The Economic Cost of Communicable Disease Surveillance in Local Public Health Agencies

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Objective. We identify economic costs associated with communicable disease (CD) monitoring/surveillance in Colorado local public health agencies and identify possible economies of scale.

Data Sources/Study Setting. Data were collected via a survey of local public health employees engaged in CD work. Survey respondents logged time spent on CD surveillance for 2-week periods in the spring of 2014 and fall of 2014. Forty-three of the 54 local public health agencies in Colorado participated.

Study Design. We used a microcosting approach. We estimated a statistical cost function using cost as a function of the number of reported investigable diseases during the matched 2-week period. We also controlled for other independent variables, including case mix, characteristics of the agency, the community, and services provided.

Data Collection/Extraction Methods. Data were collected from a microcosting survey using time logs.

Principal Findings. Costs increased at a decreasing rate as cases increased, with both cases ($\beta = 431.5$, $p < .001$) and cases squared ($\beta = -3.62$, $p = .05$) statistically significant.

Conclusions and Implications. The results of the model suggest economies of scale. Cost per unit is estimated to be one-third lower for high-volume agencies as compared to low-volume agencies. Cost savings could potentially be achieved if smaller agencies shared services.

Key Words. Public health services and systems research, communicable disease surveillance, economies of scale

In 2012, the Institute of Medicine published a report entitled *For the Public's Health: Investing in a Healthier Future*, which included a call to action toward the development of a minimum package of public health benefits (IOM 2012). This call was echoed by the National Association of County and City Health Officials (NACCHO), who published a broad policy statement listing a

proposed set of foundational capabilities and basic services (NACCHO 2012). Some states, including Colorado, statutorily established a requirement that local public health agencies (LPHAs) either provide core public health services or ensure that they are provided to the community. Yet despite the policy mandate to provide the core services, some of the core services have no dedicated funding. Indeed, none of the services are fully funded in all LPHAs. Local public health agencies and the state health department struggle to understand the cost of providing the Colorado Core Public Health Services and therefore are unable to seek clear funding to support the core services.

Although national programs such as NACCHO's Operational Definition of a Functional Health Department (NACCHO 2005), the National Profile of Local Public Health Departments (NACCHO 2010), and National Voluntary Accreditation (phaboard.org) laid the groundwork for our current understanding of the essential components and capabilities of a LPHA, governmental public health decision makers and professionals remain ill-informed about both the overall cost and the most economically efficient way to deliver essential population-based public health services. This lack of knowledge results in an inability to make a clear financial case for public health services in connection with communities, healthcare partners, and others; and limits the amount of informed decision making that can be performed by public health leaders.

This limitation was keenly felt during the 2013 Colorado legislative session. Both the state Governor and legislature supported a requested increase in state general fund support for LPHAs; however, during the debate about this funding increase, there were many questions about what community members or the state would "get" for the increased investment. While the increase was ultimately approved, it highlighted the need for more information and a clear way to understand and describe the cost and value of public health services. During the facilitated dialogue on developing a new formula to distribute the funds, agencies from all structure types and delivery settings described how they thought provision of services in their jurisdiction was as costly, or more costly, than others. Rural leaders described the expense of

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traveling long distances to deliver services to their entire jurisdiction and urban leaders described a large, complex system of partners (hospitals, schools, providers, etc.) that requires an inordinate amount of collaboration and connection and is thus more expensive.

This paper estimates the cost of communicable disease surveillance activities by LPHAs in Colorado and examines factors that cause differences in cost of services across public health delivery settings and systems to estimate economies of scale. Communicable disease surveillance includes routine activities by local and state public health officials to monitor incidences of communicable diseases and conduct routine investigations (i.e., not including confirmed outbreak investigations, which can involve both state and federal agencies). Communicable disease surveillance is in all of the previously mentioned definitions of core public health services. We selected communicable disease surveillance for our analysis after conducting a focus group and a survey of local public health officials. The focus group prioritized communicable disease surveillance for a cost analysis because it was a core public health service that was provided by every jurisdiction and was not uniformly funded across the state. This study is intended to be the first in a series of analyses of the cost of core public health services that can be ultimately used in decision making around funding and provision of core services.

We have several purposes in our analysis. First, we estimate the cost of providing the statutorily required core public health services. This will aid in appropriate funding allocation decisions. Second, we examine factors in LPHAs that increase or decrease the cost of delivering this core public health service. This will aid in the development of an appropriate funding allocation system. Finally, we examine whether there are economics of scale in communicable disease surveillance. This sheds light on whether there are ways to reorganize the delivery of this core public health service to decrease the cost of delivery.

CONCEPTUAL FRAMEWORK

Communicable disease surveillance, monitoring, and investigation is one of the core public health functions identified by both the IOM and by Colorado rule. In our analysis, we are restricting our scope to communicable disease surveillance and monitoring and excluding disease outbreak investigations. This is because disease outbreak investigations are not only unpredictable, making it difficult to collect data on time spent, but also may require sufficient

staff time that filling out time logs (as described below) is infeasible. Further, disease outbreak investigations will often be conducted by either the state or by the Centers for Disease Control and Prevention, depending on the scope of the outbreak. Routine disease investigations are included in our analysis because they are the clear responsibility of the LPHA.

The marginal cost of monitoring and investigating these communicable diseases is hypothesized to be a function of the number of cases, the types of cases, LPHA characteristics, and county characteristics. A short-run behavioral cost function is given by:

$$C_i = f(N_i, \text{case mix}_i, \text{LPHA}_i, \text{County}_i)$$

where C_i is the marginal cost of the LPHA in county i , N represents the number of cases, LPHA represents LPHA specific characteristics (described below) while county characteristics represents the characteristics of the county where the LPHA operates.

This equation was operationalized as follows:

$$\begin{aligned} \text{Cost}_i = & \beta_0 + \beta_1 \text{Confirmed Cases}_i + \beta_2'' \text{Deleted}'' \text{Cases}_i \\ & + \beta_3 (\text{Total Cases})_i^2 + \beta_4 \text{Regional EPI}_i \\ & + \beta_5 \text{Dedicated CD Employee}_i + \beta_6 \text{Other Factors}_i + e \end{aligned}$$

where Cost_i represents the cost of the LPHA in county i . “Cases” is subdivided into three different variables: (1) Total Confirmed Cases, (2) Total “deleted” cases, and (3) Total cases squared. When cases are reported to the LPHA, they are first investigated to see if the reported case was indeed an actual case of the reported disease. If the case is confirmed, the LPHA will monitor and follow-up on the case, with the precise activities a function of the precise disease. If, upon follow-up, it is determined that the reported case was not an actual case, then the case is “deleted” from the system (although a record remains). For both confirmed cases and deleted cases, investigation takes time (and therefore costs); however, the cost of investigating a confirmed case would be greater than for a deleted case. We therefore hypothesized that $\beta_1 > 0$ and $\beta_2 > 0$ and that $\beta_1 > \beta_2$. We also expect there would be some economies of scale, so cost should increase with the number of cases (as shown by β_1 and β_2), but should increase at a decreasing rate, such that $\beta_3 < 0$.

There are a number of LPHA specific factors that may affect the cost of communicable disease surveillance. First, the state assigns a regional epidemiologist to some LPHAs. Although this individual is physically located in a particular LPHA, it is intended that his or her services are provided regionally. Because it is a state-paid resource, having a regional epidemiologist in a

particular agency should not affect the LPHA's cost, leading us to hypothesize $B_4 = 0$. Second, some LPHAs have sufficient volume of cases that a dedicated employee can be assigned to communicable disease surveillance. This specialization should lead to efficiencies and therefore lower costs, leading us to hypothesize that $\beta_5 < 0$.

Also included in the model is a case mix variable, which controls for the type of reported conditions in six broad disease categories: waterborne, zoonotic, lead-based, foodborne, vaccine preventable, and hepatitis. Finally, we controlled for the population density and poverty rate of the LPHA jurisdiction.

DATA AND METHODS

The first step in identifying costs associated with routine communicable disease surveillance was to develop a workflow model for public health agencies. We conducted a series of key informant interviews and one focus group to identify major variable and fixed costs associated with communicable disease surveillance. We interviewed six key informants from public health agencies that represented different CD structures and LPHA sizes (three LPHAs in urban areas and three rural areas). We followed that up with a focus group of LPHA directors and staff. This was supplemented by input from our Project Advisory Council (PAC). We recruited the PAC members from large and small agencies as well as some LPHA directors and administrative/finance directors. Finally, we conducted a focus group of CD staff at the state health department to further refine what the LPHAs do and what the state does and to limit confusion between those roles.

The workflow model identified eight different major activities necessary for communicable disease monitoring. First, all LPHAs are required by law to check the Colorado Epidemiological Data Reporting System (CEDRS) at least daily. Reportable diseases are entered into the statewide system daily by health care providers. Twenty different conditions, including cholera, measles, plague, and typhoid fever, are required to be reported to public health agencies via CEDRS within 24 hours of identification. Forty-one other conditions, including AIDS, chlamydia trachomatis, hepatitis B and C, and leprosy, are required to be reported within 7 days. Public health agencies log onto CEDRS to identify any new cases reported in their jurisdictions.

The next set of activities revolves around time spent investigating reported routine diseases. This includes time spent communicating with providers by phone or email, communicating with regional and state

epidemiologists, receiving and reviewing disease and condition reports, and travel time to investigate particular cases.

Finally, the last major activity identified by the workflow model is in developing routine reports on disease trends in the jurisdiction. This includes data entry, data analysis, data tabulation, and time spent assessing any trends in the data to identify diseases where there may be heightened community risk.

To estimate the cost of the selected services, we used a microcosting approach. Microcosting is a method of direct measurement of costs that is often used in situations when existing data sources lack the specificity necessary to cost estimation or when average cost numbers are inadequate to distinguish the marginal cost of a particular service or intervention (Frick 2009). In this project, staff and other resources are typically used to provide multiple public health services (referred to by economists as “joint production”). The only way to determine the marginal (or incremental) cost of particular services is through one of the direct observation methods. There are several standard methods to calculate the cost associated with staff time, including time-and-motion studies, activity logs, and surveys of managers. Given the scope of our project (described below), a time-and-motion study (which required direct observation) was infeasible.

Instead, we asked staff at all LPHAs in Colorado to record their activities during each 15-minute interval of work over a 2-week time period. A time-logging instrument was developed in Microsoft Excel. The time log was developed to reflect the activities identified by the focus group and interviews. An online training program was developed to standardize the data entry by the LPHAs. LPHAs who agreed to participate had support from both the leadership and management levels, resulting in a 100 percent response rate from employees within the departments.

There were two unique data collection time periods. The initial data collection was performed between April 7, 2014, and June 20, 2014. Agencies who agreed to participate were assigned random start dates. To ensure that the results were not biased by possible seasonality of the spring data collection, the time log was repeated from October 13, 2014, to November 14, 2014.

A total of 43 unique agencies participated (86 percent of all LPHAs in Colorado). This included 41 agencies (82 percent) during the initial spring timeframe and 27 agencies (54 percent) in the fall timeframe. We had a total of 191 completed time logs covering 144 employees. Individuals who reported <0.1 FTE spent on communicable disease surveillance were dropped from the analysis, unless no employee at the LPHA worked on CD more than 0.1 FTE.

This was performed to reduce the respondent burden for agencies. We also collected time-log data for all 10 of the state-funded regional epidemiologists.

We augmented the cost survey with a manager survey for all participating agencies where we asked the managers to report the midpoint of the salary range and fringe rate for each employee who provided a time log. All managers from participating LPHAs completed the manager's survey.

We collected two additional sets of information to test the generalizability of our results and ensure that our results were not biased by atypical weeks. First, we collected data from CEDRS on reported cases for 5 years prior to our survey. We then compared the number and type of cases that occurred during the 2-week data collection period to the average number of cases based on the previous years of CEDRS data, calculating paired *t*-tests to look for significant differences. Second, we surveyed respondents and asked if the 2-week period reflected a typical week. Typical was defined as within 10 percent of the hours normally dedicated to communicable disease surveillance activities.

To calculate the total cost of communicable disease surveillance, we combined the time reported on the time logs with the salary and fringe rate provided on the manager survey to calculate the personnel cost for the 2-week period. To calculate the total agency personnel cost, we added together the personnel cost for each employee at the agency.

To calculate the total cost, we added an estimate of the fixed costs for communicable disease surveillance. To calculate fixed costs, we took the indirect cost recovery rate the LPHA negotiated with the state health department, then multiplied the total agency personnel cost by the agency's indirect rate to calculate a total 2-week cost (fixed and variable costs). The indirect rates were estimated from previously used agency level state-negotiated rates, with missing values imputed. Because of the nature of the work performed, personnel time (and thus costs) was the primary resource investment by the LPHAs. Our interviews found few other direct costs for communicable disease surveillance (supplies, etc.); similarly, fixed costs were also relatively low.

For output data, we received all reported cases (confirmed and deleted) in CEDRS from the Colorado Department of Public Health and Environment (state public health department). We requested and received permission from each participating individual LPHA to access the data. We matched the CEDRS data to the time-log data by the 2-week time period. Data on animal bites were excluded because they are recorded inconsistently by LPHAs.

To evaluate the relationship between cases and agency characteristics on cost, we estimated a statistical cost function. The dependent variable was *cost* (obtained from the microcosting data), with the independent variables as

described in the conceptual model above. The unit of analysis was at the agency level. We used ordinary least-squares (OLS) regression with robust standard errors because both the Breusch–Pagan and Cook–Weisberg (1983) tests suggested heteroskedasticity. The linktest suggested OLS was an appropriate model specification, although the results were robust to both logged dependent variable and generalized linear models. We retained the OLS model for ease of interpretation.

RESULTS

A total of 191 time logs were completed by the respondents. On average, each respondent reported spending 435 minutes per 2 weeks on communicable disease surveillance (Table 1). Given the 10 work days over the 2 weeks, this translates to an average of approximately 43 minutes per day. This distribution was highly skewed, however, with a median of 801.6 minutes per 2 weeks or 80 minutes per day. The minimum reported was 120 minutes over 2 weeks, while the maximum was 2,025 minutes over 2 weeks. At the agency level, an average of 967.5 minutes per 2 weeks was spent, with the median again markedly exceeding the mean at 2064 minutes per 2 weeks. The median of 206 minutes per day corresponds to about 3.5 hours daily or slightly less than one-half FTE at the agency level.

In percentage terms, the time was spent checking CEDRS (42 percent), communicating with regional epidemiologists, infection control practitioners,

Table 1: Time by Activities at the Agency Level

<i>Activity</i>	<i>Mean Minutes</i>	<i>Median Minutes</i>	<i>Standard Deviation</i>
Total minutes spent on CD surveillance	967.5	2,064.2	3,233.7
Minutes per time logger	435.0	801.6	1,039.5
Minutes checking CEDRS	277.5	477.9	580.7
Minutes completing routine investigations	112.5	382.9	598.4
Minutes spent communicating with regional epis, infection control practitioners, etc.	112.5	304.6	390.0
Minutes spent learning and researching	37.5	245.4	754.7
Minutes spent assessing risks and trends	0	115.4	443.4
Minutes spent traveling	0	66.7	142.7
Minutes spent tabulating data	0	43.8	123.0
Number of time loggers	2	2.6	1.7

N = 191.

etc. (18 percent), routine investigations (9 percent), learning and research (7 percent), and assessing community risks and trends (4 percent). Most time was spent checking CEDRS, with a mean of 277 minutes and a median of 477 minutes. This was followed by time spent completing routine investigations (112 minutes), time spent communicating with regional epidemiologists (112 minutes), and time spent on research (38 minutes).

The difference between the mean and median time spent reflects differences in the number of cases. On average, LPHAs had 4.8 confirmed cases over the 2 weeks and 0.7 deleted cases. The range of cases is tremendous, from a low of zero to a high of 55 confirmed and seven deleted cases. Fifteen counties who completed the spring survey had no cases assigned; 11 counties who completed the fall survey had no cases assigned; and six counties did not have any cases assigned to them over their 2-week period for either time period. The mean population size of these counties was 11,055 (Spring) and 7,516 (Fall).

Similarly, there was a wide variation in cost reported by agencies. The mean cost per 2-week period was \$2,038, but that ranged from a low of just \$63 to a high of over \$19,000.

Overall, 26.9 percent of LPHAs reported having a state-funded regional epidemiologist present in their agency, while 34.3 percent reported a dedicated communicable disease employee. The type of cases was most commonly foodborne illnesses (25.4 percent), followed by vaccine preventable (16.5 percent), zoonotic (7.9 percent), and hepatitis (6.6 percent). Lead (4.3 percent) and waterborne (0.5 percent) were less common while 38.8 percent were not classified (Table 2).

The average poverty rate in the sample was 15.6 percent, with a range of 6.5 percent to 32.4 percent. Similarly, the population density had a large range, from a low of 0.001 persons per acre to a high of 6.37 persons per acre. Most of the surveys (60 percent) were completed in the spring, while 40 percent were completed in the fall.

The regression results are presented in Table 3. As expected, both confirmed cases and deleted cases significantly increased costs. Each confirmed case increases costs by \$431 ($p < .01$), while deleted cases increase costs by \$571 ($p = .01$). Although the point estimates of the two coefficients are markedly different, a Wald test of the equivalence fails to reject the null hypothesis that they are equal ($F(1, 53) = 0.29$, Prob $> F = 0.59$).

The squared term reflects the linearity of the effect of increases in cases on costs. It was hypothesized that costs would increase at a decreasing rate, reflecting economies of scale. This is indeed what the regression finds, with a

Table 2: Mean, Standard Deviation, Minimum and Maximum for Survey Responses, Fall, and Spring

<i>Variable</i>	<i>Mean</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>
Two week spending on communicable disease surveillance	\$2,038.4	\$3,516.34	\$63.0	\$19,080.8
Confirmed cases	4.84	10.35	0.00	55.00
Deleted cases	0.70	1.59	0.00	7.00
Regional epi present	26.9%	44.66%	0%	100%
Dedicated communicable disease employee	34.3%	47.84%	0%	100%
Percent of cases: waterborne	0.5%	2.49%	0%	14%
Percent of cases: foodborne	25.4%	35.30%	0%	100%
Percent of cases: vaccine preventable	16.5%	29.20%	0%	100%
Percent of cases: zoonotic	7.9%	22.62%	0%	100%
Percent of cases: hepatitis	6.6%	19.43%	0%	100%
Percent of cases: lead	4.3%	20.01%	0%	100%
Percent poverty rate	15.6%	5.74%	6.5	32.4
Population density: person per acre	0.36	1.17	0.001	6.37
Percent of survey in fall	40%			

N = 67.

Table 3: OLS Regression Analysis of Cost of Communicable Disease Surveillance Per 2 Week with Robust Standard Errors

<i>Variable</i>	<i>Coefficient</i>	<i>Robust SE</i>	<i>t Statistic</i>	<i>p</i> > <i>t</i>	<i>Lower</i>	<i>Upper</i>
Confirmed cases	431.48	113.05	3.82	.00	204.74	658.22
Deleted cases	571.78	216.56	2.64	.01	137.40	1006.15
Total cases squared	−3.61	1.79	−2.02	.05	−7.20	−0.03
Regional Epi present	3453.31	1040.06	3.32	.00	1367.22	5539.40
Dedicated communicable disease employee	−1442.56	889.67	−1.62	.11	−3227.02	341.90
Percent of cases: foodborne	−575.73	379.07	−1.52	.14	−1336.05	184.58
Percent of cases: vaccine preventable	−628.67	361.52	−1.74	.09	−1353.79	96.45
Percent of cases: zoonotic	689.19	786.22	0.88	.39	−887.76	2266.15
Percent of cases: hepatitis	284.41	565.47	0.50	.62	−849.78	1418.61
Percent of cases: lead	−508.69	748.61	−0.68	.50	−2010.22	992.84
Percent poverty rate	−46.75	19.34	−2.42	.02	−85.54	−7.96
Population density	−1139.22	274.00	−4.16	.00	−1688.79	−589.64
Fall	−85.75	380.91	−0.23	.82	−849.76	678.25
Constant	1096.66	326.59	3.36	.00	441.61	1751.72

N = 67; *F*(13, 53) = 12.39, Prob > *F* = 0.0000, *R*-squared = 0.883.

coefficient of -3.61 ($p = .05$). This suggests that total costs reach a maximum at approximately 60 cases.

Turning to agency factors, having a regional epidemiologist present was associated with an increase in costs for the agency of approximately \$3,453. Having a dedicated employee working on communicable disease surveillance had the hypothesized negative sign ($-1,442$), but it was marginally insignificant ($p = .11$).

The type of case did make a difference in cost. Vaccine-preventable cases were less expensive to investigate ($\beta = -629$) and marginally statistically significant ($p = .09$), while other types of cases were statistically insignificant. Agencies in areas with higher poverty had lower costs as did agencies with lower population density. Finally, the season of the survey was insignificant ($p = .82$). The overall fit of the model was quite strong, with an R^2 of 0.88.

We conducted a number of tests for the generalizability of the results. We surveyed the respondents and asked, after either the first or second week of time logging, whether the week was "typical." For the first week of data collection, 54 respondents said it was typical, 27 respondents said it was a higher than average workload, and 25 respondents said it was a lighter than average workload. Five respondents answered "Don't know." For the second week of data collection, 63 respondents said it was typical, 17 respondents said it was a higher than average workload, and 25 respondents said it was a lighter than average workload. Six respondents answered "Don't know." In total, 117 respondents said it was typical, 44 higher than average, and 50 lighter than average (and 11 did not know).

Next, we tested whether the number of cases and type of cases recorded in our data collection time frame were different than the average number and type of cases over the preceding 5 years (Table 4) for each agency. The paired t -tests showed no statistically significant differences between the data

Table 4: Comparison of Cases during Survey Weeks to Five-Year Statewide Average

	<i>T Statistic</i>	<i>p Value</i>
Total cases	1.277	.209
Foodborne cases	1.049	.301
Hepatitis cases	1.903	.064
Lead cases	0.234	.817
Vaccine-preventable cases	0.744	.461
Waterborne cases	0.113	.911
Zoonotic cases	0.954	.346

collection weeks and the average over the past 5 years. Finally, the seasonality variable in the regression shows no significant difference in LPHA costs between the spring and fall seasons.

DISCUSSION AND CONCLUSION

This study investigated the presence of economies of scale in routine communicable disease surveillance. Using a survey of LPHAs, the effect of size, case mix, and other factors was investigated. We found that total costs of routine communicable disease surveillance increase at a decreasing rate. Costs vary by case type, although only vaccine-preventable cases approached statistical significance. Having a state-funded regional epidemiologist increased costs, while having a dedicated communicable disease specialist decreased costs.

The model predicts that the average cost of communicable disease surveillance with zero cases would be approximately \$26,500. The cost for a single confirmed case (1 case) would be approximately \$428. The cost per case for an agency with 10 confirmed cases would be \$405. For agencies at the top end of our distribution, with 55 confirmed cases over the 2 weeks, the cost per case would be \$288 per case, a reduction in cost per case of nearly one-third.

Additionally, having an in-house dedicated communicable disease employee reduced spending by \$144 per day. This is likely due to greater efficiency due to specialization. It may be that the specialized employee needed to spend less time on research or training or that the task could be performed more quickly by an employee with the focus on communicable disease surveillance.

The increase in costs associated with the location of the state epidemiologist is surprising. The effect of the regional epidemiologist has been controversial; it is intended by the state to be a regional resource that does not affect local agency costs. Local agencies where regional epidemiologists are located have argued that they lead to higher costs; agencies where regional epidemiologists are not located have argued that the regional epidemiologists are a state resource disproportionately benefiting the agency where they are located. Our model suggests the former argument is correct and that regional staff do create costs for local agencies.

All of these results suggest that economies of scale could be generated if smaller agencies coordinated services. Many of the activities, including the most time-consuming activity—checking CEDRS daily—must be performed regardless of whether there are any cases. We found that many agencies had

zero cases during a 2-week survey period, yet still had to spend time checking for new reports every day. This is a possible source of time savings for smaller agencies. Further, we found that specialized employees reduced total costs, even after adjusting for salary differences. These are cost savings in addition to the per unit cost savings.

Although the in-house CD dedicated employee saves time in investigation, it may not be feasible for smaller agencies with few reported cases to investigate. All of these findings point to the conclusion that coordination between smaller agencies for routine communicable disease surveillance would lead to cost savings for the agencies involved. One caution would be the finding of the unexpected increase in costs associated with the regional EPIs. If this reflects costs associated with coordination between state and local agencies, it is possible that similar costs could be incurred when local agencies tried to coordinate communicable disease surveillance with each other. Our study suggests that cost savings through cooperation are possible, but it does not test whether the savings can be realized in practice.

ACKNOWLEDGMENTS

Joint Acknowledgment/Disclosure Statement: The authors would like to thank the Robert Wood Johnson Foundation for funding this research. We would also like to thank the participating local public health agencies and their workers who carefully chronicled their time, participants in focus groups who helped us build a workflow model, and the Colorado Department of Public Health and Environment, who lent their expertise to the workflow model and provided us with communicable disease incident data.

Disclosures: None.

Disclaimer: None.

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SUPPORTING INFORMATION

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Appendix SA1: Author Matrix.