupply (weeks)</th>
<th>National Policy: Reserve stock (weeks)</th>
<th>Select the source of resupply (weeks) and reserve stock (weeks) for storage requirements calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGO Hospital</td>
<td>6</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>Public HCIV</td>
<td>4</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>Private HCIV</td>
<td>4</td>
<td>2</td>
<td>National policy by facility type</td>
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<tr>
<td>NGO HCIV</td>
<td>5</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>Public HCIII</td>
<td>5</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>Private HCIII</td>
<td>4</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>NGO HCIII</td>
<td>6</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>Public HCII</td>
<td>4</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>Private HCII</td>
<td>4</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>NGO HCCI</td>
<td>6</td>
<td>2</td>
<td>National policy by facility type</td>
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<tr>
<td>National Store</td>
<td>12</td>
<td>12</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>District Store</td>
<td>4</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>Sub-district Store</td>
<td>4</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>Public Hospital</td>
<td>4</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
<tr>
<td>Private Hospital</td>
<td>4</td>
<td>2</td>
<td>National policy by facility type</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Administrative Levels</th>
<th>Administrative data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admin code</td>
<td>District</td>
</tr>
<tr>
<td>-----------</td>
<td>----------</td>
</tr>
<tr>
<td>1000</td>
<td>ABIM</td>
</tr>
<tr>
<td>1001</td>
<td>ABIM</td>
</tr>
<tr>
<td>1002</td>
<td>ABIM</td>
</tr>
<tr>
<td>1003</td>
<td>ABIM</td>
</tr>
<tr>
<td>1004</td>
<td>ABIM</td>
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<td>ABIM</td>
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<td>1006</td>
<td>ABIM</td>
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<tr>
<td>1007</td>
<td>ABIM</td>
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<tr>
<td>1008</td>
<td>ABIM</td>
</tr>
<tr>
<td>1009</td>
<td>ABIM</td>
</tr>
</tbody>
</table>

Records: 11 of 35
Vaccine Schedules

- Target population (choose from four target populations):
  - Live Births
  - Pregnant Women
  - Total Population
  - Child-Bearing Age Women
- Usage on target population (%): This field by default is 100% or user can enter lower percentage of one of the four immunization target populations. (For example, the female target population for HPV vaccine is 1.8% of the Total Population in some countries).
- Wastage rate (%): This field sets the nationally observed wastage rates for specific vaccines and the maximum value can be 99%.
Facility and Refrigerator Records

<table>
<thead>
<tr>
<th>Facility and Refrigerator Records</th>
<th>3/10/2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSE Software Engineering Research Group</td>
<td>30</td>
</tr>
</tbody>
</table>

![Image of Facility and Refrigerator Records interface](image-url)
Report Generation

Total population by facility type (National)

<table>
<thead>
<tr>
<th>Admin Area</th>
<th>Facility Type</th>
<th>No. Facilities</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>District Store</td>
<td>80</td>
<td>2,977</td>
<td>1,189,142</td>
<td>291,336</td>
</tr>
<tr>
<td>National</td>
<td>Health Center 2</td>
<td>1202</td>
<td>200</td>
<td>212,173</td>
<td>10,725</td>
</tr>
<tr>
<td>National</td>
<td>Health Center 3</td>
<td>989</td>
<td>708</td>
<td>809,837</td>
<td>16,423</td>
</tr>
<tr>
<td>National</td>
<td>Health Center 4</td>
<td>184</td>
<td>2,145</td>
<td>303,171</td>
<td>33,654</td>
</tr>
<tr>
<td>National</td>
<td>Hospital</td>
<td>126</td>
<td>1,268</td>
<td>2,000,000</td>
<td>52,423</td>
</tr>
<tr>
<td>National</td>
<td>National Store</td>
<td>1</td>
<td>28,853,578</td>
<td>28,853,578</td>
<td>28,853,578</td>
</tr>
<tr>
<td>National</td>
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<td>1</td>
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<td>28,853,578</td>
</tr>
</tbody>
</table>

Areas Included:
Whole Country

Number of Equipment

- Working Well
- Working Needs Service
- Not Working

Export chart to excel  Back  Copy areas included to clipboard
Defining Removal Criteria
Defining Allocation Criteria
Vaccine Schedules
Forecasting Results
Result Reporting

You selected: All equipment transactions by facility: MyForecastParams

What would you like to review?
- List of all equipment transactions by facility for the selected year
- List of all equipment transactions by facility up to the selected year

Select the year: 2010

Forecast Equipment for Multiyear Plans >> Forecast Results >> Generate/Review Forecast Results >> Multi-year new equipment allocation

You selected: Multi-year new equipment allocation table: MyForecastParams

Review multiyear new equipment allocation table by:
- Equipment types
- Equipment types and models

The following forecast parameters have been loaded for comparison: MyForecastParams, MyForecastParams1

Annual investment for new equipment
- Annual investment for new equipment
- Annual energy costs of the old systems

Annual Investment for New Equipment

2017 2018 2019 2020 2021

0 100,000 200,000 300,000 400,000 500,000 600,000 700,000

- MyForecastParams
- MyForecastParams1

3/10/2010

CSE Software Engineering Research Group
• Initial development phase: Cold chain expert with software developer  
  – Work began October 2006
• Microsoft Access 2003
• Informal development process  
  – “Can you add . . . ”, “Yes”  
  – “We need to determine what types of refrigerators to allocate”, “I can do that”
• Emphasis on increasing functionality of application
Results of CCEM 1.0

• Encapsulation of Cold Chain Analysis process in software
• In country tests and demonstrations
  – Uganda cold chain evaluation, 2007
  – Workshops
    • Seattle, May 2008
    • Panama City, October 2008
• Difficult to use software with defects
• Independent consultant did not consider the tool to be usable
CCEM 2.1

• Software firm hired to “fix” CCEM
  – Scope of work: deliver a working version of the code from a reference version
• Seattle – India consulting firm working in the health domain
  – Agile methodology: Sprints, Use cases, Task estimation
• Three month contract
• Limited number of firms responded to the RFP
  – Project scale,
  – Lack of interest in Access applications
Outside development

• Initial focus
  – Development of comprehensive use case catalog
  – Port from Access 2003 to Access 2007
    • Integration of Ribbon UI
  – Addressing usability and workflow issues
Delivery difficulties

• After two months, sense of frustration on all sides
• Process not converging towards usable software
• Forecasting had not been evaluated
• Substantial finger pointing and blame assessment
Rapid Development
Steve McConnell

• Customers pose risk:
  – Don’t understand what they want
  – Won’t commit to written requirements
  – Insist on new requirements
  – Communication is slow
  – Incapable of participating in reviews
  – Technically unsophisticated
  – Don’t understand the software development process
What was going wrong

• Lack of documentation / understanding of the application
  – PATH did not have a specification
  – Developer accepted the original code as the specification
    • “We did not include correctness of the algorithms in the scope of the work”

• No possibility of testing forecasting component
  – Subject matter expert not involved at this stage
  – Developer had no understanding of what they were building

• Contractor did not consider lack of domain expertise in their risk assessment
What was going wrong

- Focus on the easy stuff
  - Fixing reports and adjusting the workflow
- Unclear process for bounding the scope and identifying completion criteria
- Some things took longer than expected
  - Integrating the ribbon
- No plan for scaled testing or understanding of results
Involvement of subject matter expert

• Initial reaction
  – “This doesn’t work”
  – Focus on advanced features such as vaccine campaigns

• Planned to lead application walk through
  – Began by describing computations and processes
    • First time this had been described
    • Documentation of computations facilitated bug discovery
climate zone matches? 

→ Y

→ 16/24 electricity available?

→ N

→ Equip preference(s) matching?

→ N

→ Allocate & calculation & cost of each match

→ Choose least cost (capital) & Allocate.

→ LOOP to next facility.

→ Y

→ Solar feasible (2)

→ N

→ Reliable supply of FP gas available?

→ N

→ Clean supply of kerosene available?

→ Y

→ Allocation process

→ LOOP to next facility

→ N

→ IS B - A > Threshold?

→ Y

→ Test:
  - no allocation < Threshold?
  - no allocation if no climate match?
  - allocation follows prioritisation of energy sources?
  - evaluation of alternative matches follows least cost criterion?
  - presentation of allocation results accurate?

→ Calculate B Required Cap. each temp.
Getting project back on track

• Extended the contract by one month
  – Made it clear that no further extensions were available

• Reduced delivery target to “beta quality”
  – Identified resources to hire consultant for future bug fixes

• Took on domain specific testing as PATH task
  – Provided detailed directions for some specific fixes
PATH management of CCEM

• Code delivered to PATH December 2009
• Field validation test (February) postponed due to lack of available field data.
• Product management plan developed with internal rebudgeting
  – Project manager
  – Technical product manager
  – Contract programmer (original developer)
Defining a software process for PATH

• How can PATH effectively manage and deliver software products?
  – Software is critical for supporting global health
  – It is critical that public health expertise is incorporated into the software
  – PATH has had great success in engineering and testing products
Managing CCEM code development

• Software configuration management
  – Access application is basically a single database
  – Data and application are integrated
  – Challenges
    • Separation and tracking of data sets
    • Import and export of data sets
    • Versioning
  – Shouldn’t be hard to do . . .
    • Can trace many of our challenges to this
Issue management

• Bug tracking and feature suggestions
• Manage task list with prioritization
• Information Services setting up Bugzilla for project use
External Development

• Development phases
  – Triage task list
  – Assign work items to contract developer
  – Test and check in work items
Testing

• Develop simplified test cases
  – CCEM Data sets
    • Refrigerators
    • Vaccines
    • Geography
    • Facilities
    • Equipment
    • Forecast parameters
  – Important result: significant testing can be done on very small data sets

• Documentation of algorithms, process, computations
• Structured walk through
Management

• Schedule with objectives
• Working with budget limitations
• Critical to manage scope
  – “CCEM is code complete”
  – Avoid adding functionality
• Needs to be judged as usable by subject matter expert
  – Deliver an in-country analysis of a cold chain
Key lessons

• Challenges and experiences from CCEM are not unique

• Lessons from CCEM 2.1
  – Need for specifications
  – Communication with developers
  – In house software testing
  – Management of data sets
  – Issue tracking
Software Development at PATH

• Existing PATH employees have picked up key skills in software product management
• Opportunity for working with Information Services Department
• Tool and process support necessary
  – Configuration management
  – Bug tracking
• Area for skill development and training
  – Software testing