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Why keep alert sirens in France?

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Abstract. This paper discusses the usefulness of keeping sirens to alert in an emergency situation likely to harm the physical integrity of property or the population in France. Sirens are the main pillars of the National Alert Network (NAN) deployed from 1954 to 2010, and these tools remain the basis of the future Population Alerting and Information System (SAIP) planned for 2022. Sirens are intended to interrupt social activities, and to induce adequate behaviour from the authorities and the population potentially endangered. But this ongoing priority raises questions: sirens present technical drawbacks; they have rarely been used (only two times in 60 years); the authorities minimize the potential of connected tools like social media, Cell Broadcast (CBC) Geo-localized Short Message Services, or Smartphone applications. Analysing the changes observed in our literature review and the lessons learned from two other countries, Belgium and the USA, we conclude that the integration of sirens in a multi-channel platform and the use of the Common Alerting Protocol (CAP) should sublimate the meaning of siren signals, if the authorities really want to make sirens part of an effective solution to alert people in France..

1 Introduction

1.1 Background

Sirens have been deployed in metropolitan France since the end of World War II to alert people in emergency situations of imminent danger to life or property (DGSGCG, 2013; Vogel, 2017; Douvinet, 2018). The alarm (a sound ascending and descending over 101 seconds, separated by a silence of 5 seconds and repeated three times) is intended to interrupt social activities (Creton-Cazanave, 2010). While the warnings inform people a few hours before the occurrence of a hazardous event (Douvinet and Janet, 2017), the activation of an alert announces the beginning of a significant threat to human lives, and is intended to generate prompt reactions, both from people and rescue services (DGSCGC, 2013). Given the responsibilities entailed, the alert is a state competence in France. It is related to civil security issues, and is regulated by the *French Security Code* (Articles L.112-1, L.711-1 and -2, L.732-7). In this context, only the government and its representatives at local level can authorize the activation of sirens: the prefect (local representative of the central government) and/or the mayors. The reasons behind the political choice to use sirens are quite simple to explain. On the one hand, sirens seek to emphasize reactivity, and allow the authorities to quickly advise the population, and to implement actions and countermeasures in a short

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time. On the contrary, sirens never seek representativeness (Pritnat, 2006). Sirens do not allow time for hesitation and do not seek to provide a comprehensive message (Reed *et al.,* 2010; Zunkel, 2015; Mathews *et al.,* 2016). Sirens quickly attract the attention of the population, day or night. But their effectiveness is based on an implicit assumption that the population understands what is really expected from them in event of a siren alert (Linsday, 2011). As documented in prior research focused on such alarms from a technical point of view only (Sorensen and Sorensen, 2000; Vinet, 2008; Matthews *et al.,* 2017), testing sirens once a month in France serves to remind residents of the role of sirens (Creton-Cazanave, 2010). A 2010 study showed that 22 % of the population were aware of sirens thanks to the regular tests (Deloitte, 2014). For the authorities, once sirens are activated, citizens must adopt a "safety behavior", waiting for complementary information (DGSCGC, 2013). Messages will differ depending on the type of event: people have to evacuate in the case of urban or wild fire, to shelter themselves in the case of floods, or to stay in houses in the case of a toxic cloud or of a terrorist act, for example. In the event of a foreseen threat, warnings should be sent with calls to put residents "on guard". These can be interpreted as a notification of the imminence of a given danger, and the French Ministry of the Interior distinguishes between the initiation of the procedure and the activation of sirens.

1.2 Research focus

Our study examines why sirens still remain the primary tool used to alert the population in France, despite well-documented shortcomings, and proposes changes that could potentially improve risk communication. The government and the Ministry of the Interior still give considerable importance to sirens in France, without reference to any demonstrated effectiveness (Vinet, 2008; Daupras *et al.,* 2015; Douvinet, 2018). Given that the National Alert Network (NAN), in place since 1954, has become unsuitable over the years (Hirel, 2002; Vogel, 2017), in 2010 the French Ministry of the Interior decided to modernize the network, replacing the old NAN system with a new network called "*Public Alerting and Information System"* (SAIP in French), to be implemented in 2022. With an initial cost estimated at more than 83 million euros, this project should enable prefects to have a "more powerful and a more resistant network" of sirens (Deloitte, 2014). The connection among sirens will be based on the *French National Shared Infrastructure of Transmissions.* Alerts will be activated in case of suddenly arising situation like explosions (e.g. projection of debris, toxic clouds, etc.), hostage takings, terrorist attacks or flash floods (Vogel, 2017). Slower phenomena (like overflowing floods, occurring in a few hours and/or days) would not justify the activation of sirens, as the time before first impact is considered long enough to initiate the evacuation or containment measures. Some new sirens will provide coverage to currently "non-covered NAN high-risk areas" (5,531 SAIP sirens are planned, compared to 4,291 in the NAN). But the effectiveness and the benefits of this project have not been explored, and it is unclear why only sirens are proposed to alert the populace.

We also seek to understand why authorities have confidence in sirens despite limitations documented in the scientific literature (Garcia and Fearnley, 2012; Beccerra *et al.,* 2013; Pappenberger et al., 2015; Daupras *et al.,* 2015; Douvinet *et al.,* 2017) in two reports of the national Senate (Vogel, 2017; Courteau, 2018). National authorities tend to underestimate the benefits of other alerting tools (radios, e-mails, phone calls, SMS, social digital media, etc.). As a good example, the SAIP® smartphone

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application (which bears the same name as the SAIP project for the modernization of the siren network), set up 8 days before the *European Football Cup* in June 2016, required a relatively light investment of 300k euros. Over a two-year period, the application was used only four times. One of these was very late (the first messages were been sent at 00:30 July 15th 2016, three hours after the terrorist attack in Nice). In another situation, the application sent a false alert (for the false Louvres attack in September, 2017). The French Ministry of the Interior finally decided to cancel the application on May 28th 2018, considering that this tool provided more disadvantages than benefits. Approaches such as Cell Broadcast, Geo-targetted SMS or alert tools related to the Internet of Things like connected watches or embedded objects such as cameras, etc.) have never been used, whereas these technologies have been used for alerts in other countries (Huang *et al.,* 2010; Whitmore *et al.,* 2015). Messages are also well recognized to successfully complete the sound signal or sirens (Leo *et al.,* 2015; Zunkel *et al.,* 2015), to increase the empowerment of people by knowledge (Becker and Bendett, 2015; Fajardo and Oppus, 2009; Jagtman, 2010) or/and to help people to take the right decisions during alarms (Bean *et al*., 2016; Zhang *et al*., 2004). In addition, when we look at the number of sirens deployed in other countries or other cities (**Table 1**), we see that their number varies markedly and that coverage rates are heterogeneous. Testing regimes differ: Denmark tests sirens silently every night, and an audio test is conducted with the public on the first Wednesday of May; Switzerland tests its sirens the first Wednesday of February. Differences also exist in the tone of alarms, with modulated sounds depending on the extent of the dangers (Austria, China, Norway, Sweden) or on the nature of the hazard (United Kingdom). Some cities are specifically equipped, like Mumbai (India), with 450 sirens spread throughout the city, or Singapore (with 2,000 electronic sirens deployed in 2012). But other countries have, on the contrary, decided to dismantle the sirens, such as for example the Netherlands since 2015, or Belgium since 2016.

COUNTRIES (or cities)	Number of sirens	Population	Average population covered by a siren
FRANCE (SAIP)	5,531	66.99 millions	12,111
ISRAEL	3,100	8.71 millions	2,810
NROWAY	1,250	5.26 millions	4,224
SOLVENIA	1,496	2.07 millions	1,377
SWITZERLAND	8,500	8.42 millions	990
Mumbai (INDIA)	450	18.41 millions	40,911
Singapore (SINGAPORE)	2,000	5.61 millions	2,805

Table 1: Number of sirens in other countries/cities, and estimation of the number of people covered by a siren.

This paper follows the questions described above. We first analyze the distribution of sirens and quantify the number of people covered, emphasizing the NAN and the SAIP networks. We next consider technical problems and failures in the activation process. We then review of the evolution of alert systems observed in two other countries, namely in Belgium, where sirens have been abandoned since 2015, and the USA, where a single alert platform (IPAWS) has integrated sirens with other alerting disseminators since 2006. Part IV looks at whether such changes could be applied in France, and proposes solutions to improve the effectiveness of sirens in the short term.

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2 Advantages of sirens in France

2.1 A state competence since 1954

In the Middle Ages, the priests were the only ones authorized to ring the church bell to alert the local population (Maillard, 2001). But this "power of alert" was transferred to the services of the State after the end of World War II, as attested by an order signed in 1954 by General de Gaulle. This led to the creation of the National Alert Network (NAN), based on electronic sirens and deployed to potentially alert populations in the event of aerial threats. A few years later, the order of January 7th 1959 defined the responsibilities of the authorities responsible for the NAN activation (mayors and prefects). The decree of May 8th, 1973 expanded the use of NAN sirens in the event of NBC (Nuclear, Bacteriological and Chemical) risks, in relation to the development of the nuclear program during the 1970s in France. Nowadays, the mayors and prefects remain the only ones authorized to activate sirens in the event of emergencies **(Fig. 1)**. Mayors consider the siren activation as a priority in the case of sudden events. In addition, they have to inform parents, heads of schools, or the guardians responsible, etc. As Directors of the rescue operations and coordination, mayors must ensure that the alert will be distributed to all the people, without any social or cultural distinction.

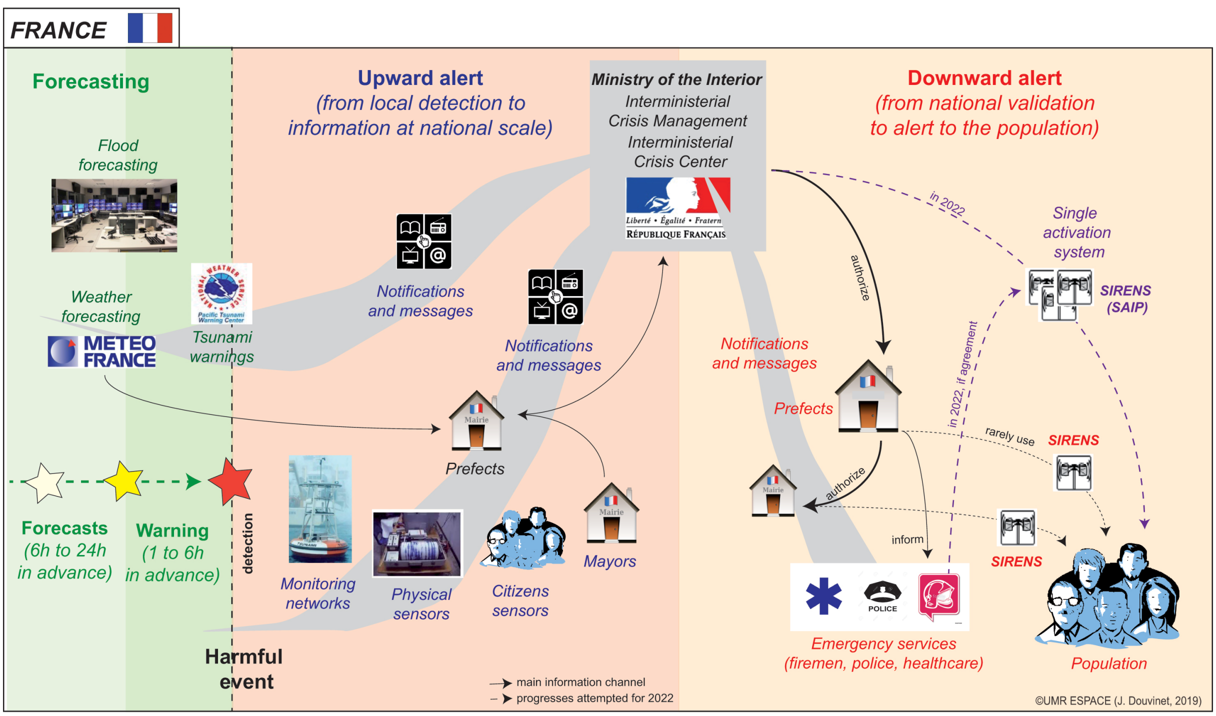

Figure 1: Place of sirens in the alerting process in France

The prefect can activate sirens alone in three situations: 1) if the mayor fails to issue the alert, 2) if the event covers several municipalities located within the area he is responsible for, or 3) when the technical, logistic, or financial capacities of the

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mayor are exceeded. According to Article L.1322-2 of the Defense Code, the prefect will be in charge of the civil defense management, with the help of the mayors, except in all areas where military operations are taking place. In this case, the government confers to a military commander the responsibility for the activation, if necessary, of sirens.

2.2 What did the National Alert Network (NAN) cover until 2010?

The distribution of sirens in the NAN network has evolved considerably over the decades. By extrapolating the database reported by the prefectures, there were around 1,000 sirens in the early 1960s (Deloitte, 2014), 2,400 by the 1980s, 3,700 early in the 2000 s, and a total of 4,291 sirens spread over 2,632 municipalities in 2010. Of the total sirens in 2010, 1,071 (26 %) were located on the roofs of town halls, 573 (14 %) on the roofs of churches, and 28 % on free-standing structures. The remaining 32% were located on other public buildings, but details are not available. The coverage of the NAN sirens (**Fig. 2**) remained fairly consistent in 2010 with population density. Sirens are numerous in the region of Ile-de-France (82 sirens for Paris) and in the major urban areas: Strasbourg (60 sirens), Marseille (57), Lyon (28), Toulouse (27), and Nice (26). 15 cities out of 22 with more than 100,000 inhabitants are equipped with more than 10 sirens (68 %), and some are very well equipped compared to the number of inhabitants (27 sirens in Mulhouse, 20 in Colmar, for example). Even if the population living in a municipality can or cannot be included in the audibility radius, we estimated a ratio between the total municipal population (INSEE, 2014) and the number of NAN sirens. It can be seen that this ratio is low for several sparsely populated areas (**Fig. 3**). In detail, 12 municipalities have one siren for less than 100 inhabitants; 3 sirens had been installed in small areas, as at Broye-Aubigney (Haute-Saône), which had 477 inhabitants in 2010, or at Bricy (Loiret), with 557 inhabitants in 2010. So the population density is not a deciding factor at local scales. In contrast, the densely urban areas of Lyon (only 2 sirens for 515,685 inhabitants in 2014), of Bordeaux (1 siren for a city of 252,040 inhabitants in 2014), and of Argenteuil (1 siren for 110,468 residents in 2014) have very few sirens, and are well-identified in figure 3, with less than one siren for over 100,000 inhabitants (**Fig. 3**).

If we relate this information to the technical standards given by siren manufacturers, 48 % of the French population was probably covered in a radius of audibility of 3 km in 2010 (Douvinet, 2018). If the effective radius of siren audibility is only 1 km, then sirens may alert only 32 % of the population in France. The power of the sirens can vary from 1.1 to 7 kw, and the power of each of the 4,291 NAN sirens is not recorded. Moreover, some sirens are no longer functional (25 % in 2010, according to Deloitte, 2014). Our estimates indicate only the population theoretically covered by sirens, without considering actual patterns of location of people at a finer spatial scale and throughout the day. Because of these factors, we cannot conduct spatial and statistical analyses among economic, political or strategic factors and siren locations.

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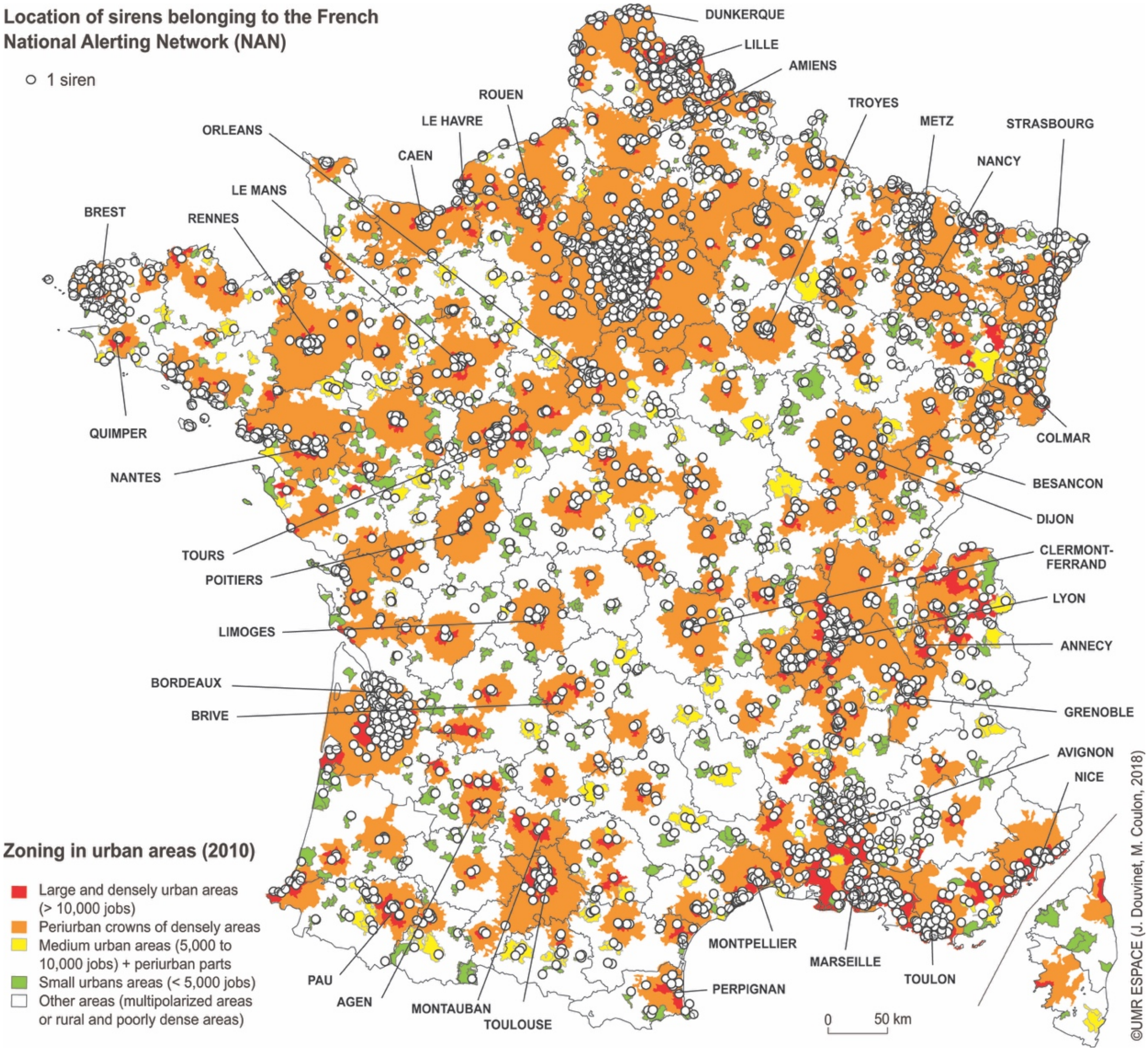

Figure 2: Distribution of the 4,291 sirens of the National Alert Network (NAN) for 2,632 municipalities in France in 2010 (Source: Deloitte report, 2014; DGSCGC database; Douvinet, 2018)

Thus, if the population density originally played a role in the distribution of NAN sirens, other reasons explain the current distribution of sirens: the location of military sites (explaining the high number of sirens near Brest and Toulon), the proximity to political frontiers (near Germany and Belgium), or the concentration of industrial sites in several areas (along the Rhine and the Rhone River valleys). Industrial risk sites, which can generate a nuclear risk or other risks related to the nature of their activities, played a secondary role in the location of sirens because these sites are equipped with their own sirens (so-called

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PPI). The authorities gave a lower priority to sparsely populated areas and to scattered individual risks. But these explanations are not systematic: the previously listed factors are not enough to explain why 2,632 municipalities have at least one NAN siren. The location of sirens is also not correlated with the creation of local emergency plans. Officially, the latter have to be created within 2 years after the approval of the Risk Prevention Plan, but only 55 % of municipalities with such planning tools were covered by sirens in 2010.

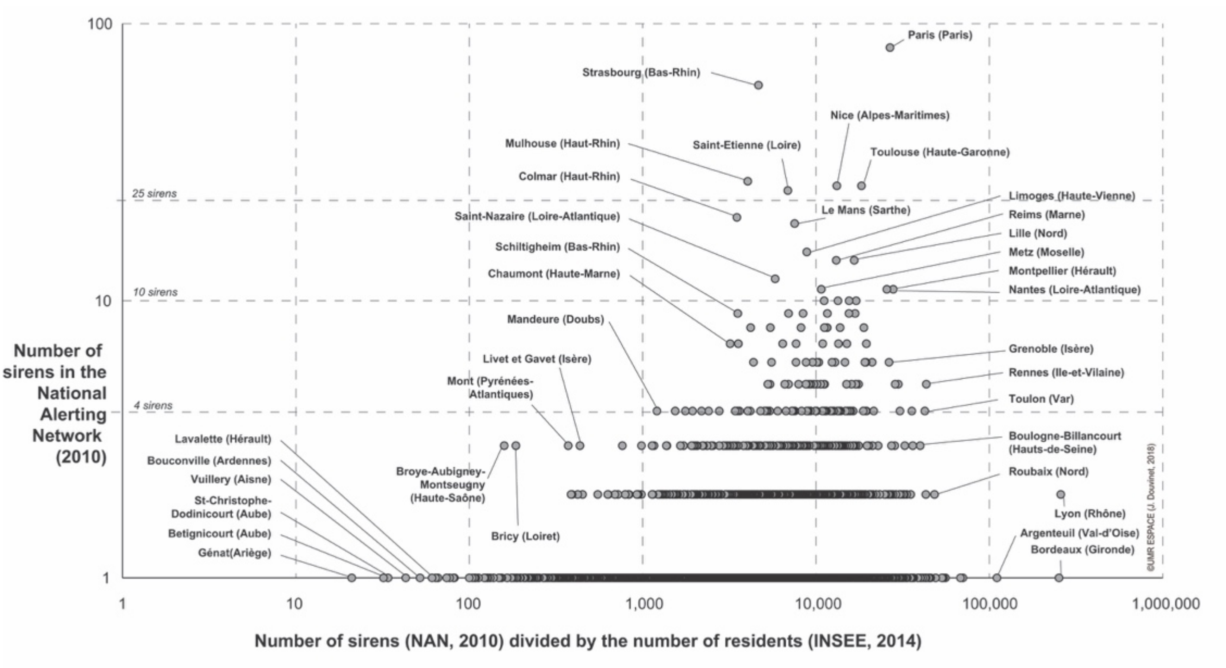

Figure 3: Number of NAN sirens by municipality and average number of inhabitants served by each siren (Source: Douvinet 2018, based on DGSCGC 2018 database)

2.2 What can we expect from the SAIP network in 2022?

The SAIP project will replace the NAN network in 2022 (Vogel, 2017) but the French Ministry of the Interior enacted in 2010. Il was defined following three guidelines: 1) the necessity to connect the sirens together, with a single electric network complying with current standards; 2) the necessity to activate the 5,531 sirens (**Table 2**), with a single software (developed in 2012-2014 by *Airbus Defense and Space,* and successfully tested and verified in 2015); 3) the necessity to improve the distribution of sirens, positioning them in 1,743 risk areas to reach a maximum number of people. This way, the distribution of the SAIP network will be based on the concept of "risk area", taking into account the speed of the processes creating hazards, the risk forecasting, and the location of sirens depending on some specific circumstances (concentration of chemical industries for example), not just the population density. Maps and delineations of the risk areas were validated by the Ministry of the Interior, dividing the distribution of sirens into two priority levels: 640 areas are now totally covered by 2,832 sirens (45 %

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belong to the former NAN). These areas are considered to have a high level of priority. The remaining 1,103 risk areas present a lower level of priority, and 2,699 sirens will be installed there from 2020 to 2022 (**table 2**).

Priority level	Number of risk areas	Number of sirens in the SAIP project	… including upgraded NAN sirens	… including new sirens	… including municipalities' sirens	… including sirens in chemical risk areas
Level 1 (2017-2020)	640	2,832	1,286	932	614	0
Level 2 (2020-2022)	1,103	2,699	191	854	533	1,121
Total sum (2022)	1,743	5,531	1,377	1,786	1,147	1,121

Table 2: Number of sirens in the SAIP project planned for 2022 (Source: Vogel, 2017)

Due to the confidential nature of databases, we cannot present the map expected for the future SAIP network over all of France. We did however have the permission to address such an analysis at a regional level. We can therefore illustrate changes between the NAN and SAIP networks in the PACA *(Provence-Alpes-Côte d'Azur)* area, a region located in the south of France. This area (**Fig. 4**) covers 31,400 km^2, with an estimated population of 4,781,000 inhabitants (INSEE, 2014). The population has doubled since the 1960s (from 2,414,958 inhabitants in 1954) because of tourism, immigrants from elsewhere in France drawn to the pleasant climate, and foreign immigration. Almost two thirds of the residents live in four major urban areas (Marseille, Nice, Toulon, and Avignon). 80 % of the population is located in coastal areas, while mountainous and rural areas in the Alpine interior regions are sparsely populated (Bopp *et al.,* 2019). A massive increase in the winter tourist numbers occurs in some areas of the Alps (Dévoluy, Val d'Allos or Serre Chevalier, for example).

Our first findings obtained in the PACA area are particularly interesting: **1)** the number of SAIP sirens will be slightly less numerous (253), including 105 new sirens, whereas the NAN had 300 sirens; **2)** the number of sirens will increase in urbanized areas, for example in Marseille (+12 sirens), around the Etang-de-Berre lagoon where chemical risk sites are numerous (+13 sirens), in Toulon (+ 6 sirens), Saint-Tropez (+ 5 sirens), or in the downstream parts of major rivers, like along the Argens River (+ 11 sirens) or along the Durance River (+ 7 sirens). The SAIP network will cover areas that were not covered until now by NAN, and in this case the population density seems once again to be the priority; **3)** all these newly-covered areas have been affected by at least one severe event in recent years (2010 along the Argens River due to sudden flash floods, in 2014 near La-Londe-les-Maures, in 2015 at Cannes...). However, the number of sirens will not increase near Cannes, due to the presence of older NAN sirens; **4)** on the contrary, the number of SAIP sirens will decrease in other areas. As an example, in the department of Vaucluse the NAN network, composed of 85 sirens (which cover about 386,100 residents within a radius of 3 km), will be replaced by only 33 in the SAIP project, and sirens will cover 315,000 residents in a radius of 4.5 km. But it must be remembered that the yellow dots in the figure below (**Fig. 4**) confirm the disappearance of some sirens in the SAIP project, even if these sirens can be stored and managed by the municipalities or communities of municipalities individually.

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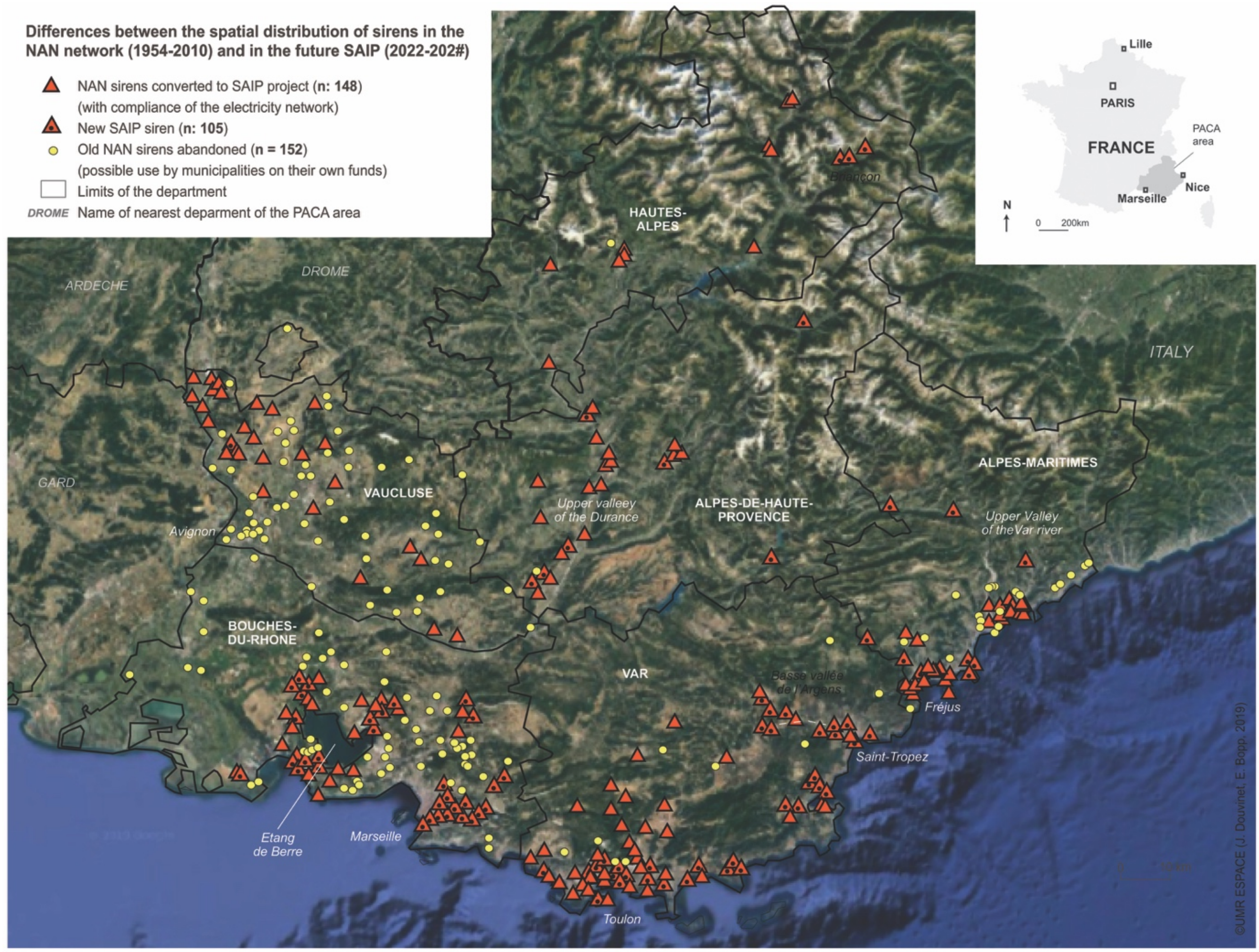

Figure 4: Location of the sirens expected in the future SAIP project in PACA (Source: DGSCGC database, 2018; Douvinet, 2018)

3 Limits and criticisms of sirens in France

The utility of sirens had already been the subject of criticisms for a few years, especially due to the limited range of the sound signal (3 km for NAN sirens and 4.5 km for SAIP), the lack of meaning for people, the non-respect of the activation guidelines, the dependence on political policy, or the lack of interconnections between sirens and other connected tools. Sirens also present technical limits (Creton-Cazanave 2010, Vogel 2017) because social, territorial, and contextual issues are rarely taken into account (Douvinet *et al.,* 2019). Unfortunately, the future SAIP network will present the same limits. For example, the industrial accident, which occurred on September 27th 2019 in Rouen (in the northern part of France), has underlined our fears about their real effectiveness: sirens located near the harmful site were activated at 7.45 am, while the accident begins at 2.40.

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3.1 Limitation #1: Technical issues

The main technical limits of the NAN network are the aging of sirens, the cost of maintenance, their operating status, their audibility, the need for compliance of the electrical circuits with the current standards, or the spatial sound diffusion (**table 2**). These concerns have already been mentioned in other countries (Reed *et al.,* 2010; Mathews *et al.,* 2017), and are also commonly referred to in various feedbacks yet gathered in France (**Table 2**). The use of sirens requires mastering the sound propagation, but the latter depends on numerous spatial factors like the strength and direction of the wind, the temperature, the air density, the nature of materials used for construction, the ambient sound in urban areas…, and is far from simple to assess in reality (Douvinet, 2018). If the audibility distance can be up to 3 km for a siren with a power of 7kw, this is actually no space longer heard beyond a distance of 800m from the source point (in ideal conditions), and the audibility distance can go down to a range of 300 m with a 1 kw siren. Sound energies between two sirens can also be canceled if they are not far enough apart: for a 4 kw siren, the spatial separation to be respected is 2.1 km in a calm urban environment, while 0.57 km in a densely urban area (Deloitte, 2014).

Technical issues	Data obtained at national scale	Data obtained at a smaller scale
Age of sirens	28 % of control systems installed before 1970 (Deloitte, 2014)	Mean age of the NAN sirens in the department of Vaucluse: 47 years (Kouadio, 2016)
Costs for maintenance	Estimated annual cost for the NAN of more than € 11 million in 2000's (Hirel, 2002)	
Operating status	Interruption of *France Telecom* services since 2011 (Vogel, 2017)	Tests have no longer been possible in Corsica since 2008 (Vogel, 2017)
Need of compliance	37 % of the NAN sirens would emit a compliant signal; for the rest, incorrect signal or lack of information (Vogel, 2017)	For the 85 NAN sirens in the Vaucluse, 32 broadcast a correct signal (SIDPC84, 2017)
Audibility threshold	A 1.2 km spatial cover in dense urban areas for a 7 kw siren (Deloitte, 2014)	800 m range in dense urban environments, regardless of power (CYPRES, 2017)

Table 3: A list of technical problems for the NAN sirens in France (Source: Douvinet, 2018)

3.2 Limitation #2: The activation time

Sirens also raise questions because the activation doctrine (enacted in 1959) remains largely unimplemented (Vogel, 2017). Fortunately, the NAN sirens have never needed to be used for their original purpose: facing an air threat. However, these tools have also never been activated in most of the emergency situations which have arisen: no sirens in sudden phenomena such as earthquakes, dam failures (Malpasset in 1969) or landslides (Boudou, 2015), whereas these have occurred in France since 1954; no alerts in the event of sudden flash floods (among the most recent, Nîmes in 1988, Vaison-la-Romaine in 1992, Draguignan in 2010, Cannes in 2015, Trèbes in 2018). When the events are progressive, like overflowing floods, the authorities prefer alerting the people door by door, with sound messages broadcast on vehicles, with the help of the communal agents, or using the official media before the evacuation starts, but not with sirens. Over a period of 60 years, sirens have only being used twice: during the Vidourle flash floods in 2014 (3 people died), and during the wildfires around Vitrolles, near Marseille, during the summer of 2017 (no victims, but 2,400 hectares burned and an estimated cost of 1.3 million euros). This is very low and surprising, considering all the dangerous situations that could have required siren activation during this period.

Given the uncertainties concerning future crises, the authorities do not know if the situation can get worse, if it can extend, or until when. So they hesitate to activate sirens without being completely sure. Populations also face difficulties in making decisions about their behavior (e.g. picking up their children from school or not, or driving). The question could be asked to whether it is useful to add an anxiety signal at a time when individuals are already in trouble. All this requires a good knowledge of the speed of the process creating the danger, which is not always predictable (like terrorist attacks or industrial accidents), and these limits, have not been reduced for the future SAIP system (Douvinet, 2018).

3.3 Limitation #3: A non-explicit meaning for population

The usefulness of sirens also implies that people are able to identify, recognize, and deal with hazards or threats that may have different origins and speeds. However, few individuals are able to identify and understand dangers only by hearing the alarm (Lutoff *et al.,* 2016; Daupras *et al.,* 2015), especially since behaviors to be expected can be contradictory. This sound signal, presented as unambiguous, is difficult to interpret in real conditions. It is "one sound on top of others" (Dedieu, 2009), which is cumulated to the ambient noise, particularly in urban areas,. Unfortunately, it is not accompanied by any information. Several studies (Becerra *et al.,* 2013, Creton-Cazanave, 2010; Daupras *et al.,* 2015) have also well-proven that decision-making is complex under stress, because it involves cognitive and perception barriers. The interpretation of the sound depends on the knowledge and past experiences of each person concerned, but also on the training and information addressed upstream (CEPRI, 2011). In addition, these elements play a key role in the decision time, before the reaction time (Colbeau-Justin, 2002, Daupras *et al*., 2015). Interpretation of an alert signal is then considered as a brake on daily activities, and it is worse to design an alert in a purely technical process. For a few researchers, this alarm is moreover a "fantasy" or even a "myth" (Mileti and Sorensen, 1990). It is impossible to produce a signal that would trigger automatic behaviors (Roux, 2006), and the adoption of reflex measures takes a while.

This idea is reinforced by the proven recurrent discrepancies between the behavioral skills ("I know what I need to do when the event occurs") and behaviors declared outside the alert ("I really do"). These lags prevail, independently of the type of the risk involved. To quantify these offsets, we observed the reactions of people during a civil security exercise carried out with the Vaucluse Prefecture on December 1st 2016, in Sorgues (near Avignon). Sirens were activated in the scenario of a toxic gas leak. This enables to estimate the population's knowledge of appropriate behaviors during an alert and to compare to the behaviors really adopted during the alert (Douvinet *et al.,* 2017). A serious problem arose: the industrial siren was set off at 8:45 am, while the municipal siren sounded at 9:15 am. Second, the surveys conducted in the area from 8:45 am to 11:30 am clearly demonstrated the lack of seriousness perceived among the respondents (65 % were not aware of the exercise), and the difficulty that they had foreseeing and applying what was expected of them (**Fig. 5**).

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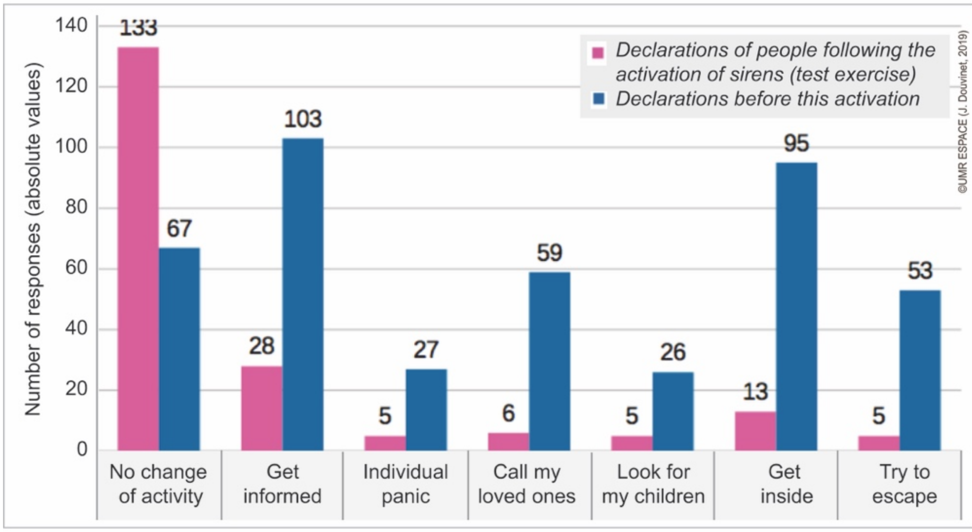

Figure 5: Differences between people's knowledge of the appropriate behavior (blue) and their behavior (pink) after hearing sirens during a civil security exercise in Sorgues (Vaucluse).

3.4 Limitation #4: Reluctance to create a multi-channel alerting chain

At the French national level, the different changes at the head of the Ministry of the Interior since the 1960s have not changed the priority allocated to sirens, which benefit from most of the funding allocated to alerting the population in France. More than 83 million euros were allocated in 2010 for the modernization of the siren network. But the state services had many opportunities to develop tools other than sirens. As a good example, the SAIP smartphone application failed due to a lengthy validation between state services, up to and including the national level, and this was not adapted to the emergency level of dangerous events (for example during the terrorist act on the July 14th 2016). When the application was launched in June 2016, the French Ministry of the Interior hoped to reach 5 % of the population (Vogel, 2017). But the usefulness of the SAIP® application was quickly under discussion. It was only used 4 times over the 2016-2018 period, while in fact, 85 events required the real intervention of the National crisis center, so-called the COGIC (**Fig. 1**). The application generated more constraints than benefits, which explains its abandonment on May 28th, 2018. The alerting chain suffers from a lack of long-term prospects for the next ten years, and this observation is in line with what can be observed in the risk prevention in general (Douvinet *et al.,* 2011). Documents are based on a technical offer that the state and technical services control, but there are few innovative initiatives which are based more on the demand of the inhabitants (Lindsay, 2011), and little wider reflection (Vinet, 2008).

4 How have sirens evolved in other countries ?

In order to see if limits and constraints observed in France are the same elsewhere, we decided to study solutions used in other countries, especially in Belgium (because sirens have been abandoned there since 2015), and the USA (where a single alert

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system has integrated sirens with other alerting channels since 2006). These countries serve as examples of good practice, but sirens have also been studied elsewhere (Stokoe, 2016; Mathews *et al.*, 2017).

4.1 Integrating sirens into a multichannel system: the United States

The US example is interesting for two reasons: **1)** the alert activation is a shared competence between different authorities, ranging from local, tribal, and territorial administrations, to state governors and the federal power (except in Hawaii, where the island governor is the only one authorized to activate an alert). This responsibility is regulated by the *Disaster Relief Act*, established in 1970 by President R. Nixon (Zunkel, 2015). This was subsequently amended by the *Stafford Disaster Relief and Emergency Assistance Act* on 23rd November 1988. The *National Response Framework* (NRF) provides an overview of the *Stafford Act* that requires federal agencies to provide assistance to local elected officials in the event of an emergency or major disaster. **2)** Since June 1st 2006, following malfunctions proven during the passage of Hurricane Katrina in 2005 in New Orleans (Louisiana), and by decision of President G.W. Bush, a single platform has been created to merge several platforms: the *Emergency Alert System* (EAS), covering 90 % of the population and coming from a long federal tradition; the *Wireless Emergency Alerts* (WEA), enabling a text of 90 characters to be sent to mobiles and pagers using relay antennas; the *NOAA* (*National Oceanic and Atmospheric Administration*) *Weather Radio*, which is in charge of disseminating the vigilance and warning bulletins in the event of potentially harmful hydro-climatic hazards. The system, called IPAWS (*Integrated Public Alert and Warning System*), enables the aggregation of such tools in a single platform. The diffusion is in application of the *Common Alerting Protocol* (CAP). IPAWS is administered by the *Federal Emergency Management Agency* (FEMA). Its activation comes exclusively from the President or the Ministry of Homeland Security (**Fig. 6**).

There are more than 8,000 sirens in USA (Stokoe, 2016; Kuligowski *et al*., 2014), deployed since the early 1900s, and they were multiplied following the entry of the country in World War II (Sorensen and Sorensen, 2000). Sirens sounded at that time almost an octave higher than their European counterparts. From the 1950s, standard signals were defined and used during the Cold War (Zunkel, 2015). In parallel, emergency services, in particular in charge of forest fire monitoring, have deployed their own tools, and alarms sound with a signal defined by the *National Fire Alarm Code* (NFPA 72).

Many cities, as in California and New England, preserved older sirens, and supplemented them with signals from church bells, megaphones, or fog horns calling for the mobilization of reservists. Sirens are tested once a month, then broadcast a first "steady tone" signal for 1 minute, followed by a minute of silence, and emit another "fast wail" signal for 1 minute. This makes it possible to check the power supply and the proper functioning of the sirens without a large number of inhabitants being likely to interpret the signal as being synonymous with a real danger or threat. In some cities, sirens are tested every weekend, every year or at specific times. These tests are defined by the local authorities. To raise awareness of the importance of this tool, especially in the case of tsunamis, the city of Honolulu created a website to "*adopt a siren"* in 2011, drawing on a previous initiative which enabled volunteer firefighters working in the city of Boston (in 2008) to know the location of fire hydrants *("Adopt a Hydrant"),* and to open them quickly if needed.

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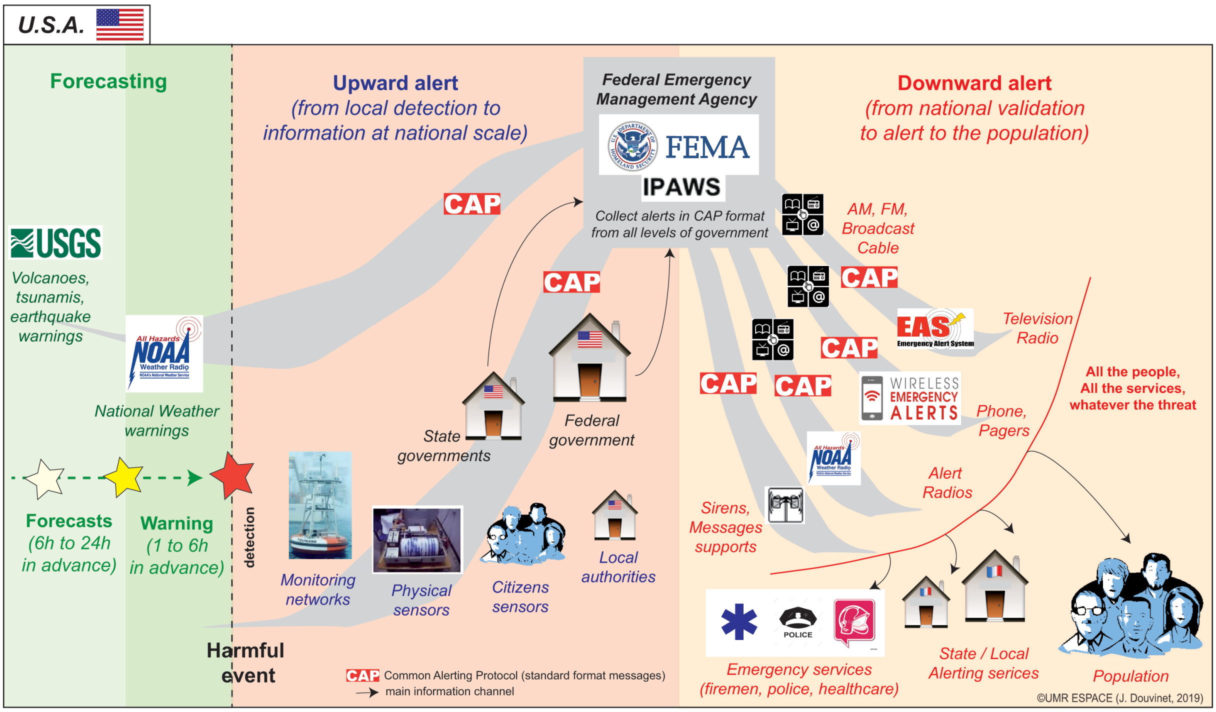

Figure 6: Place of the sirens in IPAWS: a tool among others in the USA.

The sirens can be used by local authorities or by each state, and alarms can vary from one region to another. In general, the two best-known tones refer to a danger ("steady tone") or an air threat (fast wail), but other sounds can be emitted, like for example Westminster's chimes (used for tests). Each state can use sirens differently, depending on the hazards: for example, in the Midwest, sirens sound when there is a risk of tornadoes (Kuligowski *et al.,* 2014), and alert in a 5 km radius around nuclear facilities. On the East Coast, they are more used in the event of hurricanes, like in August 2017 during the passage of Harvey. In Pierce County or Washington State, sirens along the Puyallup and Carbon valleys are triggered if there is a risk of volcanic eruptions or lahars from Mount Rainier (Sorensen, 2000).

4.2 Removing sirens by royal decision: the example of Belgium

The example of Belgium confirms that alerting decision-making is political. In this country, the alert sent to the population depends on the responsibility of authorities (mayors, governors, minister). This has been legally established through the missions of *Discipline 5*, as recalled in paragraph 1, Article 14, of the 16th February 2006 *Act on Emergency Plans and Emergency Response*. However, the operationalization of the alert is envisaged in a more global way, with a set of missions executed by other actors (such as the media or highway services), as set out in Annex D5 of the ministerial circular NPU-4.S. Several channels can be also used in parallel: sirens, police cars with loudspeakers, or highway signs managed by the PEREX *Center and Vlaams Verkeerscentrum* (IBZ, 2017). After the law on civil security and crisis planning (1963), several sirens had

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been deployed in risk areas, especially around plants that could generate significant industrial risks (in Seveso high threshold for example), and correlated to nuclear activities or weapons (Doel, Mol-Dessel, Tihange, Fleurus, Chooz in France, or at Borssele in the Netherlands). The NBC risk had conditioned the distribution of the 560 sirens that existed until 2016 throughout the country, which were managed by the *Alert Service of the Interior*. Prior to 2016, the sirens were tested every first Thursday of every quarter, with the general public, and operated between 11:45 and 13:15. At the time of the test, the siren was played a modulated sound, repeated after a 5-second interruption. A spoken message ("Test Signal") was then broadcast through the siren loudspeakers (**Fig. 7**).

But following attacks in Brussels on March 22nd 2016, the federal authorities decided to remove sirens due to numerous limitations (IBZ, 2017). These tools remained inefficient (with a signal misunderstood by the population), inaudible (the sound was no longer heard beyond a 1.5 km radius), and technically and humanly expensive to maintain. The tests produced effects of stress and panic, rather than reactivity on the part of the inhabitants. The alarm was also no longer adapted to the evolutions of the modern urban environment, nor to the increase in ambient noise (outside) in the dense urban areas. Materials used to insulate houses reducing the propagation of the indoor sound strongly reduce alarm diffusion (Zunkel, 2015). There was also no multi-hazard alert, and domino effects were also rarely taken into account (IBZ, 2017).

As a consequence, the sirens were abandoned at the end of 2016 and their dismantling was completed in January 2019. Instead of the sirens, the federal government decided to deploy a single system, *Be-Alert*©, which the *Center of Crisis Management* had started testing in 2011. From 2013 to 2015, this pilot project was evaluated in 33 municipalities. The tests rendered it possible to meet the demands of local bodies, by giving them access to an easy interface, and to send an alert in less than 30 seconds. Other avenues of improvement were incorporated after two further experimental years, resulting in a powerful tool for services operating in the field of civil security. Since June 13th 2017, *Be-Alert*© has been operational. A December 24th 2017 royal decree ended the agreement with the *National Institute of Telecommunications* to integrate the main operators (Proxima®, Télémet® and Orange®) in Belgium. These operators remain the owners of their infrastructures. But they broadcast a warning message or alerts if the *Center of Crisis Management* asks them to do so. 200 municipalities had registered by 2019, with a fee of 1,100 euros per year. The *Center of Crisis Management* finances operators depending on the number of messages (9,500 euros for 100,000 calls) and on the number of alerts. Thanks to the detection of SIM cards located near telecommunications antennas, the *Be-Alert*© system covered 67 % of inhabitants in 2017, and currently covers more than 84 % in 2019. In a danger situation, SMS (100/s), telephone calls (600/s), and e-mails (up to 10,000/s) can be sent simultaneously. In addition, a convention has been signed with the three main social networks (*What'sApp©, Twitter©, Instagram©)* to multiply the channels. In September 2019, the *Twitter*© account of the *Crisis Management Center* (@Crisiscenter BE) had reached more than 130,000 subscribers (1.1 % of the population). 3,227 tweets were sent from June 2014 to May 2018, on different emergencies situations. Exercises involving the population are carried out to explain and communicate the system, like that realized on June 30th, 2017 during the festival *Rock Werchter* in Rotselaar (40,000 calls were received by 44,000 festival-goers). All these simulation exercises validate the internal effectiveness of the system, and raise public awareness.

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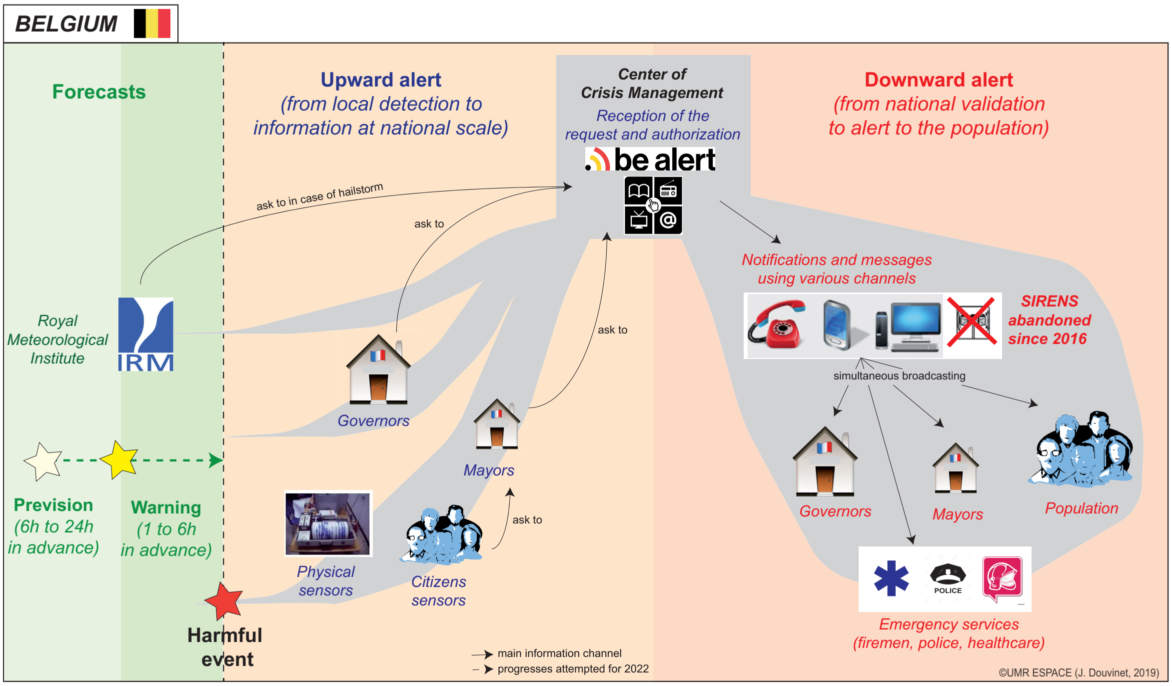

Figure 7: The alerting process in Belgium structured around the single *Be-alert* system.

5 Discussions

There is a little need to further describe and study alerting changes in other countries. Looking at the choices made in Belgium and the USA, a few options should be considered to reduce the time for the activation of sirens, and to propose three main changes in France. First, the regulatory framework should be strongly relaxed. The alert activation should be entrusted to other stakeholders or services involved daily (like in the USA), especially because they can assume this responsibility as well as the French Ministry of the Interior can. The alert diffusion could be public (firefighters in the event of fire, or flood forecasting services in the event of flash floods) or private (many providers nowadays sell alerts to municipalities). As envisaged by the SAIP project, the firefighting services should be able to request siren activation in the future. Overall, the number of authorized people or persons should be increased, in order to improve responsiveness and to reduce activation and/or reaction time.

Second, the services in charge of the forecasting and the detection of hazards should work together, with a multi-hazard and multi-channel system. Their reactivity depends on the risks involved, and on the detection period for the hazards, but also on the availability of tools, and the time before the first impact. Schematically, earthquakes require automated systems since the alerting time is limited to a few seconds, or even a few hundredths of a second, whereas tornadoes or flash floods occur in a few hours. When the latter are forecast, various services can anticipate the event and it would be appropriate to activate the alert from the moment the triggering thresholds are exceeded. This solution should give time for protective measures to be

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implemented. Actually, the authorities prefer not to activate alerts as they are afraid of the people's behavior, whereas if the population is trained, the sirens could have a real utility.

Third, it would be necessary to create a single platform to improve the coordination between services, and to federate their specific competences. However, for this to occur, France must stop multiplying the number of services, operating differently depending on the type of danger or threat. At present, CENALT *(National Tsunami Warning Center)* forecasts tsunamis, CSEM (*Euro-Mediterranean Seismological Center*) monitors earthquakes, and SCHAPI (*Central Service of Hydrometeorology and Flood Forecasting*) is responsible for flood vigilance, for example. If emergency call platforms are beginning to be shared, like those centralizing the 15, 17, and 18 calls within Greater Paris, we must go much further in this inter-service logic and promulgate, as discussed, the single 112 call number at the European scale.

In addition, a certain number of guidelines (**Table 4**) are critical for the improvement of sirens alerts in France. Some are already integrated in some international standards, in the *Common Alerting Protocol* (CAP) or in the *Early Warning System Monitoring* (EWSM), but not yet applied in France. Three principles must be respected to create a more effective alert system: **(1)** be coherent in the diffusion of messages, and not to leave areas of shadow; **(2)** have competent services confirm weak signals, announcing the beginning of an emergency situation, and relay precise and complete information on a larger scale without making assumptions; **(3)** use common references to communicate with the public (Matveeva 2006).

Major guidelines	**Advantages and desired outcomes**	**References**
Create an interoperable offer	Favour interactions between technologies and the targets	Landwehr *et al.,* 2016
Coordinate the offer	Compensate for inadequacies of each solution used in isolation	IPAWS, 2006
Design a single platform piloted by a single manager	Avoid multiplying alert tools and centralize the entire offer	Sorensen et Sorensen, 2000
Send single messages	Avoid contradictory or different messages depending on the services, to reduce uncertainties and hesitations	IBZ, 2017
Satisfy a multi-phenomenon logic	Be adapted to the plurality of phenomena, and take into account interactions between different types of risk	Nadim et al., 2013 ; Liu et al., 2017
Adapt the alert to space-time aspects	Target the alert in time and in space, so that information reaches the right people at the right time	Reghezza-Zitt *et al.,* 2015
Define a scale of alerts depending on the phenomena	Decline the systems at different levels of observation, depending on the hazards involved and the territories under consideration	Douvinet, 2018
Define the alert timing	Modulate the alert depending on the time before the first impacts	Péroche, 2016
Define a multi-channel system	Reach a maximum of people in a short time	IPAWS, 2006 ; IBZ, 2017
Adapt the alert to the needs of the targets	Be able to respond to the evolving needs of populations, to the context, and to individuals' perception of the danger	Kouabénan, 2006 ; Weiss *et al.,* 2011

Table 4. Some guidelines for improving the efficiency of alerts for the population (Douvinet, 2018)

So what would the alerting system best suited to the French context be like, taking into account the fact that sirens will be maintained for a few more years? First, the activation system must be coordinated between services, with a single platform managed by a single service. Second, the alerting system must be adapted to "space-time", and be better adapted to the needs

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of an evolving population. Each tool (sirens, smartphone applications or phone calls) must be a piece of a whole, which when merged forms a coordinated system. Third, the platform needs to be created by optimizing dissemination channels and to be adapted to contexts (in terms of mitigation, risks, regulations, etc.). It must integrate suitable reactions to be prompted from the majority of people. Finally, the platform must be developed in order to ensure diffusion using short-wave radio, to overcome network congestion and to avoid the impact of a power failure. All the guidelines will then enable a new alerting platform to be designed for France (**Fig. 8**).

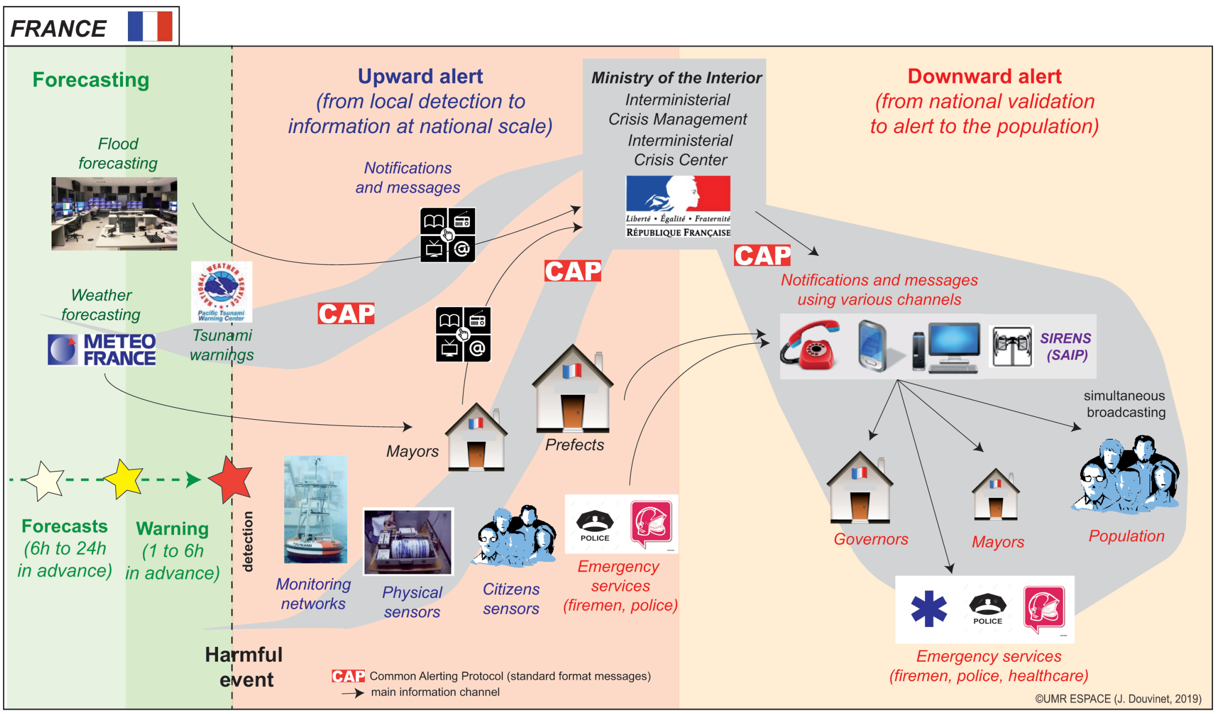

Figure 8: The ideal evolution of the alerting process in France (in comparison with the figure 1).

6 Conclusions

This study aimed to understand the reasons why sirens are the only alerting tools available in France, and why successive governments have maintained their trust in these tools since the end of World War II, despite their well-known limitations. Such a choice represents a long political tradition. On the one hand, the mayors and prefects plebiscite sirens to justify their budgets, regardless of whether they reach the audiences targeted. But it is not because tools exist that they will be used in real situations. On the other hand, the real use of sirens depends on a political decision accepted by all the stakeholders involved in the institutional chain. But the slowness of the validation process, rigidity of the administrative mechanisms, and the high number of actors involved are all obstacles to the effectiveness of sirens.

To improve the future SAIP system expected in 2024, authorities and forecasters need to work together. Important changes are expected in the technical, organizational, and contextual dimension. Challenges need to be overcome to respect the *Common Alerting Protocol* (CAP) and in the next few years, France also has the responsibility of creating a national SMS alerting system, to respect the December 14th 2018 European Decree (asking all of the European members to create a national SMS alerting solution). Progress is also needed in the human and social dimension. In France, people does not know the diversity of alert channels, which increases confusion and cacophony in an emergency situation. This reinforces a "polyphony of ignorance" (Cardon, 2015). But if the population does not understand what is expected from it, the people cannot adopt appropriate reactions. It is therefore also important to include more effective tools that can complement sirens with a clear unified message. Furthermore, we must consider the alert not as a constraint, but as an opportunity to put reflex reactions into practice in a spirit of solidarity. This requires a change of posture, because in France the alert remains synonymous with a negative event and with major damage.

Code and data availability

The data are not publicly accessible because of the confidential nature of the data. The precise location of sirens is not to be disclosed for security reasons. The data were provided to us for processing at large scales (regional and national) and not to display results at fine scales. The RGDP (European Directive, applied in France since 2016 Maty 28th) also explains a restricted access to data obtained during the crisis exercice (**Fig. 5**), because of individual and personal information.

Author contribution

The contributions of all co-authors are briefly described. J. Douvinet and E. Bopp designed the experiments and realized maps and spatial analysis treatments. J. Douvinet prepared the main part of the manuscript with contributions from all co-authors, and all co-authors ensure the good quality of the paper and improve the discussions and comments.

Competing interests

The authors declare that they have no conflict of interest.

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