Case Study: The New Terminal 2E at Paris – Charles De Gaulle Airport

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I. Historical Context

This section intends to provide the reader with background and historical information about the architect of the terminal building 2E of Paris / Charles De Gaulle International Airport (CDG), as well as an overview of some of his previous works. We also describe and comment the very unique structure of the architectural firm (Aeroports de Paris Ingénierie) in charge of the project design as well as its relationship with the airport operator.

a. ADPi and Paul Andreu

Aéroports de Paris / Architects and Engineers (ADPi) is a subsidiary of Aéroports de Paris (ADP) (Paris Airports). ADP is a public establishment in charge of the planning, design and operation of the Paris region airports (mainly Paris CDG, Paris Orly and Paris Le Bourget). It handles around 70 millions passengers a year and in 2003 it had sales for over 1700 millions euros (USD $ 2,150). ADPi is an architectural firm that provides planning, architecture and engineering services for airport facilities and other large-scale public facilities: from feasibility studies and design to construction works supervision. The firm was created 50 years ago, originally as the architecture and engineering branch of Aéroports de Paris. ADPi has been a 99.9% subsidiary since 2000 and with this status it has participated autonomously or with partners in several large-scale facilities projects throughout the world (like The Grande Arche at La Défense in Paris, the new Shanghai Pudong International Airport or The National Grand Theatre of China in Beijing). The fact that an airport operator has a whole subsidiary that designs and builds other airports or large-scale facilities is rather unusual, and it contributes to the “uniqueness” of our case and its organizational implications (discussed in a forthcoming section of this report). ADPi consists of a team of 151 people, including 49 architects and 22 engineers. Paul Andreu has worked in partnerships with ADPi for many years. In particular, he has been involved since 1964 in the planning, design and construction of Paris – Charles De Gaulle International Airport. He was born in 1938 in Bordeaux in the south of France, attended Ecole Polytechnique (class of 1958), Ecole de Ponts et
Chaussées (class of 1963) and became an Architect in 1968. In France, he has received very special awards and important national decorations like the Officier de la Légion d’Honneur and the Grand Officier de l’Ordre national du Mérite. For the purposes of our analysis, it is essential to realize that with this background, in France he is considered almost like a national hero. His masterpieces are very particular: elegant and amazing structures from an architectural point of view, but often—at least when we talk about airports—not necessarily efficient and functional from an engineering point of view.

Below we show some of the previous works by Paul Andreu and ADPi:

![Figure 1: Grand National Theatre of China (Beijing Opera)](image-url)
The design of the first Terminal of Paris CDG International Airport started in 1964 and it was based on an analysis of several existing terminal concepts. The result was an attempt to combine the various advantages of designs like finger pier, satellites and linear terminals, for handling a capacity of around 8 million passengers a year with some advantages but also with several disadvantages: the only real positive characteristic of this new design was in the transfer level: it allows minimal congestion. However, the concept has several negative points: First, the Terminal is built literally IN the ground, it is surrounded by a circular concrete structure and the parking level is right above the arrivals level. The result: there is simply no way to expand this terminal and the design is no flexible at all. Furthermore, connections are not easy and walking distances are rather long. In addition to this, a passenger needs to change levels all the time to move around the airport. Finally, the Departure level is at the bottom of the building IN the ground, - several meters below the airplanes level-, therefore there is no way to have an efficient or economic baggage system: the design of the building is such that the luggage has to be moved vertically!
ese disadvantages and tried to create a more functional concept. As a result, Terminal 2A, B, C and D are almost linear buildings organized in sections along a curved road. This definitely improved the baggage handling process and shortened walking distances for connections within each building. However, there still is the problem of long walking distances for connections from one building to any of the others, and even if they implemented inter-terminal buses, they are not very efficient and they don’t run often enough. On the other hand, progressive construction of the different sections of the terminal was a positive point, since it provides flexibility in the system design.

On a final note, another positive characteristic of the whole design was the idea of having a high-speed train (TGV) station at the airport. This makes transportation to the rest of the country very easy to international passengers, since they don’t have to go downtown to catch a train. However, for the purposes of our analysis, the design of the train station itself is not necessary functional from two perspectives: First, in order to get there one has either to walk a long distance (specially from terminals 2E and 2F) or to go through the low-efficient process of taking a bus. Second, the train station building itself is probably considered very nice from an architectural point of view, with a huge glass-roof structure. Yet, from a practical perspective, it is just impossible to wash these glasses! As a result, the train station now is “in the shadow”.

c. General architectural concepts at ADP

ADP considers that Parisian airports must reflect a certain image of prestige. Consequently, it has invested a significant amount of resources in developing high-end architectural designs using the most innovative solutions. However, given the fact that ADP is a public establishment, it is regrettable that the architectural projects for the air terminals have almost always been developed exclusively by ADP’s own teams. A public contest system to allocate projects to external contractors could have stimulated innovative solutions for both high-end designs and economic proposals. The development and operating conditions of the air terminals at CDG have allowed only a very small degree of flexibility or modularity for the adaptation of the infrastructure to the evolution of traffic. In general, the ability to expand or adapt the terminals to reality was limited. Furthermore, the level of complexity reached by the flows of people within the terminal is very high, whereas ADP has always had the control of its master plan. We also found a high degree of complexity when we look at the techniques of construction used: the styles that were selected for the structures of the hall 2 F put a public institution (ADP) in a situation where, during a considerable period of time, it was not possible to determine if the project could be finalized. This situation was true not
only regarding the design (the action plan was refused by the control office), but also regarding the construction itself, since the contractor (for the construction) had serious problems during the installation of some of the pre-fabricated structures for the roof that were likely to collapse. In addition to this, the hall (2F) was conceived and built without knowing neither its future user nor the nature of the traffic that would be handled there. It was initially designed for several companies, although it was finally allocated to Air France five months before the opening. Also, the hall was originally conceived to handle Schengen traffic (internal, from only the European Union). As a result, the second finger of the terminal had to be transformed to handle a mixed national/international traffic: last-minute modifications were necessary for the aprons, the creation of controls for international traffic, commercial areas after customs, the extension of the lounges areas and the change of the baggage control system. Since the construction of the hall 2F, nevertheless, ADP seems to have become aware of certain extreme conceptions regarding the architectural design: the hall E, symmetrical of the hall F, was simplified and the projects of the future air terminals favor a linear architecture, more modular and evolutionary.

II. Why an additional Terminal?

The Parisian airports handled in 1995 over 50 million passengers. In 2000 that number increased to 73.5 million: 48.1 million by CDG and 25.4 million by Orly. This means a global annual growth of 6.1%, with a growing rate of 11.4% at CDG and a negative rate at Orly. This allowed ADP to remain among the first six airport operators of the world in terms of number of passengers. Cargo movements in Paris represent only around 5% of the total. This increase in traffic was due partially to the dynamism of the airlines, specially Air France as the main carrier in France and representing approximately half of the traffic of the Paris region. Air France made of CDG - Terminal 2 its main platform during this period. By setting up in particular the infrastructures necessary. In 2001 we observed a decrease in the traffic levels of around 3.5 %, CDG falling 0.6 % and Orly 9.6 %. This was due to the attacks of September 11, 2001 and to the financial problems of an national carrier: Air Liberté. As the reader is surely aware, to anticipate and forecast the traffic demand –and therefore the demand of airport services- in the long run is a very difficult, but fundamental exercise to
plan on issues related to an airport capacity. The existing forecast analyses for the region show an increase in the traffic during the upcoming years, although with a much smaller growth rate than the one we observed during the 1990’s. The traffic level for the Paris region might grow up to around 100 million passengers in 2010, and approximately 130 million passengers in 2020 (CDG and Orly), assuming that there are no limits in the airports capacity. However, the infrastructure development of ADP is restricted by physical (capacity of the runways and air terminals), financial, and environmental constraints and regulations.

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Surface</th>
<th>Capacity (passengers / year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDG 1</td>
<td>195,000 m²</td>
<td>9.6 million</td>
</tr>
<tr>
<td>CDG 2 – A et B</td>
<td>100,000 m²</td>
<td>10 million</td>
</tr>
<tr>
<td>CDG 2 – C et D</td>
<td>103,500 m²</td>
<td>10 million</td>
</tr>
<tr>
<td>CDG 2 – F</td>
<td>130,000 m²</td>
<td>12 million</td>
</tr>
<tr>
<td>CDG 2 – E</td>
<td>220,000 m²</td>
<td>11 million</td>
</tr>
</tbody>
</table>

The maximum (or saturation) capacity of the landside (terminal buildings) is not easy to estimate, especially because this measure only makes sense when it is done with respect to a certain level of service (length of queues, number of passengers per square meter). Considering a “normal” level of quality –according to international standards- and the current distribution of traffic in time, the capacity of CDG without Terminal 2E is around 44 million passengers in 2001. With the actual traffic level of 48 million passengers, the quality at CDG was somehow degraded, especially in air terminal CDG1. With the opening of the terminal E, the "normal" level of service capacity of CDG was intended to be around 55 million in 2005.

The table below shows the surface and the capacity of CDG Terminals 1 and 2:

As the reader can certainly observe, both the level of service and the forecasted demand at Paris CDG International Airport showed that a new terminal was necessary. That is why the construction of terminal 2E was decided. The project started in 1997 and the Terminal was open to the public in 2003. The total cost of the project was round 750 million euros, of which 50 million were provided by Air France. Some examples of projects similar in size are the Beijing Opera (400 million euros with a surface of 150,000 m²) or the Shanghai-Pudong International
Airport (510 million euros with a surface of 220,000 m² and 20 million passengers per year. It is important to note that the same architect, Paul Andreu, has been the designer of all the terminals at Paris CDG International Airport.

III. A brand new building: what went wrong?

This section provides the reader with a general perspective of the various types of issues that were involved in the accident of the Terminal 2E. In the first subsection, we present a brief description of what actually happened. In the second subsection, we analyze some of the organizational issues that probably were a determinant factor in the accident as well as the role and influence of some of the stakeholders in the events. This will lead us to a discussion about the influence of the architectural firm in the construction & supervision process, about Paul Andreu’s design ideas and about some general “cultural” elements of the French society. Finally, we describe the reaction of the ADP authorities immediately after the accident and the crisis management process.

a. What happened?

Around 7:00 am in the morning of Sunday, May 23rd 2004, six modules (ready-built concrete + external metal structure) of the roof structure of the boarding area in terminal 2E at CDG Airport collapsed for yet unknown reasons leading to the collapse of the glass structure as well as the three footbridges that linked the boarding area with the central area of the terminal to the North (called “Isthme”) and one footbridge used to board the plane to the South side of the terminal (see images below). The structure (called “Jetée” or “threw” in French) is 650m long total: a section of around 30m collapsed. Six persons died and 3 more were injured.

We present below several images and pictures to help the reader understanding what exactly happened:
Figure 5: CDG Terminals 2E (top) and 2F (bottom right of the picture).
Picture taken one day before the collapse of the structure.
Source: www.airliners.net

Figure 6a,b (above): Schematic representations of Terminal 2E (boarding area to the left of the image) and the area of the accident (in red). Source: ADP press office.
Figure 7: Schematic representation of the lateral section of the boarding area.

Figure 8a,b,c: Pictures of Terminal E: inside (before the collapse) and outside views.
b. Organizational factors & stakeholders

There have been several arguments present in most of the discussions after the accident is the high level of complexity within the design & construction process. The first element of this debate is the fact that ADP has always been both judge and jury when it comes to the design & construction of the air terminals. Usually, when the construction of a large-scale facility takes place, there is someone (a person or a company) that orders the execution of the work (“maître d’ouvrage” in French) and the one that actually executes the work (“maître d’oeuvre” in French). The first one (“maître d’ouvrage”) is the one that usually defines the “action plan” and the needs (physical requirements like surface, number of aprons, number of check-in counters, etc.), while the second one (“maître d’oeuvre”) is the one that will be in charge of the execution during the different stages of the project, he is supposed to coordinate all the different contractors and activities at the construction site, his work is supervised by the “maître d’ouvrage”. In the case of the Paris airports, ADP has always been the one that order the work and ADPi (subsidiary) has always executed the work. This may lead us to think that there was not a broad vision and an effective supervision of the project & construction site. In other countries –like the Shanghai Pudong Airport for example-, the supervision job is done by a different organization, generally a local authority or by the airport operator.

The second element of the discussions and investigations about the accident has been the huge number of stakeholders involved in the project: around 400 different firms or organizations! This is obviously a very difficult situation to manage. Even with a small number of stakeholders, a project of such scale has a high implicit degree of complexity. Thus, with 400 firms involved somehow in the construction of an air terminal the probability of a coordination error or of an individual mistake (suppliers, contractors, constructors, supervisors, etc.) is considerably high.

The third element of critique is the delays during the construction process. Although delays and politically or otherwise imposed deadlines can certainly have an impact on the quality of the work, this is a factor that we often find in projects of this magnitude and it is not unique to ADP.

Finally, probably one of the most important arguments of the discussion is the difficult and obstinate character of the architect who wants to impose his particular design shapes regardless of costs, risks and efficiency. Although it is true that the
calculations of the design of the structure were made first by ADPi then by a third party (GTM, the contractor in charge of the construction of the roof), it is also true that this is not the first time that Paul Andreu has problems with the realization of his design (not to go that far, the design of the hall 2F of the same airport had some structural problems during the construction phase, as we mentioned above). Besides, a simpler structure is obviously less risky and one has to consider the trade-off between the desire for “elegance” & “high-end” architectural designs and efficient less-risky designs.

c. Crisis management

After the accident, ADP immediately implemented a emergency plan. The terminal was evacuated and emergency services came to the site. The 3 injured persons were provided with medical care and the families of the deceased were provided with psychological attention. Both an administrative and a criminal investigation were started in order to establish the causes of the accident. Working together with the airlines, ADP reorganized all the flights to and from terminal 2E and reallocated them to other terminals. Mid-range flights were allocated to terminal 2B and long-range flights were assigned to terminals 2A, C and F. Several ADP employees from different areas of the company volunteered the following day (Monday May 24th) to assist and guide the passengers. A total of 80 employees not in duty at that time showed up between 6am and 8pm that day. Also, ADP’s website provided updated information on terminal and gate changes for the flights affected by the accident.

There was, of course, a very broad coverage of the accident by the media (TV and radio plus the main newspapers) during the whole week. A considerable amount of people discussed technical issues (possible causes), the fatalities, the traffic reorganization, etc. Generally speaking, there was a very well coordinated response/attitude from ADP executives to the media. Very few of them spoke publicly and a couple of clear & concise press releases during the week were enough to handle the “media side” of the crisis. Among the people who made public statements that week were Pierre Graff (ADP’s CEO), Paul Andreu and Hubert Fontanelle (ADPi project manager for the construction of the terminal 2E). Almost none of the 400 stakeholders made public statements after the accident (not surprising of course). The contractors are in charge of the execution of the
project (construction); some days after the accident, rumors about the causes of the collapse were heard affirming that the accident was due to errors during the construction stage and not design mistakes. This would make the contractors (and not ADPi) liable for the accident. Therefore, during the first days after the accident the contractors remained silent and left ADP to handle the media (this was actually convenient for ADP, since they could show that they were handling the crisis and they gave the impression of a very “transparent” firm). Finally, if there was an error of design, the architect is the one that is legally liable, since he signs the design plans of the building.

IV. Implications

a. Technical issues.

The commission for the administrative investigation about the events of May 23 turned in a first preliminary report on the causes of the accident on July 6th. The future of the terminal building remains unknown even if it reopened partially on July 15ht. One of the first hypotheses about the causes of the accident indicates that it is probably the perforations of the concrete “vault” (roof structure) made to install metal support parts that could have caused the collapse of the terminal 2E. This was established in a press communication released by the Ministry of Transportation, based on preliminary results of the administrative investigation. The commission is led by Jean Berthier, president of the National Council of Engineers and Scientists of France, and the preliminary analysis are based only on physical observations. Indeed, not to interfere with the criminal investigation -- and also for safety reasons--, the investigators have not examined the debris. On the other side, they were able to dismiss two hypothesis often suggested as the explanation of the accident: the first one was about landslide (the origin of the accident being the fact that the ground glided), and the second one suggested structural weakness (low-resistance material) of the posts supporting the whole building.

The actual causes of the collapse have not yet been determined. The investigators simply emitted the possibility that "the perforation could have produced a progressive degradation of the concrete". The team of Jean Berthier now will try to understand why "the accident occurred only two years and four
months after the construction was finished”. Are we talking about an increase in effort or a decrease in the resistance of materials? Did the concrete suffer from the variation in temperature day/night? These are unfortunately questions that we don’t know when (if ever) they will be answered, since the French government has no official “deadline” for the investigations.

b. Stakeholders

There will probably be consequences for most of the stakeholders involved in the project. However, the most important are for:

1.) Air France, not only because they were one of the investors in the project but of course because they were the main user of the building!
2.) Airbus and the new A380, since the new terminal 2E was able to provide services to at least two of them simultaneously. Although a new satellite (terminal S3) is currently under construction at CDG and it will be able to host several A380 simultaneously (with special footbridges that will allow passengers to enter the plane on both levels)
3.) ADP, first of all from a financial perspective (although its situation is reasonably strong thanks to a very high level of traffic at CDG during recent years) but also from an institutional / media point of view: its public image was severely damaged after the accident, nationally and internationally (and this might affect some of the many international projects that ADPi is currently undertaken: Beijing Opera, Dubai Airport, Oriental Art Center in Shanghai, Casablanca Airport in Morocco, etc.)
4.) The ADPi engineers and architects, for obvious reasons

Also, some of the publicly-traded firms that were the most affected by the accident are:

i.) Air France and the SkyTeam (the second biggest airlines partnership) members: most of the flights of these airlines operated in Terminal 2E. They had to be relocated with the consequent decrease in the level of service for the passengers.
ii.) Vinci: GTM, subsidiary of Vinci Group, was in charge of the construction of the “vault” of the terminal. It is difficult to evaluate the impact but th
ere were definitely negative repercussions.

iii.) Eiffage: its subsidiary Eiffel built all the glass structure that collapsed after the concrete structure collapsed. Eiffel is the technological leader in innovation of the group Eiffage (in charge of the renovation of Grand Palais, a Paris landmark and a National Museum).

iv.) Ginger: one of the main design & drawing firms of the project (after AD Pi)

v.) Elior: the insurance company of terminal 2E at CDG since June 2003. The contract was far from being insignificant since it represented approximately 14 M euros ($18M) per year, i.e. around 1.6% of the total income of Elior.

c. Financial repercussions

It is difficult (if not impossible) to quantify and evaluate the financial impact of the accident. Naturally, people in Paris involved in the events are unwilling to spread reports or to give information about their highly embarrassing problems. Besides, the fact that the investigations are still going on makes it even more difficult to quantify any losses, since there is no clear responsible of the accident yet, but only assumptions and hypothesis. In this subsection we can at least present an overview of the initial costs and investments made in the terminal building: Terminal 2E represented a global investment (construction plus equipment, including parking and a future automatic baggage system) of around 750 million euros ($950M). Of this amount, around 150 million euros were invested in the boarding area (the one with the roof that collapsed, called “Jetée” of around 650m long, of which 30m collapsed). The rest of the terminal (central check-in area and security filters) was partially reopened on July 15th and is currently operating. A new temporary boarding area is currently under construction and it should be operating soon (in some months from now). After reading these numbers, a not very careful reader may think that the financial impact is not that big, or that in any case it is not bigger than the initial investment. However, this is totally wrong, since the cost of the accident includes not only the initial investment potentially lost but also the cost of reconstruction, investigations & all the consequences of the accident (basically for ADP or for the stakeholder that will result accountable), and especially the cost for the airlines of operating with a low level of service, of
reallocation of gates and terminals, etc. The latter is, in the opinion of the author, the biggest cost of the accident and it is unfortunately very difficult to estimate. Nevertheless, some clarity in the numbers can be expected once the investigations will be finished.

d. Reorganization at CDG

The first operation realized in terminal 2E after the accident was to shore up the vault (the roof structure) of the boarding area. This was made with two objectives: first, to allow the investigators to work in the site without safety concerns, and second, to partially use the area. The part that was reopened in Terminal 2E is the check-in area and some of the security controls. What changed was the flow of passengers, since now they have to be transferred to the airplanes by bus, although the length of the rides to take the passengers to the plane is similar to the “normal” length in any other terminal (approximately 6 minutes).

Below we present a schematic representation of the works in progress:

![Figure 9: In red, the representation of the works to shore up the vault of the boarding area of Terminal 2E at Paris CDG International Airport.](image-url)
Terminal 2E handled around 20,000 passengers per day and this traffic was immediately transferred to the other terminals at CDG. By mid-July, ADP undertook some structural modifications to the terminals in order to get a balanced distribution of flights and traffic. Most of the flights operated by airlines members of the SkyTeam alliance (Air France, Aeromexico, CSA, Delta and Korean Airlines), all of them handling international traffic, were reallocated to Terminal 1 and Terminals 2A, 2C and 2F, since these are the terminals that have the necessary infrastructure to handle international traffic (customs, passport controls, etc.). The domestic (or Schengen) flights were transferred to the terminals 2B and 2D.

On the other side, these modifications leaded to the reallocation of other flights, since the flow of connecting passengers was then modified for some airlines like Air Canada and the Star Alliance members. These flights left terminal 2A and operate now from terminal 1 in order to minimize connection distances and times.

Terminal 3, which operates close to its saturation capacity during the weekends but not during weekdays, received some of the flights that were transferred from Terminal 2E. Terminal 3 has a mixed boarding area that allows the handling domestic and international traffic. Besides, ADP asked the Civil Aviation Authority (Direction Général de l’Aviation Civile, DGAC) to analyze the possibility of reallocating some flights or airlines from CDG to Orly.

The number of security controls was increased globally by 30%, with the goal of absorbing completely the traffic transferred from Terminal 2E. Three security controls were created in terminal 2A, four in terminal 2B (duplicating current capacity), and seven in terminal 2F and six in terminal 2D.

Also, as a result of the transfer of international traffic to terminal 2B, all of the flights operating from this terminal will be now international and the domestic flights previously operating there will be transferred to terminal 2D, which will be able to handle the new traffic thanks to an increase in the number of gates by 25%.

With the spirit of maximizing the use of resources, some of the check-in counters will be used by more than one airline, specially the ones that are members of the
same alliance. Specifically, two airlines previously using two groups of 4 counters will now share one group of 6 counters.

Finally, the last modification resulting from the accident is the creation of new boarding areas to replace the ones used in Terminal 2E. In terminal 2C a new area with the capacity to handle three large-range airplanes simultaneously was created. Also, two new temporary boarding areas in terminal 2E are under construction, assuming that there will not be safety concerns if the non-affected area of Terminal 2E is used.

V. Key learnings

This section presents the conclusions of this report in the form of a list of key learning points that the author considers to be the main lessons to remember of this case study.

- An extremely large number of stakeholders involved in the project. It is extremely difficult to deal with such a number of stakeholders (400 in this case). The degree of complexity introduced by this factor is extremely high.

- The fact that ADP has always been both judge and jury when it comes to the design & construction of the air terminals. An organization where the executor and the supervisor are two different entities has proved to be more efficient and less likely to result in quality errors.

- In large-scale projects that require more efficiency than elegant designs, working with an architect of difficult personality who wants to impose his particular designs regard less of costs, risks and efficiency may result in negative repercussions.
- For supervision and accountability purposes, it would be desirable that there was a single person or entity in charge of the project instead of having the responsibility spread among several stakeholders.

- An efficient system of accountability is necessary. The appropriate authorities must demand deadlines and concrete results of an investigation.

- From a broader perspective of society, it would be convenient to analyze how it is possible that after a record of several important failures, someone’s work can still be considered as top-quality and why he or she is still in charge of important national projects.¹

VI. Bibliography


6. www.airliners.net

¹ In the opinion of the author, results should count more than degrees or awards. In the very particular case of Mr. Andreu and the Paris Airports, we have historically observed several mistakes: a structural failure was one of the few that we had not seen prior to this accident.

8. www.adp-i.com

9. www.paul-andreu.com

10. www.proavia.com (French Airport & ATC Technology Trade Association)

11. Oral & informal written communications with Julien Siquier, Francois Consigny and Cecile Thevenin (ADPi employees or former employees) and Professor Richard de Neufville (MIT - ESD)