

Immunization calculation engine: An open source immunization evaluation and forecasting system

Noam H. Arzt | Daryl Chertcoff | Samuel Nicolary | Michael Suralik |
Michael Berry

HLN Consulting LLC, Mission Viejo, CA, USA

Correspondence

Noam H. Arzt, HLN Consulting, LLC,
9 Pemberly, Mission Viejo, CA 92692, USA.
Email: arzt@hln.com

Abstract

Introduction: The immunization calculation engine (ICE) is a free, open-source immunization forecasting evaluation and software system whose default immunization schedule supports all routine childhood, adolescent, and adult immunizations based on the recommendations of the Advisory Committee on Immunization Practices (ACIP). ICE utilizes its immunization rules and patient data to evaluate and return the validity of each immunization in the patient's history along with one or more evaluation reasons. It also returns a recommendation for each vaccine group along with one or more recommendation reasons.

Methods: In January 2020, ICE was first released as a Docker image along with the traditional zip archive file which had been used up to that point. Docker enables software providers to easily distribute their software so that it can be run “out of the box” in the user's local environment. Software running in Docker containers drastically reduces the complexity of software distribution and set up.

Results: Clinical systems of many types use ICE. The project began within the public health arena as a feature of Immunization Information Systems (IIS), but electronic health records (EHR) and personal health records (PHR) have also deployed ICE. While it is not possible to identify the specific impact of ICE on clinical care without additional research, it should be pointed out that once deployed within an IIS, EHR, or PHR the display of ICE results is performed for every patient viewed by a user and often for every patient appearing on a report. In a typical month, thousands if not millions of evaluations and forecasts are performed by ICE and displayed to the users.

Conclusions: The ICE Project believes in minimizing the barriers to installing and using ICE anywhere. To that end, there is no registration required to download the source code or runtime code for the ICE service and its default rule. Similarly, the Project created a Docker image of ICE to facilitate easy and seamless implementation.

KEYWORDS

immunization, clinical decision support, public health, EHR, COVID-19

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

© 2021 The Authors. *Learning Health Systems* published by Wiley Periodicals LLC on behalf of University of Michigan.

1 | INTRODUCTION

The Immunization Calculation Engine (ICE) is a free, open-source immunization forecasting evaluation and software system whose default immunization schedule supports all routine childhood, adolescent, and adult immunizations based on the recommendations of the Advisory Committee on Immunization Practices (ACIP).¹ ICE evaluates a patient's immunization history and generates the appropriate immunization recommendations for patients. The core component of ICE is the ICE Web Service, which evaluates a patient's immunization history and generates the appropriate immunization recommendations for the patient.

This article seeks to enable wider availability of ICE as a computable knowledge artifact, along with technical detail important to understanding its use and enabling its deployment. This is preceded by a description of ICE, drawing on previously published material.

2 | BACKGROUND

The following is an excerpt from a previously published background article (with original references) by this same author which explains much of the background, philosophy, and use of this product.²

“A key element of preventive care is the provision of immunizations for vaccine-preventable diseases. Over time, however, the immunization schedule³ that clinicians consult has become more complex, and routine immunizations have become more numerous across a patient's life span. This has made it more challenging to monitor and adhere properly and consistently to the guidelines. While computer-based clinical decision support (CDS) can be an effective strategy for improving the quality of care, many clinical information systems either lack CDS or are slow to keep their CDS in line with the changing guidelines.³⁻⁵ These changes may include new vaccine series, addition or elimination of specific vaccines by specific manufacturers, or changes to clinical recommendations with respect to specific vaccines, dose series, accelerated/catch-up schedules, or age groups....”⁶

“Because of the large investment needed to develop and maintain a clinically compliant, high-quality electronic immunization schedule, as well as competing priorities for system feature development and enhancement both in the public and private sectors, a more shared approach to deploying CDSi (Clinical Decision Support for Immunization) solutions may be inevitable.^{7,8} As more and more clinical and public health processes and workflows come to rely on immunization evaluation and forecast, inconsistent evaluations and forecasts from different products will only serve to confuse clinicians as well as patients....”

“The ACIP defines and publishes a recommended immunization schedule that constitutes the best practices for immunization, and it updates and refines several times per year.⁹ The routine childhood schedule for 0 to 18-year olds has 13 separate footnotes, with as many as 13 subbullets for some footnotes.[†] The end result is that it is difficult for providers to monitor and consistently adhere to the ACIP

guidelines that are lengthy, complicated, and growing.¹⁰ The process of updating a CDSi algorithm to changing guidelines involves the full system development life cycle of activities: analysis to determine what the new guidelines mean and how applicable they are, modification of the software code that guides the algorithm, and extensive testing of the new algorithm to make sure that the changes have been applied correctly and that existing rules have not been adversely affected or broken in the process.”

“Though the underlying rules instantiate the ACIP recommendations and have been recently documented through a collaborative, CDC-led national effort, the devil is still in the details, and individual providers, IIS, and even state departments of education still define rules that vary for different purposes even within a jurisdiction let alone between them. Wright et al¹¹ described a wide variety of activities that need to be performed to deploy CDS successfully for clinical use. ACIP recommendation changes need to be not only monitored but also evaluated and assessed since the recommendations themselves may be clinically clear but not stated in a way that is easily transformed into computer-based rules. In addition, even the clinical recommendations may not be uniformly interpreted in a consistent way requiring a medical panel of experts within each organization to review and affirm their interpretation of ACIP pronouncements.”

“In an effort to harmonize the outcomes of existing CDS tools used by IIS and other systems, CDC funded the CDSi project to develop new clinical decision aids for each vaccine on the children's immunization schedule....”

3 | DEPLOYMENT

Clinical systems of many types use ICE. The project began within the public health arena as a feature of Immunization Information Systems (IIS), consolidated repositories of immunization information within a geographic area that assist clinical care in administering the *correct* immunizations at the right time.¹² IIS also support population-level data analysis and surveillance for both clinical care organizations and public health. As of April 2021 six IIS in the US are using ICE fully, partially, or have committed to deploy it.

Electronic health records (EHR) also use ICE and to date at least a half dozen systems have deployed ICE especially for ambulatory care. Personal health records (PHRs) have also deployed ICE to help consumers evaluate the validity of their past immunizations and to remind them about upcoming immunizations due now or in the future. These systems are used by thousands of clinicians every day to inform their practice, as well as by schools, childcare centers, and others to meet their needs for accurate, consolidated immunization records. For example, for a child ICE might recommend that an eleven month old is due for an MMR vaccine as she turns one year old, or that an adult who does not have a recorded tetanus booster or annual flu vaccination is due for those vaccinations *now*.

While it is not possible to identify the specific impact of ICE on clinical care without additional research, it should be pointed out that once deployed within an IIS, EHR, or PHR the display of ICE results is

performed for every patient viewed by a user and often for every patient appearing on a report. In a typical month, thousands if not millions of evaluations and forecasts are performed by ICE and displayed to the users. It would be hard to link improvement in immunization rates specifically to use of ICE or any other evaluation and forecasting system without a carefully constructed research protocol which to date has not been performed for ICE.

In January 2020 ICE was first released as a Docker image along with the traditional zip archive file which had been used up to that point. Docker has quickly become one of the most popular software distribution options available. It enables software providers to easily distribute their software so that it can be run "out of the box" in the user's local environment. Software running in Docker containers drastically reduces the complexity of software distribution and set up. In most common scenarios, the downloaded software can be run with a simple command. No special set up is required, and as a result, most installation errors are avoided. At the same time, the ability to change runtime configuration options is still available to the user if desired or needed by the local environment. The ICE software itself has three downloadable options: as a Docker image from Docker Hub, as a zip file from the ICE website or the source code itself. We have found that those who set up ICE with the Docker image got up and running fastest, made the least number of mistakes during set up, and more quickly updated the software to new versions as they became available.

Three additional releases were made in that fashion between January and September 2020. From the original posting of the Docker image until the middle of October 2020 over 275 pulls were executed

for the ICE Docker image. Docker does not make available any profile or statistics on the number of distinct sites who pulled the image.

4 | TECHNICAL ARCHITECTURE

Systems utilize the ICE Web Service by passing a Virtual Medical Record (vMR)¹³ to its Web Service which adheres to the Decision Support Service (DSS)¹⁴ standard. It is the responsibility of the "calling" system to follow the vMR Implementation Guide, as well as an implementation guide made available by the ICE project, to construct a valid message.¹⁵ In response, ICE utilizes its immunization rules and the data in the vMR, such as the patient's date of birth, gender, immunization history, and disease indicators, to evaluate and return the validity of each immunization in the patient's history along with one or more evaluation reasons. It also returns a recommendation for each vaccine group along with one or more recommendation reasons. Once again, it is the responsibility of the receiving system to be able to absorb the results of an ICE service request into its workflow and system. The ICE system architecture is displayed in Figure 1 below.

ICE's Web Service architecture scales to support simultaneous real-time processing of many patients submitted by one or more systems. It can also service requests for multiple immunization schedules; each immunization schedule would represent a separate ruleset for evaluation should a site determine that this was necessary. For example, a single ICE deployment could enforce one immunization schedule utilized by an IIS, another immunization schedule used by multiple

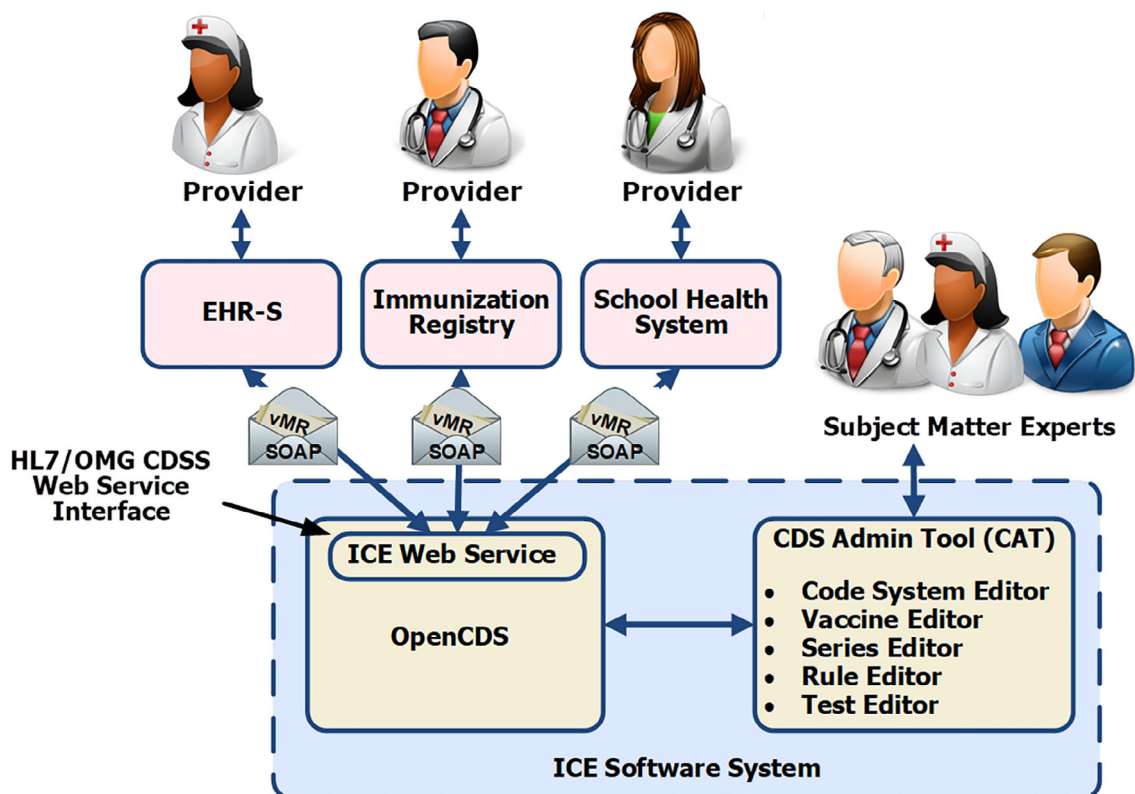


FIGURE 1 ICE system architecture

EHRs, and a third immunization schedule utilized by a school health system.

Due to its standards-based Web Service interface, its Java-based implementation, and its complete lack of dependence on any commercial software, ICE can be deployed in diverse technical environments and easily integrates with third party clinical systems such as Immunization Information Systems (IIS), Electronic Health Records (EHR), and Health Information Exchanges (HIEs). Updates to the ICE software are made available for download periodically, and updates to the ICE rules are also made available for download based on the frequency of change of the underlying clinical guidelines developed by ACIP. ACIP meets approximately three to four times a year and on an *ad hoc* basis when warranted (eg, as vaccine Emergency Use Authorization applications are sent to the US Food Drug Administration). CDC evaluates ACIP decisions and publishes them in their Morbidity and Mortality Weekly Report (MMWR).¹⁶ HLN convenes a subject matter expert workgroup made up of public health and clinical experts to review ACIP decisions but does not usually make modifications to ICE rules until the recommendations are published by CDC in the MMWR.

The ICE Project believes in minimizing the barriers to installing and using ICE anywhere. To that end, there is no registration required to download the source code or runtime code for the ICE service and its default rule. Similarly, the Project created a Docker image of ICE to facilitate easy and seamless implementation. Docker allows for ICE to be distributed in a *container* which is a pre-configured, executable software object that contains all the products necessary to run ICE in one simple package. It is standardized, lightweight, and secure, and can be installed and executed easily in either a Linux or Windows environment.¹⁷

We are committed to continuing to make available a Docker image of ICE as well as potentially other runtime formats to facilitate installation and update. We will continue to solicit feedback from users on the usefulness of these formats.

5 | TECHNICAL IMPLICATION AND TEST PLAN

The following steps are required to download the Docker image of ICE, install it, and test it properly:

1. Download the latest Docker image¹⁸:

```
% docker pull hlnconsulting/ice:latest
```

2. Start the service:

```
% docker run --log-opt max-size=100m --log-opt max-file=5 --rm -d
-p 32775:8080 --name ice hlnconsulting/ice:latest
```

This will make the ICE service available on host port 32775, and set the log options to reasonable values. See the docker-run command documentation for options.

If you wish to set ICE to a different timezone, you can set the container environment variable TZ equal to your desired timezone (eg, - America/New_York), as follows:

```
% docker run -e TZ=America/New_York --log-opt max-
size=100m --log-opt max-file=5 --rm -d -p 32775:8080
--name ice hlnconsulting/ice:latest
```

You can test the ICE service by running the scripts found under:

```
https://github.com/cdsframework/ice/tree/master/
curl-rest-tests
```

To View Logs While the Service is Running

```
% docker logs -f ice
```

To Shut Down the ICE Service

```
% docker exec -it ice /usr/local/tomcat/bin/shutdown.sh
```

5.1 | Configuration

The following environment variables (with their defaults) are supported:

- TZ="UTC"
- DEBUG="N"
- KM_THREADS="8"
- OUTPUT_EARLIEST_OVERDUE_DATES="Y"
- ENABLE_DOSE_OVERRIDE_FEATURE="Y"
- OUTPUT_SUPPLEMENTAL_TEXT="Y"

These variables may be overridden at run time by specifying a different value for the environment variable.

CONFLICT OF INTEREST

The authors assert that they have no conflicts of interest.

ENDNOTES

^{*} That is, the set of rules that specify the number and timing of all routinely recommended immunizations.

[†] Note that this was based on the guidelines as published when the original article was written but it has not substantially changed since then.

REFERENCES

1. <https://www.cdc.gov/vaccines/acip/index.html>. Accessed October 9, 2020.
2. Arzt NH. Clinical decision support for immunizations (CDSi): a comprehensive, collaborative strategy. *Biomed Inf Insights*. 2016;Suppl. 2: 1-3. <https://journals.sagepub.com/doi/pdf/10.4137/BII.S40204>.
3. Richardson JE, Ash JS. A clinical decision support needs assessment of community-based physicians. *J Am Med Inform Assoc*. 2011;18 (suppl 1):i28-i35.
4. Garg AX, Adhikari NK, McDonald H, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. *JAMA*. 2005;293(10):1223-1238.
5. Dexter PR, Perkins S, Overhage JM, Maharry K, Kohler RB, McDonald CJ. A computerized reminder system to increase the use

- of preventive care for hospitalized patients. *N Engl J Med.* 2001;345(13):965-970.
6. Ash JS, Sittig DF, Dykstra R, et al. Identifying best practices for clinical decision support and knowledge management in the field. *Stud Health Technol Inform.* 2010;160(pt 2):806-810.
 7. Zhu VJ, Grannis SJ, Rosenman MB, Downs SM. Implementing broad scale childhood immunization decision support as a web service. *AMIA Annu Symp Proc.* 2009;2009:745-749.
 8. Dixon BE, Simonaitis L, Goldberg HS, et al. A pilot study of distributed knowledge management and clinical decision support in the cloud. *Artif Intell Med.* 2013;59(1):45-53.
 9. <http://www.cdc.gov/vaccines/schedules/index.html>. Accessed April 30, 2021.
 10. <https://www.cdc.gov/vaccines/schedules/downloads/child/0-18yrs-child-combined-schedule.pdf>. Accessed April 30, 2021.
 11. Wright A, Ash JS, Erickson JL, et al. A qualitative study of the activities performed by people involved in clinical decision support: recommended practices for success. *J Am Med Inform Assoc.* 2014;21(3):464-472.
 12. <https://www.cdc.gov/vaccines/programs/iis/index.html>. Accessed April 30, 2021.
 13. <http://www.hl7.org/Special/committees/dss/projects.cfm?action=edit&ProjectNumber=184>. Accessed April 30, 2021.
 14. <http://www.hl7.org/special/Committees/projman/searchableProjectIndex.cfm?action=edit&ProjectNumber=757>. Accessed April 30, 2021.
 15. <https://bitbucket.org/cdsframework/ice/downloads/ICE-Implementation-Guide-distrib.pdf>. Accessed January 19, 2021.
 16. <https://www.cdc.gov/mmwr/index.html>. Accessed April 30, 2021.
 17. <https://www.docker.com/resources/what-container>. Accessed October 12, 2020.
 18. <https://hub.docker.com/r/hlnconsulting/ice>. Accessed January 19, 2021.

How to cite this article: Arzt NH, Chertcoff D, Nicolary S, Suralik M, Berry M. Immunization calculation engine: An open source immunization evaluation and forecasting system. *Learn Health Sys.* 2022;6(1):e10285. <https://doi.org/10.1002/lrh2.10285>