THE USE OF PATHFINDER AS AN EVACUATION PLANNING TOOL A CASE STUDY IN CONCERT HALLS.

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Abstract. Evacuation planning as part of fire safety management, is mandatory in Portugal for new and existing buildings. Estimating the egress time is paramount for the development of emergency evacuation plans. For this estimation, fire drills are undertaken. However, carrying out fire drills demands a certain amount of time and financial resources. In addition to that, fire drills might not be realistic for the worst case scenarios, such as having one or more exits blocked due to fires, or when other types of emergency situations are considered such as earthquakes or even terrorist attacks. For these reasons, a robust and validated People Movement (PM) model, such as Pathfinder, can be a very useful tool for emergency evacuation planning. For instance, with Pathfinder, it is possible to evaluate many combinations simulating various situations. In this paper, the two major concert hall theaters in Porto, Portugal, are used as case studies: Casa da Música and Coliseu Porto. Using Pathfinder it was possible to represent different scenarios, estimate egress times in a set of combinations with all or part of the exits available. This paper presents some simulations using Pathfinder and compares their results with the times of real egress video camera footage. Therefore, it was possible to assess the simulation tool, evaluating the results and calibrating with the real data in a variety of situations and occupations.

Keywords: Pathfinder; Emergency Evacuation Planning; Egress Times; Fire Drills; Simulations; Concert Halls.

1. INTRODUCTION

As part of any adequate fire safety management for existing buildings, the assessment of the means of escape, which includes the time the occupants will take to

reach a place of relative safety, is paramount. With this assessment, emergency evacuation plans are developed. For this, fire drills are undertaken.

However, carrying out fire drills often can demand certain amount of time in organizing and conducting them, which can have negative impact in both aspects: on the business continuity and wellbeing. In addition to that, fire drills might not be realistic for the worst case scenarios, such as having one or more exits blocked due to fires. Indeed, the challenge increases when other types of emergency situations are considered, either natural or non-natural, such as earthquakes or even terrorist attacks.

For these reasons, a robust and validated People Movement (PM) model, such as Pathfinder, when appropriately used can be a very useful tool for emergency evacuation planning. For instance, with Pathfinder, it is possible to evaluate many combinations in a short time, simulating various situations (i.e, fire risk scenarios).

In this paper, the two major concert hall theaters in Porto, Portugal, are used as case studies, namely: Casa da Música (by renown Pritzker winner architect Rem Koolhaas, 2005) and Coliseu Porto (a classic building from 1940). Both can hold many hundred spectators. For instance, Casa da Música can accommodate near 1250 persons, while Coliseu Porto around 3500 people. By using Pathfinder it was possible to represent different (fire risk) scenarios, for estimating egress times in a set of combinations with all or part of the exits available. This allowed the emergency management team to prepare and train the evacuation personnel.

This paper presents some simulations using Pathfinder and compares their results with the times of real egress video camera footage. Therefore, with this, it was possible to assess the simulation tool, evaluating the results and calibrating with the real data in a variety of situations and occupations.

2. USING PATHFINDER AS AN EVACUATION PLANNING TOOL

Pathfinder can be used as an evacuation planning tool for assisting emergency planners on assessing the egress time(s) in different scenarios, without the need of conducting real scale evacuation fire drills. Using the Pathfinder, after having the scenario built up within the model it was easily possible to change the exits' availability during the simulations. For instance, to consider a blocked exit in order to see the impact on the egress.

Another aspect which is relevant to be mentioned is related to the population density within the built environment. Although typically the worse scenario is used, that is, with full capacity, it is possible to try different layouts and space usage, to evaluate/predict the building occupants' behavior in such conditions. This is of great importance for all involved in planning, specially regarding auditoriums that can hold a great number of persons.

Therefore, in order to use Pathfinder as a simulation tool, it is required to calibrate the model. As such, in this paper, we present two case studies, where real times were compared with the Pathfinder estimated egress times.

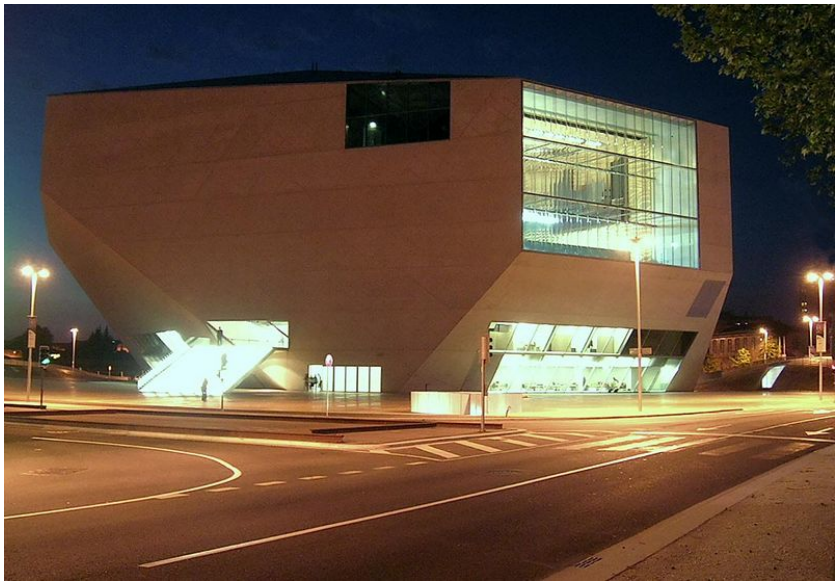

Figure 1. Casa da Música: external view

In both examples presented, the model was put up by using a two dimensional emergency plan image imported into Pathfinder. After having the scale calibrated, some core-parameters were established, such as: the areas where the building occupants were considered to be placed, the location of the exits and the exit paths. When there are seats, each one was plotted and put in place.

3. CASE STUDY: CASA DA MÚSICA

Casa da Música is a modern concert hall designed by architect Rem Koolhaas and opened in 2005. There are two Auditoriums, the main one is named "Sala Suggia", as an homage to Guillermina Suggia, Porto's native world class cellist, having a top capacity of 1244 places. The other Auditorium, "Sala 2" can receive up to 250 persons seated or 650 standing.

3.1. Casa da Música: Sala Suggia

As mentioned previously, the main Auditorium of Casa da Música, "Sala Suggia", has a full capacity of 1,244 people, but it can vary according the layout used. For example, without the choir places, located at the back of the stage, the audience is limited to 1,069 seats. Total area is around 1,100 square meters.
Table 1 shows a comparison between real egress times of the public leaving the audience towards the outside and those egress times obtained using Pathfinder. The real egress time was obtained by visioning the internal video surveillance footage (i.e., Closed-Circuit Television: CCTV). It should be noticed that many of the spectators left the room slowly as they were chatting with some colleagues.

Figure 2. Casa da Música: Sala Suggia parcial view

Date	Event	Audience	Real Time	Pathfinder
10.04.2016	NOS Club	1000	04:33	02:42
12.04.2016	Piano concert	738	04:05	01:50
17.04.2016	Classic Orchestra	900	05:55	02:21
16.04.2016	Vozes da radio	1000	07:07	02:42
17.04.2016	Choirs - Voice	638	04:10	01:34

Table 1. Comparison between real times and Pathfinder - Sala Suggia

Furthermore, this condition, is very likely to have increased substantially the overall egress time than expected in a real emergency situation. Nevertheless, the values in the table can be used as benchmark for calibrating the model.

The Pathfinder model is shown in figure 3. Each seat row was plotted and put in location, having people assigned up to the maximum number of seats. The only way out for each seat row is at each end. With this, it was not possible to have agents (i.e., the representation of the building occupants) going over seats or surpassing other agents.

Figure 4 shows a snapshot of the simulation process, having only the usual 4 exits, left and right, and the rear emergency exits closed (red rectangle). This represents the layout used to collect data shown at table 1.

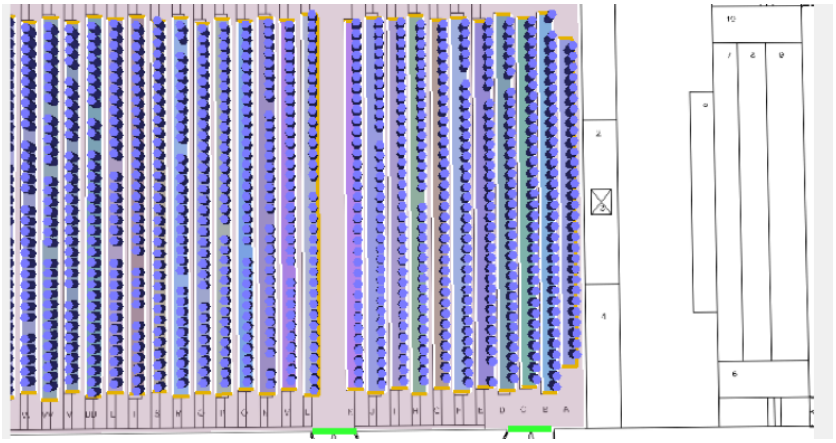

Figure 3. Sala Suggia Pathfinder model

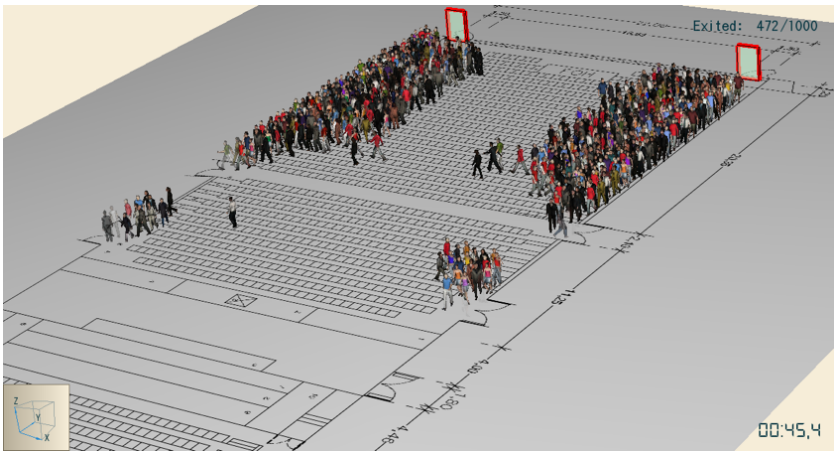

Figure 4. Sala Suggia Pathfinder model during simulation process

Figure 5. Casa da Música: Sala 2 parcial view with seats

Date	Event	Audience	Real Time	Pathfinder
11.04.2016	Passaro e Fogo	211	04:00	02:42
14.04.2016	Legendary Tiger Man	638	07:47	03:44

Table 2. Comparison between real times and Pathfinder - Sala 2

3.2. Casa da Música: Sala 2

Sala 2 is the second largest auditorium of Casa da Música. It was designed as a multipurpose space and, therefore, it is ideal for any type of event. The access is made through two glass and aluminum doors, integrated into the partition panels of the foyer. These ports slide, assisted by a lower engine, and have a safety opening system from the inside. The chairs, in purple tone, are an elegant tribute to the Portuguese designer Daciano da Costa, author of this model in the70's. It has capacity for 250 people seated or 650 standing, although in the former, including the foyer. Total area is around 320 square meters.
Table 2 presents two concerts held in April, one with 211 people seated and the other, a rock concert with 638 spectators standing. Similarly to the table 1, real time was computed by visioning CCTV footage. It was noticed that many of spectators left slowly, taking longer than what they would probably take during a real emergency situation.

Figure 6 shows a snapshot of the simulation process, having only the usual 2 exits, left and right, at the bottom of the auditorium. The emergency exit located at the left (when looking towards the stage) is close. This is represented in the model with a red line. This scenario is compliant with the layout of the concerts shown at table 2.

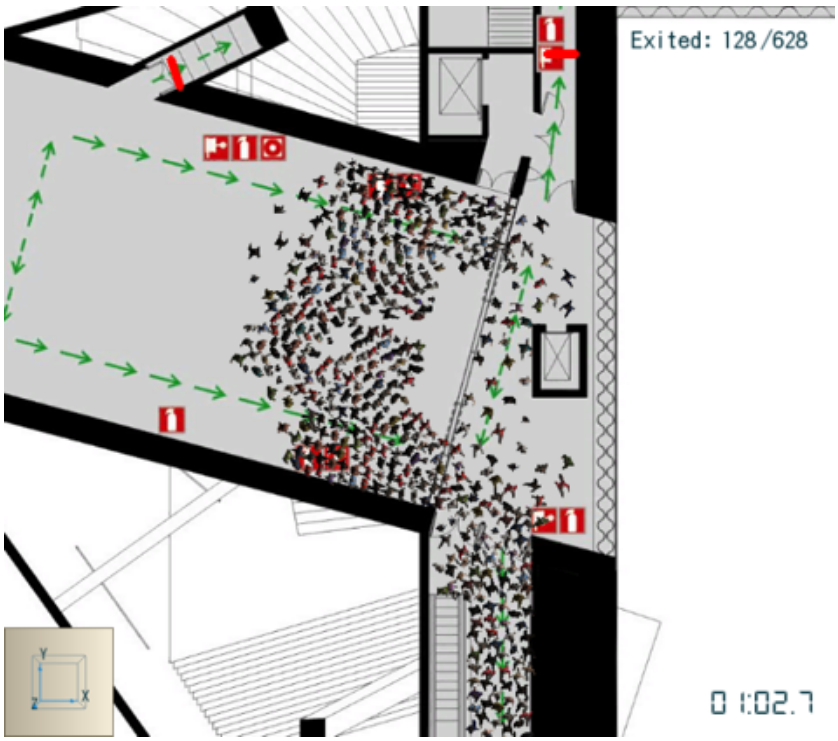

Figure 6. 2D Pathfinder snapshot showing egress with the emergency exit closed (red line)

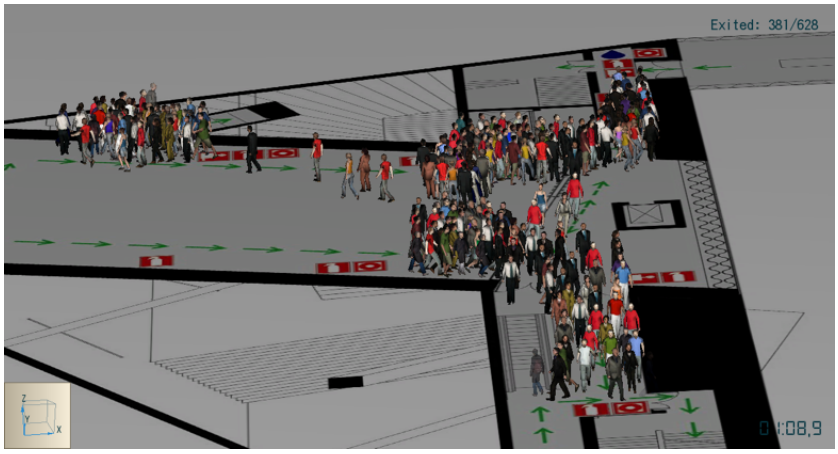

Figure 7. 3D Pathfinder simulation snapshot showing the emergency exit near the stage open

The Pathfinder tool can be used to estimate the improvement when opening an emergency exit might have in the total egress time. Figure 7 shows the same situation presented before in figure 6, this time having the emergency exit, near the stage, open.

4. CASE STUDY: COLISEU DO PORTO

The Coliseu do Porto is a theater in Porto, Portugal. A local landmark which is a leading venue for music and cultural events. The building was finished in 1941 having the architect Cassiano Branco, among others prior to him, to complete the whole project.

In the 1990s two important events marked the history of the venue. In 1995, the building was nearly sold to a Brazilian Church (Universal Church of the Kingdom of God). However, a mass demonstration of the people of Porto, promoted by several prominent members of the Portuguese and, especially, the city's cultural milieu sparked an intervention that prevented the deal to take place. The venue was handed over to a group of citizens that, still today, manages the Coliseu as a cultural venue.

In 1996, a fire destroyed part of the venue, including the stage, the back-stage and part of the auditorium. Rebuilt over a very short period, it showed some limitations and the venue suffered new interventions in 1997 and 1998. It was officially reopened in November 1998, about two years after the fire, and has since then regained its role as one of Porto's most dynamic cultural spots.

The main auditorium of Coliseu Porto has a capacity for 3,500 people standing and 2,955 seated when we count the first and second stalls, the dress circle, the boxes, the upper circle and the reserved and general gallery.

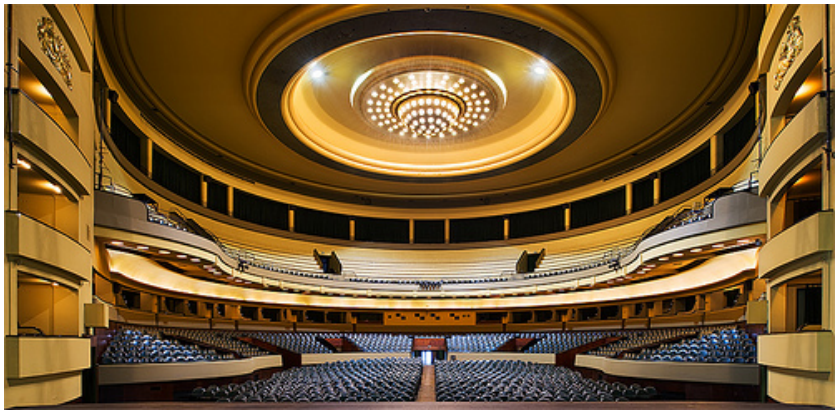

Figure 8. Coliseu Porto: view of the concert hall from the stage

Concerts with full capacity will have the seats removed and people standing at the parterre. In June this year, Jeremy Clementine concert filled up almost completely the Coliseu. The real egress time was around 8,5 minutes. Since there is no CCTV inside the main auditorium, times were estimated using a stopwatch.

The Pathfinder model that was developed considered two scenarios: 1,394 people standing at the parterre, the official maximum capacity, and 1,894 people, an additional 500 spectators. This is part of a process to increase the number of people at the parterre in the standing audience scenario.

In both, total estimated egress times were under 4 minutes, indeed, the 1,394 people scenario was just below 3 minutes.

Figure 9 presents a snapshot of the simulation process, showing the Pathfinder 3D view rendering, for the 1,394 standing spectators scenario.

When comparing those times with the Jeremy Clementine's concert, it must be noticed that the Pathfinder model only has a fraction of the spectators, namely those standing at the parterre. Nevertheless, after the end of the concert, most of spectators left the main auditorium in less than three minutes. This same situation was observed in several concerts afterwards. So, the estimated time by Pathfinder is a realistic one. This shows it can be used for testing some more complex scenarios, such as having one or more blocked exits and estimating the egress times in those scenarios.

Figure 10 shows how spectators are distributed during the egress timeline. Interestingly, the number of egressing spectators at the circular corridor around the main auditorium ("Ferradura", horseshoe in Portuguese) is never more than roughly two hundred at any given time. This in an interesting aspect, showing that the flow capacity of that corridor is well dimensioned so as to avoid bottlenecks.

Further improvements to the models are needed, including adding the second stall, the dress circle, the boxes, and upper circles. And more data on real

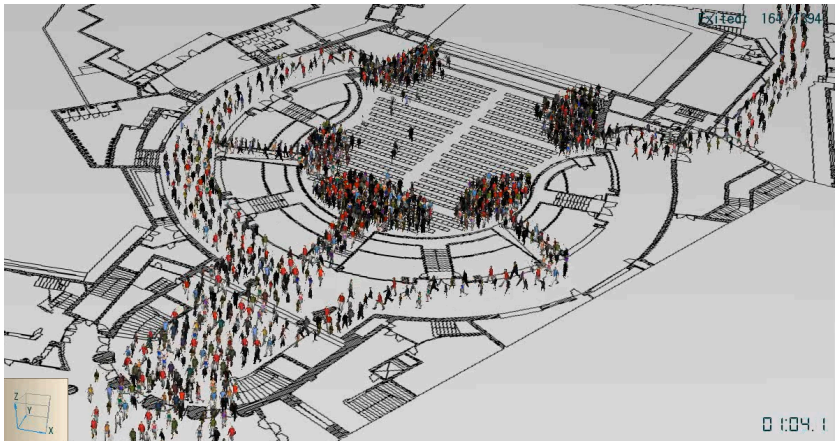

Figure 9. Pathfinder 3D rendering of Coliseu Porto egress with 1,394 standing spectators

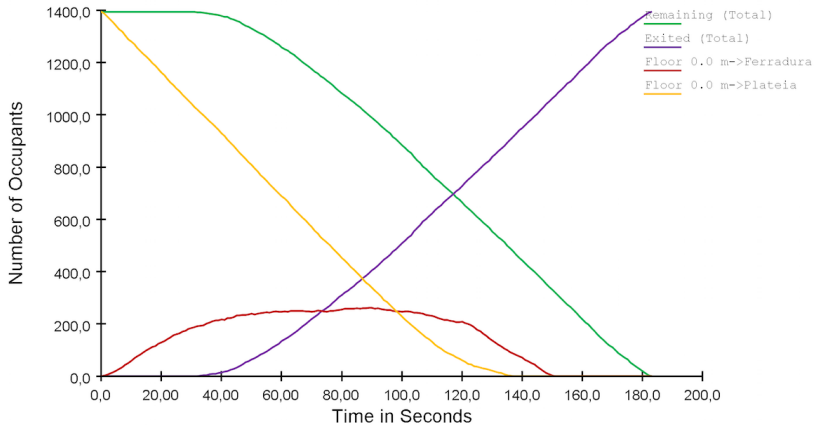

Figure 10. Pathfinder number of spectators during egress per location

egressing times, in order to make more precise comparisons and calibrate the model.

The preliminary results are encouraging, allowing managers to better understand the dynamics of people movement, and realize the egress times. With a proper model put up and more reliable data, it will be possible to perform more experiments and possibly acquire valuable information to validate or improve the existing emergency proceedings.

5. CONCLUSIONS AND FUTURE WORK

As shown in both examples, Pathfinder can be a useful tool to estimate egress times, even if they are considering ideal (fire risk) scenarios as safety margins can be used to balance this aspect; and to evaluate other options, such as opening an extra emergency exit.

The two case studies presented were developed using a test version of Pathfinder, without having much detail and optimization of all core parameters. The experiments made were only mere preliminary tests to evaluate the tool and prove its application as a valuable aid for the emergency planner and the safety manager. Pathfinder simulations can be expanded to increase the number of possibilities and scenarios. For instance, to test a blocked exit, by fire or another event, such as a terrorist attack or simply a riot and/or conflicts amongst the spectators.

The aforementioned examples are among the ways to extend the work presented and stem other research, exploring the Pathfinder possibilities to its limit.

It is expected that through the case studies shown in this paper, some additional light can be brought in how evacuation plans can be developed and assessed as part of the whole fire safety management package, having the particular context of the Portuguese building facilities management as an example. It is also expected that further work and research can be developed exploring the Pathfinder capabilities for this type of real application.

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