

EpiMass: A Clinical and Epidemiological Platform for Mass Gatherings

Miguel Felício Raposo Vieira
miguelfeliciovieira@tecnico.ulisboa.pt

Instituto Superior Técnico, Lisboa, Portugal

June 2018

Abstract

This paper presents a clinical and epidemiological web platform designed for supporting the basic needs of a first aid post during Mass Gatherings (MGs), called EpiMass. The World Health Organization (WHO) defines an MG as a concentration of people which has the potential to strain the local emergency response mechanisms. EpiMass was built over a 3-tier architecture, based on the MEAN stack (MongoDB, Express, Angular, and Node.js), i.e., a state-of-the-art open-source framework for developing web applications. It enables clinical and epidemiology professionals to perform actions and gather information relevant for their roles. The platform offers integrated data visualization tools and an API which gives the ability to extract the data for analysis with other platforms. This allows for near fast real-time reporting with a preliminary analysis giving some statistics and visual clues over the data, as well as the possibility to do a more thorough analysis with external specialized software. An early prototype of the platform was implemented and tested during the 2018 Torres Vedras Carnival, where it has shown to be viable to collect data during MG events.

Keywords: Mass Gatherings, Clinical Information Systems, Epidemiological Surveillance, Web Platforms, MEAN Stack

Background

The World Health Organization (2015) describes a Mass Gathering (MG) as "(...) a planned or spontaneous event where the number of people attending could strain the planning and response resources of the community or country hosting the event". Olympic Games, the FIFA World Cup, Hajj, and the Glastonbury Festival are all examples of MGs.

Portugal is a country particularly prone to hosting MGs, due to its climate, the importance of tourism and also its culture. The number of MG events in Portugal has been increasing over the years, mostly because of the increased number of cultural events, namely music festivals, where people from all over the world come together to attend performances by their favorite artists.

The challenges associated with this kind of events can place a strain on the local resources. The extent of their impact may vary according to the MG features, environmental factors, participant characteristics and venue characteristics. The main hazards include transmission of infectious diseases, injuries

and trauma, illnesses due to the use of alcohol and drugs, environmental effects, natural disasters, and deliberate acts (World Health Organization, 2015). A sudden epidemic outbreak must also be taken into account at MGs. Therefore, public health surveillance systems have a crucial role in the early detection of a possible outbreak, in order to avoid its spread among the participants.

Despite the importance of these issues, an integrated tool for managing epidemiological risks is not available in Portugal yet. The size of most national MGs is not comparable to the scale of the Olympic Games or the Hajj, for which some work has already been done in this field, due to the magnitude of these events and the number of countries involved. Therefore, it is of utmost importance to develop a system for improving public health surveillance of MGs in Portugal.

The Department of Epidemiology of Instituto Nacional de Saúde Doutor Ricardo Jorge (INSA) has been tracking multiple MG events in Portugal, including the BOOM Festival (Mexia, 2016), the Ananças Festival (Mexia et al., 2017), and the Torres

Vedras Carnival (Rodrigues and Mexia, 2015), for epidemiological surveillance. The teams in the field identified the need of a tool to collect and analyze data in real time, which would enable detection of any situation that could put public health at risk during an MG, such as a sudden epidemic outbreak. This demand led to a partnership between Instituto Superior Técnico (IST) and INSA, for the development of a lean clinical information system that could be rapidly deployed at MG events to support professional teams and collect data in real time for epidemiological surveillance.

Methods

Dr. Ricardo Mexia, an expert on epidemiological surveillance from INSA, provided an initial list of requirements identified during past MG events in Portugal. I have also joined the epidemiological surveillance team of the 2017 Andanças Festival, to understand the real needs of the professional teams present at an MG event, and derive the system requirements for the platform. Figure 1 pictures the epidemiological surveillance team of the 2017 Andanças Festival.



Figure 1: Epidemiological surveillance team of the 2017 Andanças Festival. Source: INSA.

The requirements for the clinical information system, called EpiMass, were collected and discussed in further meetings and interviews with stakeholders, including INSA, Andanças Festival, Cruz Vermelha Portuguesa, BOOM Festival, and the Comissão para a Planificação da Resposta em Saúde no contexto de Situações Críticas e de Exceção no Algarve. The main requirements identified are:

- Offer an information system for supporting the basic needs of a first aid post, including registration of all health occurrences. Many first aid posts are kept in temporary infrastructures with low resources, and without a clinical information system to support the data collection. An information system to easily collect data
- during MGs would contribute to an improvement of public health in general.
- Present a lightweight web application runnable in tablets and smartphones. The professional teams do not always have the resources, like laptops and custom software at the first aid post to manage incidents and collect data. The platform must be capable to run in any device, so tablets and smartphones can be used.
- Collect data in real-time for epidemiological surveillance, allowing the early detection of outbreaks and avoiding spreading and contamination. Otherwise, if an outbreak is not detected in time, it can place a strain on the local emergency response mechanisms.
- Support multiple events at the same time and store data over time in a common repository. This way, a posteriori analysis can be done to compare data from different editions of the same event, or even for the evaluation of the impact of public health programs.
- Establish different user categories for different roles and accesses to the platform. Each user role has a set of functionalities available, according to its permissions. Furthermore, each user should only have access to one event at each time, and the administrators should not have access to clinical data. This increases data safety and allows a better control over secure information.
- Provide statistical information about each event, such as the number of patients treated and the patients which are on the waiting list, providing an overview of the health occurrence status to the event producers.
- Enable tools for epidemiological analysis of the collected data, with bar charts facilitating the creation of reports as well as the gathering of overviews about the data.
- Ability to collect data while operating offline (disconnected from the network), but keeping the application synchronizable with the central server for posterior analysis. The network connectivity may face problems during MG events, so it is important to maintain some functionalities available, such as the collection of data.
- Exchange data with other information sources, such as health care providers. For example, an option for clinicians to get access to patients allergies may contribute to a better diagnosis and treatment. Furthermore, if a patient needs to be transferred to a hospital, the collected

data could be later integrated into the patient's EHR.

A review of the literature focusing on public health surveillance at MGs was made in order to identify systems documented in the literature available for epidemiological surveillance. The systems identified provided a further expertise which contributed to the development of the platform.

EpiMass is based on the MEAN stack (Holmes, 2015), one of the most recent technologies for building web applications based on web platforms. The MEAN stack is a free and open-source JavaScript software stack that allows developing an entire web application in a simpler and easier way when compared with other alternatives. Angular (Eschweiler, 2016) is used on the front-end of a web application, while Node.js (Wilson, 2018) and Express (Hahn, 2016) are used to setup the server. MongoDB (Banker et al., 2016) is a document-oriented database. Furthermore, REST (Fielding and Taylor, 2002) allows to use JSON (a lightweight JavaScript data-interchange format) to represent an object, making it easier to integrate MongoDB with Node.js. These components are being used by many high-profile companies, since they are open-source and do not require purchasing license to be used.

Currently, the EpiMass platform has two fully functional modules available, namely a clinical module for the registration of health occurrences, and an epidemiological module for real-time reporting and preliminary analysis of the data collected. The clinical module was tested during an MG event and the feedback received by the healthcare teams in the field has contributed the validation of the approach taken for coping with the need of the epidemiologists at MGs.

Results

EpiMass is available at <https://epimass.inesc-id.pt/> and can be accessed through any device with a web browser and network connectivity. The domain was provided by the Instituto de Engenharia de Sistemas e Computadores, Investigação e Desenvolvimento em Lisboa (INESC-ID). The central server and the database are hosted at the Infraestrutura Nacional de Computação Distribuída (INCD). Figure 2 presents the EpiMass homepage.

Architecture

The EpiMass platform offers several functionalities which are available according to each of the four supported user roles:

1. **Administrator**, which is only for administrative purposes. The administrator is the user

role responsible for managing users and events. This user do not have access to clinical data.

2. **Clinical**, which is the role assigned to the professionals at the first aid posts. Its main functionality is to register health occurrences during an MG event. Only this user role has access to patient data.
3. **Epidemiologist**, which is the only user with privileges to access the tools available for epidemiological analysis of the collected data.
4. **Producer**, which is the user role designated to the producer of the event, so this user can have an insight of the health occurrences status.

The platform follows a 3-tier architecture, which means that is composed of three tiers, namely the presentation tier (client), the application tier (server), and the data tier (database).

I developed several components to build the user interface. These components use the Angular Material Design developed by Google, which is common in Google products, conveying a familiar experience to the user. I also used the font-awesome package, i.e., a suite of pictographic icons, to provide a user-friendly look on the platform. Furthermore, I implemented toast notifications to notify the user that a given action was or not completed with success. The notification toasts appear on the bottom right corner of the browser.

Regarding the application server, I developed a set of differentiated API methods for both administrative and clinical purposes, including functionalities to register new users, register patients, get events, get data from the registered health occurrences, and update these occurrences. There are more methods available for retrieving data and also for user authentication. Thus, an authorization method was implemented to handle the API requests on the server-side.

Moreover, the different APIs make data integration faster and easier, as they provide a flexible way to extract and manipulate data, and allowing the user to do so without having to understand the implementation behind the APIs, thus being able to use it in a blackbox manner. These methods are called through services every time a user makes a request through the platform. Then, the web server processes the requests and displays a response to the user on his browser.

EpiMass has two main modules available, namely the clinical module, and the epidemiological analysis module. The functionalities presented in these modules are controlled by the application server. The clinical module is available only for users in the clinical role. This module allows users to register health occurrences on the platform and is com-

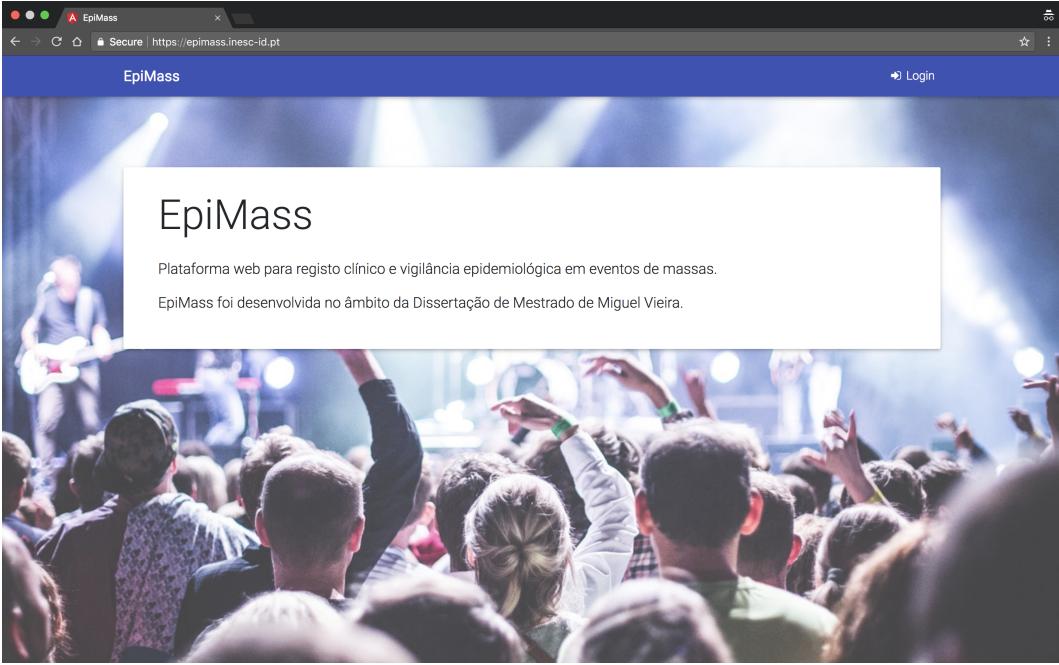


Figure 2: Homepage.

posed by a set of functionalities, such as register a new patient, search for a patient, add a patient to the waiting list, and register a new occurrence.

The epidemiological analysis module is only available for the epidemiologist role. This module has three bar charts available. The first one consists in the distribution of the health occurrences registered by diagnostic groups, allowing a preliminary epidemiological surveillance in real-time. The second bar chart shows the occurrences distribution by age group, while the last one presents the number of occurrences according to the destiny of the patient after going to the first aid post.

The database is composed of JSON-like documents organized into three collections, namely:

1. **events**, which includes the created events. Each event has its own characteristics, namely the name, location, beginning date, and ending date.
2. **users**, which contains the registered users. This way, the user details are obviously kept separated, being only accessible for administrative purposes. Each user has a name, email, password, role, and event. The field event is not present on users with the role admin since they do not have access to clinical data.
3. **patients**, which consists of the collected health occurrences. Each patient has an event associated, the arrival moment to the first aid post, its personal data and the occurrence data. Further, each document has the patient destiny

after going to the first aid post, and the exit moment. This collection was structured in order to easily allow API calls. A document from the patients collection is presented below, with the several fields existent:

```
{
  "_id" : ObjectId("5b1fcf6a0f2b204e2c1b7861"),
  "arrivalMoment" : {
    "date" : {
      "day" : 13,
      "month" : 6,
      "year" : 2018
    },
    "time" : {
      "hours" : 2,
      "minutes" : 49,
      "seconds" : 29
    }
  },
  "event" : "santospopulares01/06/2018lisboa",
  "personalData" : {
    "name" : "Jane Smith",
    "birthDate" : "25/04/1988",
    "age" : 30,
    "gender" : "female",
    "residence" : "portugal",
    "adress" : "Lisboa",
    "contact" : null
  },
  "occurrenceData" : {
    "arrivalDate" : {
      "date" : {
        "year" : 2018,
        "month" : 6,
        "day" : 13
      }
    }
  }
}
```

```

        "month" : 6,
        "day" : 12
    },
    "jsdate" : "2018-06-11T23
:00:00.000Z",
    "formatted" : "12/06/2018",
    "epoch" : 1528758000
},
"symptomsStart" : "12/06/2018",
"motif" : {
    "estadoConscienciaAlterado" :
        true,
    "intoxicacaoAlcoolica" : true
},
"diagnosticGroup" : "
    intoxicacaoAgudaAlcoolica"
},
"destiny" : "transferred",
"exitMoment" : {
    "date" : {
        "day" : 13,
        "month" : 6,
        "year" : 2018
    },
    "time" : {
        "hours" : 3,
        "minutes" : 5,
        "seconds" : 19
    }
}
}

```

Dashboards

Dashboards were developed for each user role, providing different functionalities to the users. The access control is made through Router Guards on the client-side. The user interface of the dashboard changes dynamically according to the user role.

The administrator dashboard, as the name suggests, is only available for the users with the role of administrator of the platform. The dashboard has two main functionalities, namely to create a new event, on the left, and to register a new user, on the right.

The clinical dashboard was designed according to the above mentioned list of requirements list. Firstly, the name of the user is presented along with the event where he is participating. Then, a panel with the number of patients already treated is highlighted, in order to keep track of the state of health occurrences at the event. This panel allows one to get an insight, in real-time, of how many patients were discharged and how many were transferred to another health care provider, such as to a hospital or to a primary care center. There is also a panel with the patients which are on the waiting list. It is presented on the right side of the dashboard allowing easy access to this important information.

Figure 3 illustrates the clinical dashboard with all the features described above.

The epidemiologist dashboard is only available for the users with the epidemiologist role. It is similar to the clinical dashboard, but instead of registering health occurrences, the user can visualize the data registered through bar charts developed for epidemiological analysis.

Finally, the producer dashboard is composed only for the first panel of the clinical and epidemiologist dashboards. This panel allows the event producer to get an insight, in real-time, of the status of health occurrences in the first aid posts of the event.

Evaluation

I integrated the epidemiological surveillance team of the 2018 Torres Vedras Carnival. At the event I had the opportunity to perform assessment tests of the EpiMass clinical module, as well as to get information on the field from the actual potential users of the platform.

In this event, the platform was employed at two first aid posts at the same time, which shared information on the platform. All the health occurrences were registered with success. The registration of the occurrences was kept in duplicated, since the platform was only used for testing purposes. The platform was successfully tested online and locally (i.e., without an internet connection). Figure 4 illustrates me performing tests to the EpiMass platform at one of the first aid posts during the event. The teams at the field were satisfied with the result, particularly given that the form to collect data is very similar to the one they were using. The form was adapted from the one that has been previously used by INSA at MG events. It has been reviewed and improved over the years with the experience gathered at many MGs. Furthermore, I also included some fields of the form used by Cruz Vermelha Portuguesa at the Torres Vedras Carnival.

After the fieldwork at the Torres Vedras Carnival, I started to develop the epidemiological analysis module of the platform. This module is only available for users with the epidemiologist role on Epi-Mass. It contains bar charts of the data collected, according to the diagnostic group, age group, and destiny of the patients after going to the first aid post. These charts are based on the data presented in the daily report of epidemiological surveillance of the Torres Vedras Carnival, and on the reports available on the INSA's repository from other events.

A total of 249 health occurrences were reported during the 2018 Torres Vedras Carnival. The two most reported cases were due to acute alcohol intoxication, and traumatic injuries, with 119 and 72

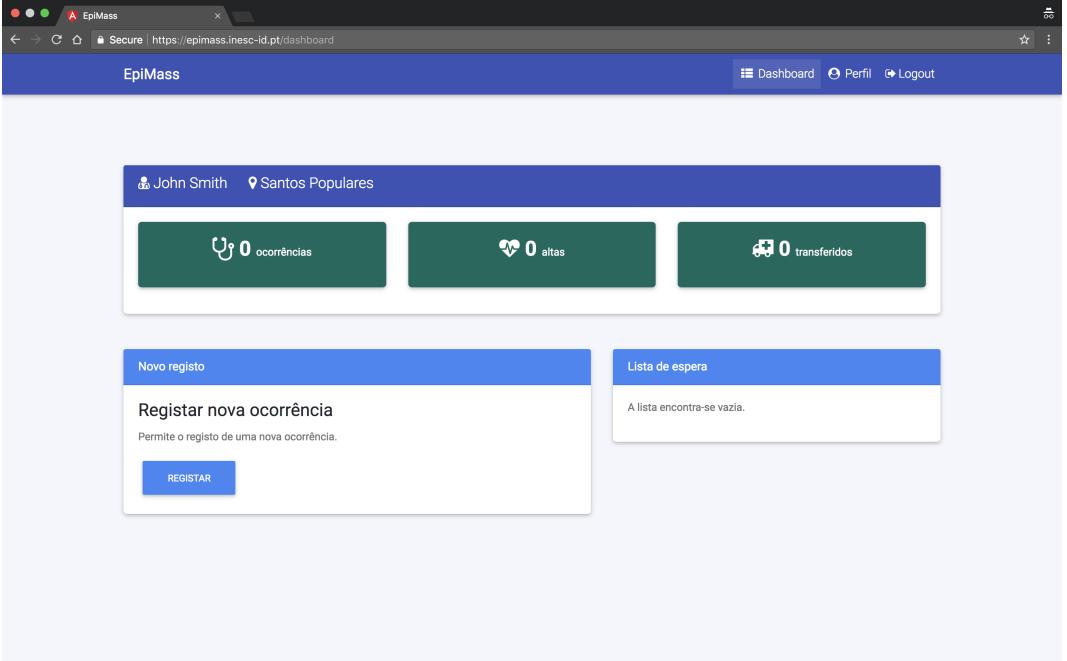


Figure 3: Clinical dashboard.



Figure 4: Performance tests at the Torres Vedras Carnival.

cases, respectively. There were no outbreaks associated to this event.

Figure 5 illustrates the distribution of the health occurrences by age group of the participants, during the event. I also implemented the possibility to filter the health occurrences by gender. The age groups that were associated to more occurrences correspond to patients between 15 and 29 years of age, representing 80% of the cases. Regarding the gender, the incidence was about the same, namely 50% for both men and women.

Software implementing a first prototype of the EpiMass platform has been developed in the context of my MSc thesis. Both the clinical and epidemiological modules demonstrated to be functional, and the feedback obtained was very positive. The plat-

form is able to collect data in real-time, and provides tools for a preliminary epidemiological analysis during MGs. Furthermore, the performance of the clinical module was tested at the 2018 Torres Vedras Carnival, where there were reported about 250 health occurrences. There were no outbreaks during this specific MG event.

Discussion

This paper focus on the requirements analysis and implementation of an early prototype of EpiMass. The EpiMass platform was developed according to the list of requirements gathered and presented to me by Dr. Ricardo Mexia, an epidemiologist from Instituto Nacional de Saúde Doutor Ricardo Jorge (INSA). These requirements had been refined during past MG events by the healthcare professional teams in the field. Moreover, to have a better understanding of the challenges involved, I was also present at an MG to understand and experience, in first hand, the system requirements for the platform.

State-of-the-art technologies for web development were used to develop EpiMass. The platform is based on the MEAN stack (MongoDB, Express, Angular, and Node.js), a full JavaScript framework for developing web applications. The best practices for security security and authentication of communications were also taken into account, since the EpiMass handles private and sensitive data. Furthermore, all the technologies used are open-source, and they do not require additional costs such as licens-



Figure 5: Distribution of the health occurrences by age group.

ing for using the software that was implemented.

The platform has user access control and there are dashboards for each user role, with different functionalities according to their permissions. The user interface was developed to be intuitive, familiar and user-friendly. It is fully responsive and is accessible from any device, since it is available online through a web browser. Currently, EpiMass has two fully functional modules, namely for data collection and for a preliminary real-time epidemiological analysis. In addition, the ability to easily produce reports was taken into consideration. Modularity was also a priority, and more modules can be implemented and added to the application server, increasing the number of available functionalities in the platform. The database was designed to be flexible, presenting many features for extending the API methods, for instance, to extend the interoperability with other web services.

EpiMass was tested during an MG. The platform was shown to be robust enough to handle this flow of data and seemed to be very well accepted by the professionals that participated in the study that were on the field. In fact, most of these professionals provided good feedback as well suggestions for improvement and, moreover, some professionals expressed their wish to use this platform in the near future in similar events.

Not all requirements were accomplished due to time constraints and the necessity to implement other essential functionalities. Currently, the clinical module still does not allow editing or deleting health occurrences already registered (i.e., the API

methods were developed, but the functionalities are still not available on the client-side). Also, the epidemiological analysis module has limited features implemented, such as filtering the occurrences by day.

The ability to sustain losses of connection would translate in an increased robustness of the application, and therefore would be a massive gain for a platform such as EpiMass, working in often complex situations. Therefore, in this thesis, I deeply studied the subject and the technologies, but again, this is a very recent and permanently evolving technology, and in some cases lacking good documentation. In fact, a prototype of the offline module was started, but again, due to time constraints, unable to be completed. Nonetheless, these developments can still be picked up in future work.

Furthermore, the possibility to exchange data with other information sources was not developed. However, there are a set of API methods that can be called through a middle application to access data from health care providers, such as a patient's history. These specific functionality depends on further interaction with service providers, namely the ones responsible for healthcare providers, both in the National Health System and the private sector. Finally, since EpiMass is modular, an additional module for participatory surveillance could be developed and added to the platform.

Acknowledgments

I would like to thank all of those involved in this work, especially my supervisors, Prof. Mário Gaspar da Silva, Prof. Bruno Martins, and Dr. Ricardo Mexia. A special thanks to the Department of Epidemiology of Instituto Nacional de Saúde Doutor Ricardo Jorge, and to the teams present at the first aid posts of the 2017 Andanças Festival and the 2018 Torres Vedras Carnival.

This work was produced with the support of INCD funded by FCT and FEDER under the project 22153-01/SAICT/2016.

References

Banker, K. et al. 2016. *MongoDB in Action*, 2 edition. Manning Publications.

Eschweiler, S. 2016. *Angular 2: A Practical Introduction to the new Web Development Platform*. Leanpub.

Fielding, R. T. and R. N. Taylor 2002. Principled design of the modern web architecture. *ACM Transactions on Internet Technology (TOIT)*, 2(2):115–150.

Hahn, E. 2016. *Express in Action: Writing, building, and testing Node.js applications*, 1 edition. Manning Publications.

Holmes, S. 2015. *Getting MEAN with Mongo, Express, Angular, and Node*, 1 edition. Manning Publications.

Mexia, R. 2016. Sistemas de Vigilância Epidemiológica em Eventos de Massas (BOOM Festival/Andanças). Instituto Nacional de Saúde Doutor Ricardo Jorge, IP.

Mexia, R., A. San-Bento, and M. Castro 2017. Uma catástrofe num festival de verão—resposta na área da saúde. *Boletim Epidemiológico Observações*, 6:8–15.

Rodrigues, N. and R. Mexia 2015. Relatório da vigilância epidemiológica do carnaval de torres vedras 2015. Unidade Saúde Pública Moinhos, ACES Oeste Sul/ Instituto Nacional de Saúde Doutor Ricardo Jorge, IP.

Wilson, J. 2018. *Node.js 8 the Right Way: Practical, Server-Side JavaScript That Scales*, 1 edition. Pragmatic Bookshelf.

World Health Organization 2015. Public health for mass gatherings: Key considerations.