Final report for the CT Practice Based Research Network research project conducted by the Connecticut Association of Directors of Health and Institute for Community Research

Measuring quality in local public health emergency preparedness: the H1N1 experience

The PBRN research project titled "Measuring quality in local public health emergency preparedness: the H1N1 experience" (or Quality Improvement = QI study) was conducted in 2012 and was aimed primarily at developing measures of quality in public health practice that are specific to the H1N1 context, and to test and validate the new measures. The QI study assessed the quality of Connecticut Local Health Departments (LHD) responses during the H1N1 influenza season in 2009-2010.

Quality Improvement (QI) is a systematic approach for understanding and measuring performance and identifying solutions to performance gaps, and implementing changes to improve outcomes. Measures of performance of LHDs are critical to QI of public health practices. Performance measures can link actual LHD practices to health outcomes, but many other factors that impact health outcomes are outside the control of the public health agencies. Relatively few formal and systematic tests of performance and QI measures in public health research have been undertaken [1], and none to date using advanced psychometric techniques like Structural Equation Modeling (SEM[1]). There are rare applications of SEM to measure construction and testing in performance assessment or quality improvement research in public health, none based on powerful statistical software like Mplus [2]. We only found mention of one yet unpublished factor analytic analysis [3] that approaches the methodology we suggested.

The project proposed to apply systematic methods for developing sound and valid measures from a psychometric perspective following recent advances in SEM modeling with latent variables. Most measures used in performance assessment in public health are in fact indexes, not scales, which is the main challenge for building and validating them. We will employ in this project Multiple Cause Multiple Indicator (MIMIC) modeling of categorical indicators[4] in particular and appropriate index construction and validation procedures for causal indicators [5,6]. The original study design proposed to focus on key areas of variability between LHDs, as well as variability across four distinct phases: pre-pandemic, pre-vaccine, post-vaccine, post-pandemic. The ultimate response rate (43 out of the currently existing 78 LHDs in CT) however and results from the preliminary qualitative data collection led us to restrict the analyses of LHD variability, and to consider two main phases, pre-vaccine and post-vaccine.

Prior research identified, among others, QI measure domains like: (a) response coordination, communication practices, conducting outreach, and monitoring influenza-like illness (ILI) in the pre-vaccine phase; (b) communication and coordination, community mitigation practices, actual vaccination strategy (including dealing with vaccine shortage); and (c) community engagement and partnership, communication and coordination, and evaluation of activities during the post-outbreak phase.

Because the community health outcomes for the pandemic emergency services offered by LHDs are influenced by a range of external factors outside of the control of LHDs, we proposed to use a proxy self-assessed outcome measure, following the format of self-assessed capability, i.e. the extent to which each LHD rates retrospectively their capacity for timely and effective implementation during each phase as poor, acceptable, or excellent. We were able however to obtain secondary data on vaccinations by the LHDs from the CT DPH, for 32 of the 47 LHDs eventually surveyed, which allowed us to use an actual outcome measure for the H1N1 vaccine period.

The study comprised 2 main phases, a preliminary qualitative data collection one, and the survey (quantitative) phase.

1. Preliminary phase:

In this first study stage, published literature and other PBRN reports were first screened to identify themes relevant to the H1N1 response of CT LHDs. In particular we resorted to an additional information source, from a thorough review of all the email communications from one LHD that were archived from the entire period of the study (April 2009-February 2010). This allowed us to develop a comprehensive list of topics and activities related to the LHD response to the H1N1 epidemic, which had three uses in our study: 1. As a memory jog for the focus group participants, which we distributed as a 1 page 'main events' sheet to the participants before the focus group session were initiated; 2. to develop two lists of 'important events' for each period (pre-vaccine/after vaccine availability) that were inserted in the survey, also used a memory jogs (not employed in the measurement analysis); 3. To develop a detailed timeline of events that guided the formulation of focus group guidelines as well as survey questions.

2. Focus groups

Four focus group sessions were organized with LHD representatives covering four geographical areas if the state; we asked for the director or another better positioned staff who was involved in the H1N1 response and was knowledgeable about their LHD actions to participate in the focus group sessions. A registration form was filled out, emailed or done on site (name, responsibilities in LHD, responsibilities during H1N1). Organizers provided snacks and coffee, and the co-PI (analyst) participated to all sessions. Two experienced public health professionals were chosen as facilitators and they were provided with guideline sheets (see Appendix) and instructed before the sessions.

Based on extensive discussions among the co-PIs and the project director, and after reviewing the detailed H1N1 timeline of events, several guiding themes for discussions were proposed:

1. The LHD role in influenza vaccination in general.
2. Specific activities during H1N1 – pre-vaccine and after vaccine became available
3. Barriers and obstacles during H1N1 for LHDs.
4. How LHD communicated to the community.
5. Important attributes or activities that could best summarize LHDs performance during H1N1.

Focus groups summary findings

Some findings from analyzing the transcripts of the four focus group discussions are detailed below. Many LHD representatives concurred that in their response to H1N1 epidemic there a number of cross-jurisdictional issues arose, for instance residents living in one jurisdiction but working/having their primary care physician (PCP) in another, or resident participating in flu vaccine clinics across the borders.

The issue of specific timing of response activities was also stressed, such that LHD activities occurred at different calendar times, but also followed local specificities. We concluded then that

in the quantitative questionnaire we will need to ask specific questions on specific activities during specified periods, like the 2 pre-vaccination/vaccination phases.

Some communication themes emerged as important in the discussion, among them: consistency and conciseness, or the need to coordinate among staff and present consistent concise messages to the constituents in a continuously changing environment; timeliness of reactions and messages in a dynamic world; the existence of local networks that were re-activated ('reacquainting with partners') with this opportunity; LHDs becoming more involved in the 'management of information' activity, both as a source of information, but also as active consumers of it (LHDs had to get themselves informed from a variety of sources, such as: CDC, CT DPH, other states websites).

The focus groups yielded also a comprehensive list of constituents LHD communicated with: school representatives (private too, children/youth, school (& summer) camps, PTAs, daycares, parents, groups of stakeholders (regular or ad-hoc; like hospitals, older adults), long-term residential facilities, CEOs, etc., which was then used to build questionnaire items. An additional comprehensive list of communication activities also emerged, e.g.: bulletins, hotline, posters, website, (electronic) billboards, curriculum (for schools e.g.), video information, signs (e.g. hand washing), pamphlets, press releases, 1-on-1 calls, Powerpoints, PSAs, Facebook, Twitter.

Issues of power/authority to enforce public health measures in their jurisdictions were often mentioned, like mandating measures vs. advising and guidance.

Also notably, new categories or activity dimension were unraveled that were not foreseen in the initial application and setup of the focus groups discussion format. One such emerging theme was *flexibility*, which became a common theme of quick and adaptable responses to the dynamic and complex challenges of the N1N1 epidemic. Some specific instances of such flexibility were: organizing fast classes (just-in-time training), e.g. on vaccinating kids; vaccinating other region's residents; planning for very different roles than what H1N1 required; modifying LHD staff roles during H1N1.

3. Survey development and administration

Surveys were developed and launched online on Surveymonkey.com, with the option offered to LHD representatives to fill out paper surveys, of they requested it. The questionnaire was confidential, and data was merged with data from annual reports provided by CADH. Data from Surveymonkey has been saves as SPSS *.sav file and processed further; most variables had to be re-labeled, and their long description (variable label) replaced (those from the same general category had the same label, e.g. q0006_0001 through q0006_0017 all had the same label 'Which of the following are in your LHD jurisdiction? (choose all that apply)' which were redefined as e.g. q0006_0001 'In your LHD jurisdiction - 1 Public High school(s) ').

New measures were created for the before vaccine/after vaccine available periods, for communication with constituents, and activities performed by the LHDs (the original survey is provided as Appendix).

Survey data explorations and analyses

47 LHD representatives completed the survey: 23 full time (a median of 13.7 FTE), 8 part time (1.2 FTE), and 16 districts (8.85 FTE).

Table 1. Characteristics of participating Local Health Departments (LHDs)

LHDs in CT	FTE	Total Revenue	Total Fees
Part time	1.2	104,563	2,789
Full time	13.7	1,236,300	105,577
District	8.9	1,170,000	247,634

13 of them (28%) did not provide vaccination before, and of the 34 who did, 10 did not provided it to children. Interestingly, 8 of those who did not provide vaccination before H1N1 did so during that emergency: two LHDs did it once, and 6 others did it every month (Oct. 2009 to Feb. 2010). Most of them rated their own performance as good or excellent.

The original study design proposed to survey all LHDs, i.e. obtain a full census of the entire population, but in the end only 47/78 = 60.3% participated. This raised two additional challenges, one related to potential systematic differences between participants/non-participants, which need to be investigated, and a second related to the planned inferential conclusions about the measure tests.

We explored hence the differences between the 47 participating LHDs and the other 31, in terms of a number of structural characteristics. Data from the CT DPH annual report database was used for comparisons, and existing current LHDs (N=78) were retrieved from the website (https://www.han.ct.gov/local_health/localmap.asp).

The 47 participating LHDs were:

- more Full time LHDs (23 vs. expected 19), slightly more districts (16) than expected (12), and fewer part time LHDs (7 vs. 15 expected);
- more urban (41) than expected (37), and hence less rural (5) than expected (9);
- LHDs with more residents (average of 61,200 vs. 25,300)
- unemployment rate (average of 8.5% vs. 7.4%)
- total fees (average of $221,000 vs. $96,000).

Participating LHDs were however similar in terms of:

- having a nurse staff, having a health education staff; income; poverty rate; number of housing permits; area (in square miles); federal grants, state, or local funding; total non-fee revenues; FTE's, FTE per 1,000 residents, number of vaccinations.

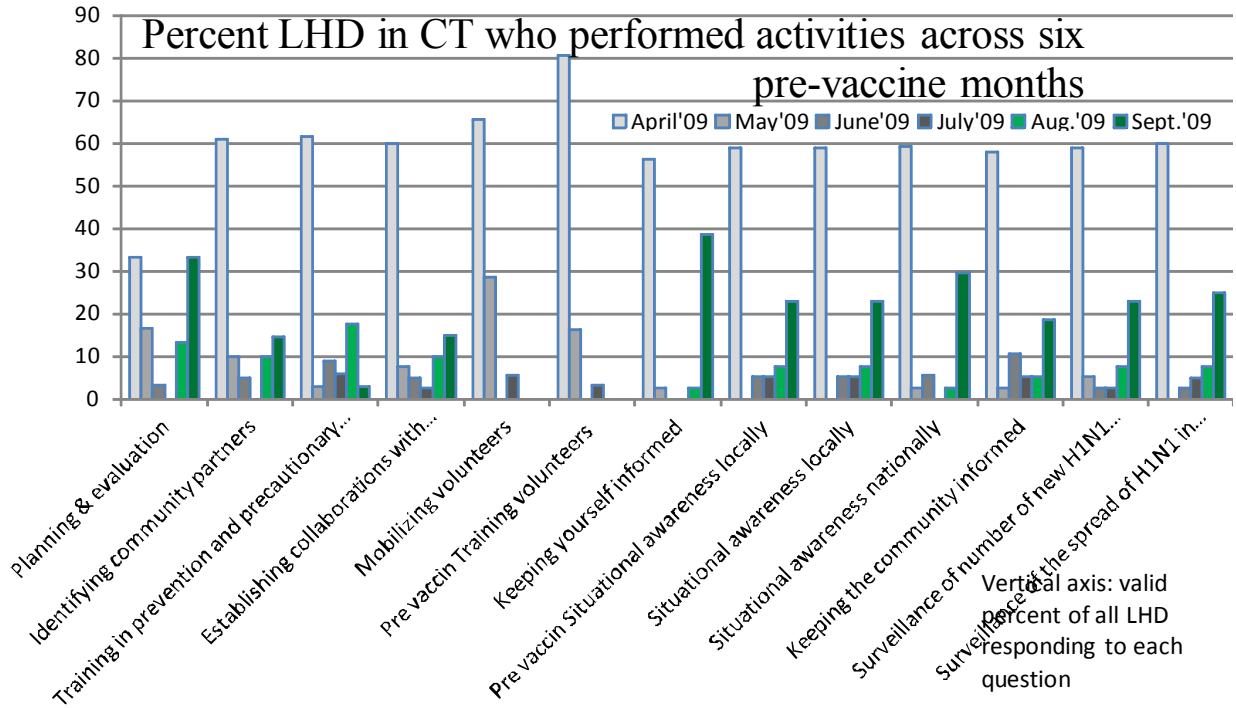
In terms of vaccination rates, based on a subsample of 33 LHDs for which data was obtained, the percent ranged from 2% to 50%, with mean of 11% and a median of 44%.

4. Measures used in analyses

Two composite measures for both the period prior to availability of H1N1 vaccine (April-September, 2009) and during the vaccine H1N1 period (October, 2009 - February, 2010) were built: 1. one of frequency of communication, with Schools, daycares, parents, medical providers, local media , general public, and the state DPH, and 2. a composite of engagement with local media, through press releases, PSAs, responding to reporter inquiries, participating in media interviews, and participating in public access call in shows (TV/radio).

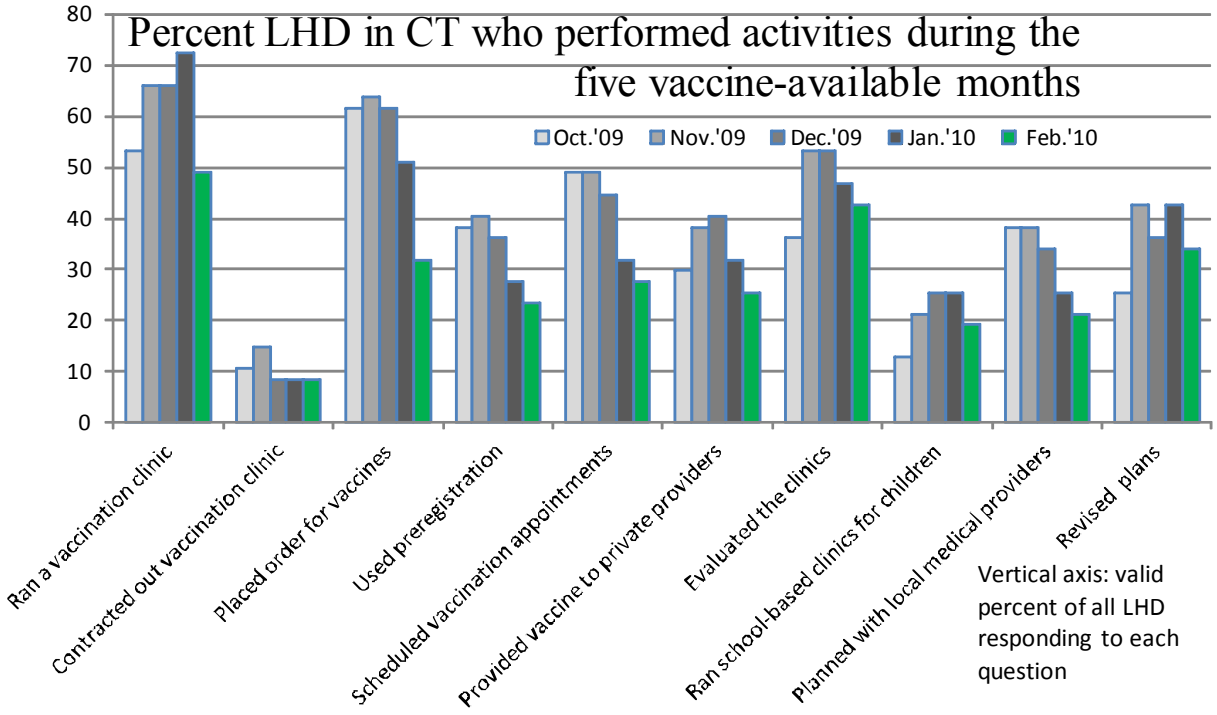
For illustration, Figure 1 shows activities performed during the pre-vaccine period.

Figure 1. Activities performed by LHDs during the pre-vaccine period.



In addition, for the period prior to availability of H1N1 vaccine a detailed list of communication activities was given to LHDs, regarding communication with a comprehensive list of community partners (General public, Local government, Public schools, Private schools, Schools & summer camps, PTAs & Parents, Childcare facilities, School based clinics, Colleges/universities, Long-term care facilities, Group care homes, Senior centers, Correctional facilities, Hospitals, Medical providers, Community health centers, Churches, Military facilities, CEOs /businesses) by any of these means: hotline , posters , website , billboards , curriculum (for schools e.g.), video information, signs (e.g. hand washing), pamphlets, 1-on-1 calls, Powerpoints, Facebook, Twitter. A measure of communication with each constituent was built (by any means, only for those community partners existing within each jurisdiction, however), and then a global measure of concrete communications was computed by averaging the constituent specific measures.

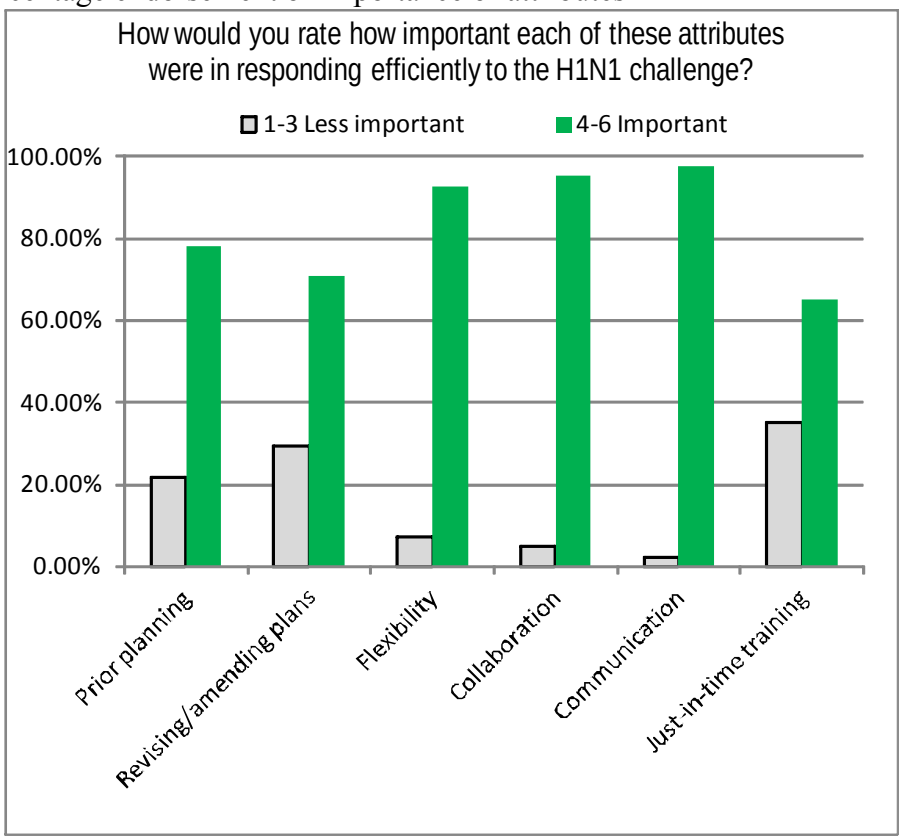
Figure 2. Activities performed by LHDs during vaccine period.



The measure items collected online did not have the initially planned reach, timeliness and equity domains specified, as they did not emerge as such from the focus groups. Instead, activities were listed primarily by 2 periods, pre and post-vaccine availability. To increase variability and hence be able to detect more nuance in these measures, instead of using blanket yes/no questions about each activity ('Has your LHD done X?'), we asked when each LHD has engaged in each activity by month, e.g. Prior to the availability of H1N1 vaccine, when did you initiate and/or conduct any of the following activities? (list follows, e.g. 'Internal organizational briefings') with check-off boxes for: Apr.'09; May '09; June '09; July '09; Aug.'09; Sept.'09).

LHD representatives were also asked how they would rate how important each of the attributes were in responding efficiently to the H1N1 challenge, from among: Prior planning, Revising/amending plans, Flexibility, Collaboration, Communication, Just-in-time training. Communication, Collaboration and Flexibility were seen by most as important (see Figure 3).

Figure 3. Percentage endorsement of importance of attributes



5. Exploratory Factor Analysis (EFA) analyses

An exploratory factor analysis run on the summary correlational matrix data for the pre-vaccine period, with 12 activity items and 19 communication ones yielded solutions for 2 factors only, but 13 Communication items were excluded because they cause the sample covariance matrix to be non-invertible); the output which indicates that 5 communication items are grouped around a common factor, and 12 activities (except 'contracting vaccination clinics') belong to a 'Pre-vaccine activities' factor.

Similarly, the exploratory factor analyses run on the summary correlational matrix data for the after vaccine period, with 10 activity items and 13 communication ones yielded solutions for 2 and 4 factors, but the 4 factor solution indicated that factors 3 and 4 have no distinct items with sizeable loadings, so the 2 factor solution was retained, which indicates that the communication items are grouped around a common factor, and all the activities (except 'contracting vaccination clinics') belong to a 'Vaccine related activities' factor.

The ESEM approach is not available in the most current version of Mplus with summary data (either correlational or covariance matrices), and the number of cases relative to the number of variables to be analyzed makes this analysis impossible with raw data.

6. Composite Measure Development and preliminary testing

Indices (indexes) like quality performance measures are better known as formative measures, or causal indicator measures.

We followed however for this report the procedure proposed in the original application. The method we report on is the common approach that emphasizes that indices differ from scales, by presenting these characteristics[5,7]:

a) the indicators are defining characteristics of the unobserved construct;

b) a change in the value of one of the indicators is not necessarily expected to be associated with a change in all of the other indicators;

c) the indicators are not expected to have the same antecedents and consequences, and

d) eliminating an indicator can alter the conceptual domain of the construct.

We followed the modeling procedure starting with specifying one overall latent construct for each period, pre-vaccine and during-vaccine, then re-specifying the model by grouping the indicators that have the same sign for their weights (regression coefficients for regressing the latent factor on each indicator). Because of the low sample size (47 LHDs), which for some models, such as those for the H1N1 vaccine period, which included the actual vaccinations administered , as a health outcome (with only 32 valid cases), reduces the covariance coverage dramatically, we used the strategy proposed in the initial application, i.e. to build a correlational (and covariance) matrix and feed it as input to the Mplus program, with the option of setting the sample size to reasonable values (~=100) that allow for model estimations. We report here the final models with two such underlying formative measures for each period, re- and during-vaccine, as shown in Figures 2 and 3:

The models indicate that the Pre-vaccine QI measure has one dimension only, grouped around these activities (see Figure 4):

1. Establishing collaborations with community partners;
2. Keeping themselves informed;
3. Situational awareness locally;
4. Situational awareness nationally;
5. Surveillance of number of new H1N1 cases;
6. Surveillance of the spread of H1N1 in their community.

The vaccine-period QI measure on the other hand has two formative factors, grouped as follows (see Figure 5):

1. Ran a vaccination clinic;
2. Contracted out vaccination clinic;
3. Provided vaccine to private providers;
4. Evaluated the clinics;
5. Ran school-based clinics for children;
6. Revised their plans;
7. Used preregistration;
8. Frequency of communication with community partners.

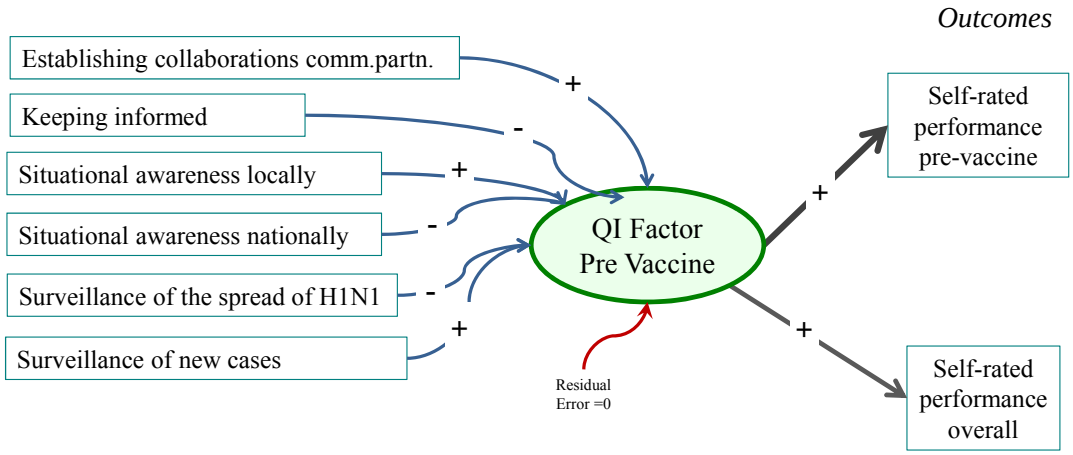
and

1. Placed order for vaccines;
2. Scheduled vaccination appointments;
3. Planned with local medical providers;
4. Engagement with local media.

These findings suggest that while pre-vaccine availability LHDs were involved in a number of communication and specific activities, six such distinct activities seem to congregate in a Quality Improvement /Performance formative measure/index, as indicated by how strongly the measure predicts self-assessed effectiveness during this period, and during the whole H1N1 emergency (in the absence of a better indicator of effectiveness).

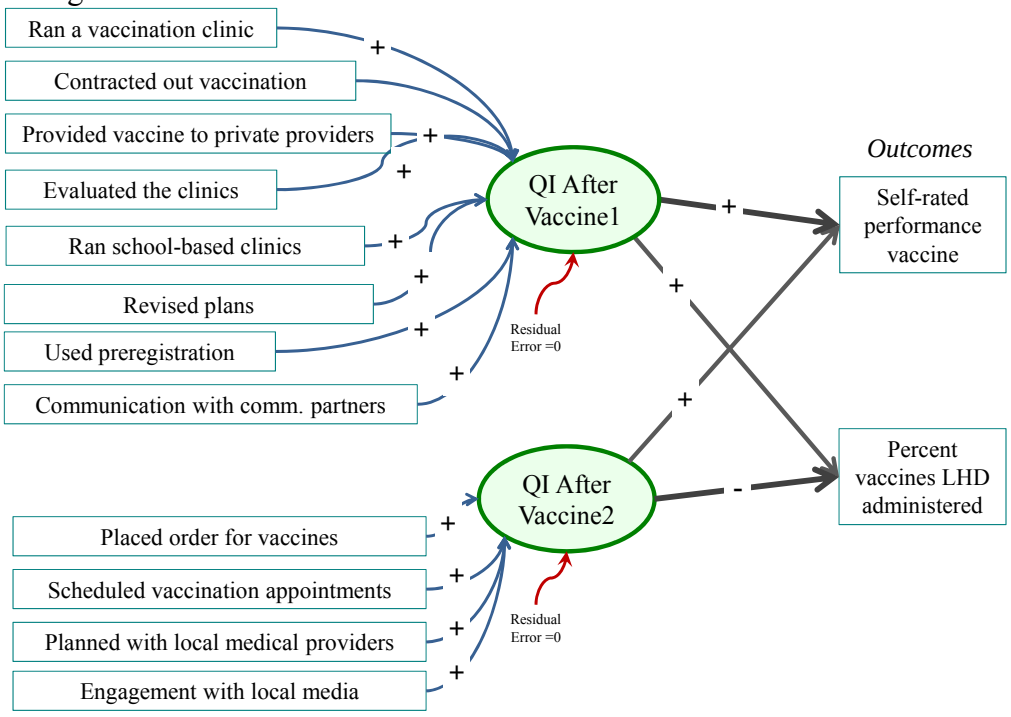
On the other hand, after the vaccine became available, a set of two such activities are grouped in two formative measures/indices, which then predict the self-assessed effectiveness during this vaccine period, and the percentage of vaccine administered by the public agency itself.

Figure 4. Measurement model design for LHD Quality Improvement (QI)/performance during H1N1– pre-vaccine



Two indicators of outcome success were used to anchor and text the measure, which congregated into yielded one QI factor/index

Figure 5. Measurement model design for LHD Quality Improvement (QI)/performance during H1N1– after-vaccine



Two indicators of outcome success were used to anchor and text the measure, which yielded two QI factors,.
The '-' sign indicates that one factor has a reverse impact on one outcome.

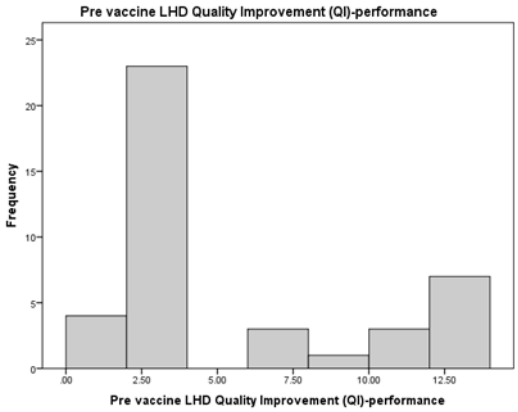
We therefore built the QI measures according to the Mplus formative testing analyses, i.e. as sums of weighted items, with the weights being the unstandardized regression coefficients from the final QI testing models.

The QI measures emerged from our analyses are shown in Figures 6 (a-c); they show that prior to vaccine availability, there seem to be two clusters of LHDs with relatively low performance, and a second group with better performance (scores above 5.0). An analysis of differences by type (district, full time, part time) in QI revealed no significant differences.

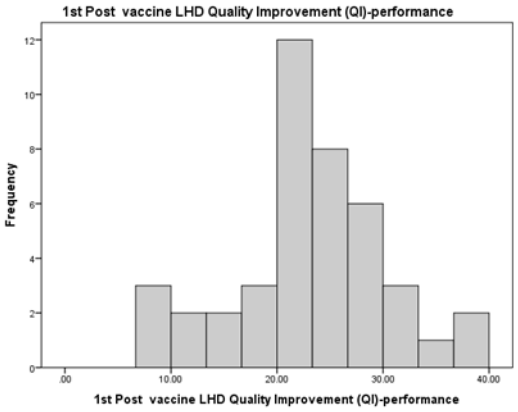
On the other hand, there are two distinct post-vaccine QI/performance indices, which seem to be distributed fairly normal.

Figure 6. a, b, and c. LHD Quality Improvement (QI)/performance measures histograms

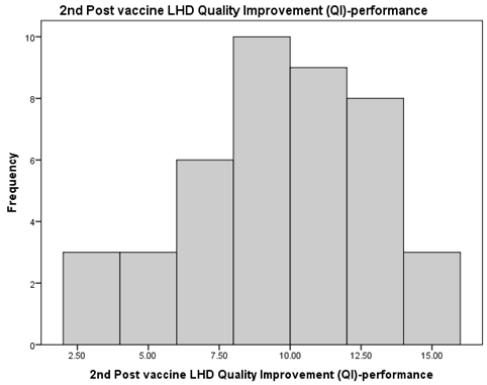
a.



b.



c.



7. Implications for practice

Assessing performance/quality improvement (QI) of local health departments (LHDs) during public health emergencies is a challenge in states with complex organizational structure, like Connecticut. We followed a strict methodological measure development and testing approach to assessing pre-vaccine and post-vaccine QI measure (index) development, which led to a uni-dimensional index for the pre-vaccine period (April-September 2009) and two indices for the vaccine period (October 2009-February 2012).

The indicators of these QI indices are shown in Figures 4 and 5 above. These measures indicate that pre- vaccine availability, the central activities that led to better (self-assessed, however) performance were preparatory actions, primarily surveillance and situational awareness. After the vaccine became available, two clusters of such activities seemed to emerge, to the extent that the QI measures predicted the self-assessed overall performance, as well as the actual number of vaccines administered by the LHDs. These two clusters seemed to revolve around actual actions to acquire and administer the vaccine (the first QI cluster), and more about planning and strategizing the actual vaccinations (the second cluster/index).

8. Analysis caveats and recommendations

The most important limitation is the small sample of LHDs used in the analyses; our solution of using summary data in the form of correlational matrices and standard deviations (and means) and inferring from the sample correlations that such observed relations exist in a (hypothetical) LHD population is the most important weakness of the analytical approach.

Moreover, formative measures are notoriously difficult to formally validate, going so far as to recommend avoiding their use, at least temporary [8]. One current standard of formative measures development and testing follows the procedure spelled out long ago[5]. An entire issue of Psychological methods (2007, 12(2)) was devoted to the debate around such measures, and the discussion is still ongoing[9,10]. One simple solution may have been overlooked, even though it seems to address the main issue in constructing and testing such measures: to be able to estimate models testing its structure, at least two effects of a formative measure are needed, in addition to its causal indicators, but the testing leads to different conclusions when different such measures are chosen[7]. This solution is to combine the classical well-developed reflective measure testing with an initial step involving canonical correlation or principal component analysis [11]. It then proposes to construct two (or more) new composite measures off the original set of causal indicators, which will be then used as reflective (effect) indicators of the hypothesized formative construct.

Appendix A

Electronic files included as attachments to this report:

1. LHD_Dataset2010_22Nov2011_1year.sav
SPSS data file with descriptive data from annual reports merged into it
2. result48_18sept12_work.sav
Working SPSS data file
3. PH_Survey_cleaning_newvariables.sps
SPSS syntax file for cleaning the Surveymonkey data
4. PH_analyze.sps
SPSS syntax file with analyses
5. PH_Describe.spv
SPSS output file with descriptives of the data
6. LHD_Dataset_22Nov2011_1mostRecent.xlsx
Excel data file with annual reporting data that was merged with survey data
7. PDF file of the complete online survey.

Appendix B

i. Further recommendations for next analytic steps:

1. The issues of Reach, Timeliness and, Equity have not been captured in the new measure, primarily because they were not confirmed as potential dimensions in the focus groups phase of the investigation; this may in fact indicate they are not necessarily separate dimensions of such QIU measures; more testing needs to be done to settle this issue.

2. Include more specific covariates in models (like ease of communication with each constituents); sample size of however precluded even more sophisticated model building.

3. There is a need to replicate models with large samples of LHDs.

ii. Methodological specifications and recommended solutions:

- Formative constructs (FC) are commonly conceived as composites of specific component variables or dimensions.
- FI's (formative items or indicators) are obtained by a census of potential indicators, rather than a domain sampling from the universe of indicators, as for reflective measures. [12]
- FC are an extreme type of multidimensional constructs.
- Misspecifications of FC as reflective constructs (common scales, like attitudes) has impact on both Type I and II errors[13] . ('forcing a square peg into a round hole').
- To validate formative constructs, researchers need to attend to four criteria closely:
  1. If causality is directed from the indicators to the construct, the construct is formative.
  2. Formative indicators may not be interchangeable and will often employ different themes. Therefore dropping FIs is potentially more damaging than for reflective indicators.[14]
  3. Formative indicators are *not* required to co-vary with one another.
  4. It is not necessary for the indicators to have the same antecedents and consequences.
- The FM model is reversed (as in principal component analysis, [15]):

$$\eta = \gamma_1 y_1 + \gamma_2 y_2 + \ldots + \gamma_n y_n + \zeta \quad (1)$$

vs. for regular scales:

$$y_1 = \lambda_1 \eta + \varepsilon_1 \quad (2)$$

$$y_2 = \lambda_2\eta + \varepsilon_2$$
$$[\ldots]$$
$$y_n = \lambda_n\eta + \varepsilon_n$$

Multi-co-linearity testing can be done using Variance Inflation Factor (VIF), which should be < 3.3.[5]

For **content validity** testing is recommended to:

1. Investigate potential multidimensionality of the performance index.

Because of the form of equations modeled (2), principal components analysis rather than factor analysis should be used to evaluate the reduced dimensionality of the measures (Chin, 1995).

- Item-reliability can be evaluated as test-retest reliability only, but not as item-to-total correlations or squared-multiple correlations[14], because they not relevant for FM, since items are not expected to be internally consistent .[16]

2. Evaluate validity coefficients (formative item weights γ's) for significance and size; may decide to keep some even if non-significant, to ensure the entire measurement domain is preserved.

3. Assess the extent of measurement error by gauging the error ζ, in fact R^2. Follow Cohen's[17] guidelines for multiple regression: f^2 values of 0.02 ($R^2 = 0.0196$), 0.15 ($R^2 = 0.13$), and 0.35 ($R^2 = 0.26$) refer to a small, moderate, and large effect size, respectively. Here, if error variance is less than say 25% (explained variance is 75% or >), one can re-estimate and set error variance =0.[18]

4. Interpretation of FC depends on the dependent (outcome) variables included in the model.[19]

In fact Franke et al. show that the selection of the outcome variables is as crucial as the selection of FIs (quoting Diamantopoulos[20]).

5. Rejection of the proportionality constraint implies the rejection of the formative conceptualization (formative indicators FIs have proportional effects on the >1 outcomes of the FM)[21].

6. One should also check the MIs (modification indices), for FI->outcomes direct effects, if MI>6.9, researchers may want to include them, or exclude that FI.

7. Different scaling options may impact the fit of the model[22]: one can scale by:

i. setting one FI->FM coefficient to 1
ii. setting one FM- >Outcome coefficient to 1
iii. Setting Var(FM) to 1

Note: constructs are latent variables ('concept, model, schematic idea' [23], p. 506).

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