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COMPUTATIONAL SIMULATION OF THE KISS NIGHTCLUB FIRE: IMPACT OF EMERGENCY EXIT WIDTH ON EVACUATION SAFETY

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Major fire disasters highlight the decisive role of evacuation route design. The Kiss Nightclub fire (Santa Maria, Brazil, 2013), which resulted in 242 deaths, demonstrates how bottlenecks and insufficient exit capacity can critically affect outcomes. This study applies computational evacuation modeling using the Fuga v.2.0 program to simulate parametric evacuation scenarios of the nightclub, testing simplified layouts and different exit widths. A simulated population of 1,000 agents was considered, incorporating discretized anthropometric body sizes, random initial positions, and realistic movement parameters. Results indicate that even compliance with the 4.4 m minimum exit width prescribed by ABNT NBR 9077:1993 would not have ensured safe evacuation under the conditions of the tragedy. Simulations show that an exit width on the order of 8.8 m would have been required for the Required Safe Egress Time (*RSET*) to approach the Available Safe Egress Time (*ASET*), estimated between 1 and 2 minutes due to rapid smoke development. Furthermore, internal barriers reduced the effective width to approximately 1.65 m, producing *RSET* values up to five times greater than the reference *ASET*. These findings highlight the relevance of performance-based assessment and computational evacuation modeling as complementary tools for evaluating evacuation safety in complex building configurations.

Keywords:Fire evacuation; Emergency exits; Computational simulation; KissNightclub fire; ABNT NBR 9077.

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SIMULAÇÃO COMPUTACIONAL DO INCÊNDIO DA BOATE KISS: IMPACTO DA LARGURA DAS SAÍDAS DE EMERGÊNCIA NA SEGURANÇA DA EVACUAÇÃO

RESUMO

Grandes desastres relacionados a incêndios evidenciam o papel decisivo do dimensionamento das rotas de evacuação. O incêndio da Boate Kiss (Santa Maria, Brasil, 2013), que resultou em 242 mortes, demonstra como gargalos e capacidade insuficiente de saída podem comprometer criticamente os desfechos. Este estudo aplica modelagem computacional de evacuação utilizando o programa Fuga v.2.0 para simular cenários da casa noturna, testando configurações simplificadas e diferentes larguras de saída. Foi considerada uma população simulada de 1.000 agentes com perfis antropométricos discretizados e posições iniciais aleatórias. Os resultados indicam que mesmo a conformidade com a largura mínima de saída de 4,4 m prescrita pela ABNT NBR 9077:1993 não teria garantido evacuação segura nas condições da tragédia. As simulações indicam que seria necessária uma largura mínima da ordem de 8,8 m para que o Tempo Necessário para Evacuação Segura (*RSET*) se aproximasse do Tempo Disponível para Evacuação Segura (*ASET*), estimado entre 1 e 2 minutos devido à rápida formação de fumaça. Além disso, barreiras internas reduziram a largura efetiva para cerca de 1,65 m, produzindo valores de *RSET* até cinco vezes superiores ao *ASET*. Esses resultados destacam a relevância da avaliação baseada em desempenho e da modelagem computacional como ferramentas complementares para a análise da segurança de evacuação em configurações complexas de edificações.

Palavras-chave: Evacuação em incêndios; Saídas de emergência; Simulação computacional; Incêndio da Boate Kiss; ABNT NBR 9077.

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1- INTRODUCTION

Major fire disasters often result from the convergence of multiple adverse factors, many of them underestimated by those responsible for the built environment. For various reasons, including statistical probability, such factors may align and lead to large-scale fires and severe tragedies, with material and human losses that frequently astonish both decision makers who minimized their likelihood and society as a whole.

Although each major fire tends to have unique characteristics, they also share recurrent patterns that can usually be identified. Among the most critical of these patterns is the design and adequacy of evacuation conditions, particularly the provision of escape routes and emergency exits. This aspect plays a decisive role in the conception, planning, and approval of safe buildings.

As a result, and reinforced by lessons learned from past disasters, building codes and fire safety regulations have for decades established parameters for the proper design of escape routes and emergency exits. These guidelines consider essential factors such as type of occupancy, number of occupants, built area, and building height.

The Kiss Nightclub fire (Boate Kiss – Santa Maria-RS, Brazil, 2013) is a tragic and emblematic case that illustrates the importance of proper evacuation conditions. The event has been documented both in technical investigations and in social or detailed journalistic reconstructions (e.g., Arbex, 2018; McCann, Victora, 2023), which portray the human and social dimensions of the tragedy. Multiple contributing factors led to its catastrophic scale, resulting in 242 deaths (Braga; Moita, 2017; Machado; Bem, 2025), but the difficulty of evacuation had a decisive impact.

This study aims to demonstrate, through computational evacuation modeling, how the width of emergency exits influences evacuation time,

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considering the actual layout of the Kiss Nightclub near its main exit, as well as to estimate the minimum width required to avoid a tragedy of such magnitude. As a contribution, the results are expected to provide relevant findings for advancing discussions on this topic and to support improvements in Brazilian emergency exit regulations, fostering safer design and planning of built environments.

2- BACKGROUND

2.1-The Kiss Nightclub Fire

The Kiss Nightclub fire began with the use of a high-temperature pyrotechnic device, prohibited in enclosed spaces. The device was ignited by a member of the band performing at the time and struck the flammable acoustic foam lining the ceiling. As the material burned, it released large amounts of toxic gases, leading victims to asphyxiation and poisoning. Similar factors had already caused previous tragedies and, unfortunately, continue to do so, as exemplified by the recent nightclub fire in Kočani - North Macedonia, 2025 (Testorides, Grdanoski, 2025).

Investigations (Arigony*et al*., 2013; Silva *et al*., 2013; Trevisan; Jesus, 2013; Rabello Sodré, 2024) indicated that, in the case of the Kiss Nightclub, risks had been underestimated by different actors: managers, users, and public authorities. The following aspects stand out:

1. **Managers** – implemented significant changes to the environment, including modifications to escape routes and evacuation flows, in addition to using inadequate finishing materials that differed from those specified in the original design submitted to the Fire Department. Many of

these alterations were carried out without prior approval from the competent regulatory agencies.

2. **Users** – a member of the band used a low-cost pyrotechnic device prohibited indoors, which significantly increased the probability of ignition.
3. **Public authorities** – the nightclub operated without the required license, in a context where, at the time, the State of Rio Grande do Sul had excessively relaxed procedures for issuing the Fire Department Safety Inspection Certificate (*Auto de Vistoria do Corpo de Bombeiros* – AVCB), thereby facilitating the approval of buildings.

Although each Brazilian state has its own legislation regarding the design of escape routes, the national regulatory framework is provided by the Brazilian Association of Technical Standards (*Associação Brasileira de Normas Técnicas* – ABNT), particularly through ABNT NBR 9077 (ABNT, 1993; amended in 2001; revised in 2025). The 2025 edition formally cancels and replaces previous versions; however, the analysis conducted in this study is based on the version in force at the time of the Kiss Nightclub fire (1993, with the 2001 amendment).

Although the standard does not explicitly address cognitive and psychological aspects related to human perception and response (Braga; Moita, 2023), it establishes the minimum physical safety requirements for building evacuation. In parallel, international standards such as National Fire Protection Association- NFPA 101 – Life Safety Code (NFPA, 2018) adopt comparable principles, reinforcing the global relevance of egress design criteria.

2.2- Definition of Emergency Exit – NBR 9077

For the purposes of this study, the conceptual definition of emergency exit follows NBR 9077 (ABNT, 1993, p. 4):

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> **3.48 – Emergency exit, exit route, or exit**
> "A continuous path, properly protected, provided by doors, corridors, lobbies, exterior passageways, balconies, vestibules, stairways, ramps, or other exit devices or their combinations, to be traversed by the user, in case of fire, from any point of the building until reaching the public way or an open space, protected from fire, in communication with the street." (free translation).

NBR 9077 (ABNT, 1993) treats the terms "emergency exit," "exit route," and "exit" as conceptually equivalent, emphasizing the continuity of a protected path leading to a place of safety.

By contrast, NFPA 101 – Life Safety Code (NFPA, 2018) adopts a segmented structure for means of egress, distinguishing between exit access, exit, and exit discharge. This conceptual separation reinforces the structural independence of each component of the escape system and provides a more granular analytical framework.

Although both standards formally aim to ensure safe evacuation, they differ in their degree of conceptual segmentation and prescriptive detail, as well as in the balance adopted between safety requirements and practical design considerations.

2.3- Safe evacuation time

The time required for the safe evacuation of occupants is one of the central parameters in building fire risk analysis. For this evaluation, the classical concepts of ***ASET*** (Available Safe Egress Time) and ***RSET*** (Required Safe Egress Time) are widely employed in fire safety studies (Kinateder*et al*., 2015; Schröder, 2016).

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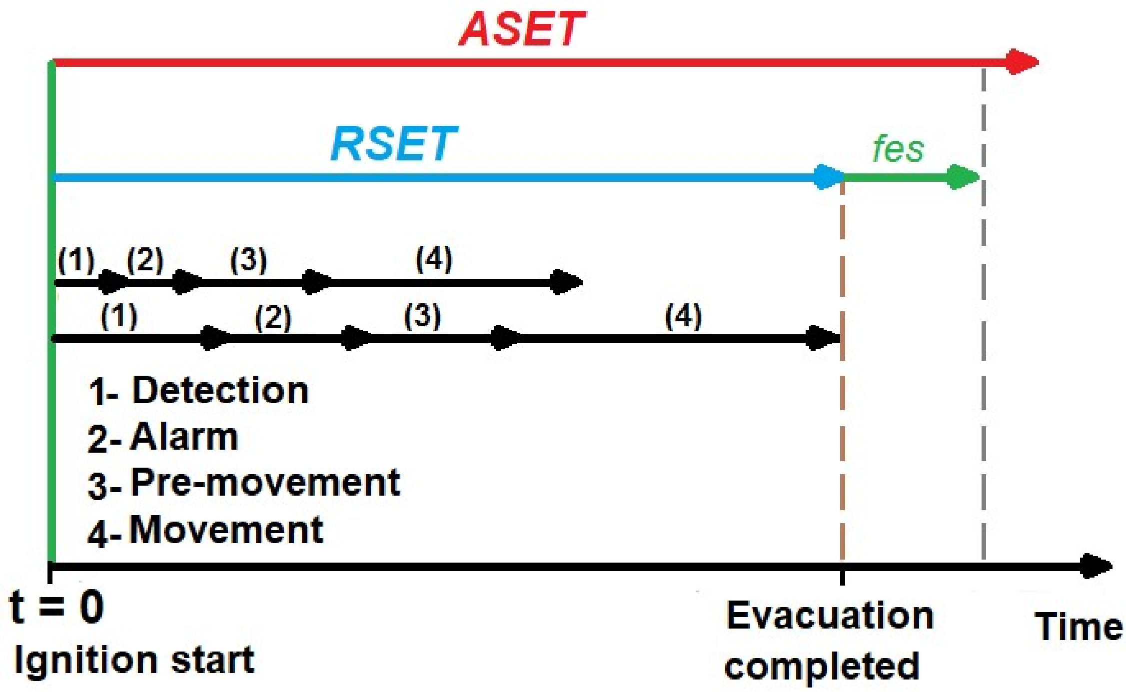
ASET represents the available time before environmental conditions become critical, whereas *RSET* refers to the time required for occupants to detect the fire, cognitively process the situation, respond to the alarm (when present), and move to a safe exit.

To ensure safety, it is a necessary condition that *ASET* exceeds *RSET*. In practical terms, this relationship can be expressed by Equation (1), where *fes* is an empirical safety factor (Schröder, 2016):

$$ASET > (RSET + fes) \quad (1)$$

Figure 1 illustrates this relationship between *ASET* and *RSET*, also outlining schematically the main phases of the evacuation process(detection, alarm, pre-movement, and movement itself) which directly influence the total evacuation time.

Figure 1- Conceptual representation of the relationship between Available Safe Egress Time (*ASET*) and Required Safe Egress Time (*RSET*).



Source: Adapted from Schröder (2016).

3- METHODOLOGY

Computational simulation in the field of fire safety has become increasingly relevant, as it enables verification and analysis that complement technical knowledge and support decision-making (Pan *et al*., 2007; Uliana *et al*., 2022; Kinkel *et al*., 2025). In this context, a computational model of the evacuation process at the Kiss Nightclub was developed, with the aim of providing well-founded and contextualized insights for the discussion of issues related to the sizing of emergency exits.

The study was carried out through computational experiments using the Fuga v. 2.0 program. This software, developed in Python, simulates human movement in building evacuation scenarios. Its modular architecture consists of a core module, responsible for generating the environment and calculating optimal routes, and a dynamic module dedicated to agent movement. In this stage, movement is represented through the incorporation of ergonomic parameters such as anthropometry, rotation, translation, and walking speed. The program also allows real-time path adjustment using fuzzy logic, enabling agents to deviate from obstacles or from other individuals during evacuation.

The Fuga platform was originally developed during the author's doctoral research (Braga, 2018) and has since been refined for academic applications in evacuation analysis. From a methodological standpoint, the model follows a rule-based multi-agent system (MAS) approach, in which each agent operates according to local decision rules guided by precomputed distance maps and a wall-shading algorithm combined with collision-avoidance mechanisms. Unlike continuous social-force formulations, the system adopts a discrete logic structure that allows explicit control of geometric constraints and movement parameters.

The software is a research-oriented academic tool available for collaborative research and is not a commercial product. It has not undergone formal certification under international regulatory frameworks, and its application in this study is limited to parametric evacuation analysis under controlled geometric and behavioral assumptions.

Agents were modeled under non-panic conditions, following rule-based cooperative behavior toward the nearest exit. Limited local adaptive adjustments were implemented through fuzzy logic mechanisms; however, the model does not incorporate cognitive impairment or irrational crowd dynamics.

The geometric configuration of the nightclub was discretized using a regular grid with a spatial resolution of 5 cm. Structural elements such as walls, barriers, and fixed obstacles were represented as non-transposable grid cells. Based on this discretization, distance maps were computed using shortest-path algorithms to determine optimal evacuation routes. The model has been previously tested through controlled in silico trials, demonstrating high consistency between defined and simulated walking speeds (errors below 1%) and evacuation times comparable across repeated runs. These outcomes support the internal consistency and reproducibility of the simulations.

In this study, the Kiss Nightclub environment was modeled in simplified form, preserving the critical elements for evacuation, particularly exit routes and exit widths. Simulations were performed considering (i) obstructions located at the entrance and exit areas of the nightclub and (ii) exclusively the restriction imposed by the width of the main exit. The metal railings present in the actual nightclub were not individually modeled as discrete obstacles; instead, their restrictive effect was represented through the effective reduction of available exit width, which constitutes the primary geometric constraint analyzed in this study. Internal obstructions unrelated to these areas were not considered, as they did not represent the primary limiting factors in the evacuation process.

A population of 1,000 agents was generated based on three discretized anthropometric body-size categories (small, medium, and large), following the profiles proposed by Still (2000) and covering approximately 95% of the population. The human body projection was discretized onto the 5 cm grid, and a grid cell was considered occupied when more than half of its area was covered by the projected body image, resulting in binary occupancy profiles.

The three categories correspond to different occupied areas and discretized body projections: small (28 grid cells, 700 cm²; maximum lateral dimensions of 40 cm × 25 cm), medium (36 grid cells, 900 cm²; maximum lateral dimensions of 50 cm × 25 cm), and large (52 grid cells, 1300 cm²; maximum lateral dimensions of 60 cm × 30 cm). The resulting profiles are irregular binary shapes derived from the discretized human projection, rather than simplified rectangular or circular geometries.These variations influence spatial occupancy and collision handling but do not incorporate differences in height, weight, or age. Agents were assigned random initial spatial distribution and orientations, always located beyond the entrance/exit area.

Each scenario was simulated multiple times to account for stochastic variability in initial positioning. Simulations were executed until complete evacuation was achieved, and the total evacuation time recorded corresponds to the movement component of the *RSET*.

The evacuation times obtained from the simulations were then compared with the concepts of *ASET* and *RSET*in order to evaluate the adequacy of safety conditions. The results presented in the following section quantify the relationship between exit width and evacuation performance under the defined geometric and behavioral assumptions.

4- RESULTS AND DISCUSSION

4.1- Recent investigations on the Kiss Nightclub fire

Before presenting the simulation results, it is important to situate this study within the broader body of recent investigations on the Kiss Nightclub fire, which have adopted complementary methodological perspectives. Hennemann *et al*. (2022), through coupled fire simulations using the Fire Dynamics Simulator (FDS) and evacuation simulations using Pathfinder software, calibrated with laboratory tests and documented evidence, analyzed both the actual building conditions and a scenario compliant with Brazilian standards, emphasizing the combined influence of combustible finishing materials and emergency exit configuration on casualty outcomes.

Freitas and Rodrigues (2023), based on structured fire investigation procedures and numerical simulations of fire development, emphasized the multifactorial nature of the tragedy, identifying structural violations including insufficient egress width and obstructed exits. More recent work by Freitas and

Rodrigues (2026) expanded this analysis through integrated fire and evacuation simulations, reinforcing the role of exit configuration and regulatory non-compliance in evacuation failure.

From a behavioral perspective, Ono *et al*. (2025), based on survivor surveys, highlighted delayed fire recognition, social interaction, and confusion during the initial stages of evacuation, emphasizing the influence of perceptual and cognitive factors.

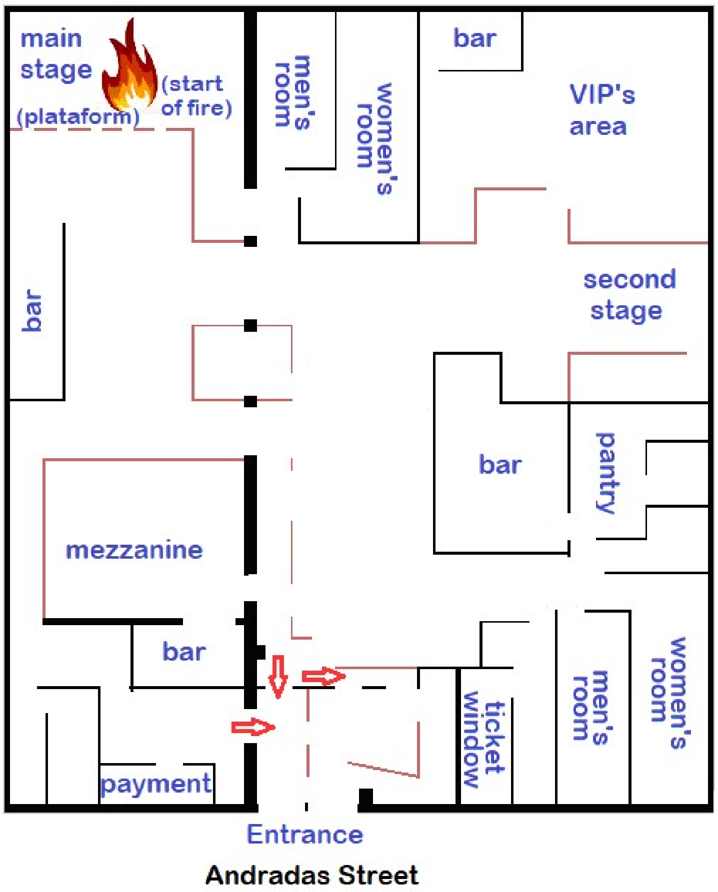
While these studies incorporate fire dynamics, evacuation modeling, and behavioral variability, the present work isolates the geometric constraint of exit width under controlled evacuation assumptions, aiming to quantify its specific impact on evacuation performance.

Despite the significant advances achieved through integrated fire dynamics, evacuation modeling, and behavioral analyses, there remains value in isolating specific geometric parameters in order to quantify their individual contribution to evacuation performance. In particular, the direct impact of exit width under controlled behavioral assumptions warrants focused examination, as it allows a clearer assessment of prescriptive design limits. Accordingly, the present study adopts a parametric computational approach to evaluate evacuation times as a function of exit width in the Kiss Nightclub configuration.

4.2- The built environment

The Kiss Nightclub had a rectangular shape, measuring approximately 23.18 m along the front facade and 26.45 m in depth. Its 2009 design indicated a total built area of 615 m² (Silva *et al*., 2013). The nightclub essentially consisted of a single main floor, although internally it featured mezzanines and small stairways, as well as an office on a partial second level located above the left side of the entrance. Figure 2 provides a simplified top view of the nightclub, highlighting its main architectural elements.

Figure 2 - Simplified top-view layout of the Kiss Nightclub highlighting the main circulation areas and exit routes (not to scale).



Source: Adapted from Braga and Moita (2017).

Internally, the Kiss Nightclub had a sophisticated layout with different sectors and corridors. There were two independent performance areas: a larger main hall with an elevated stage,where the fire originated, and a smaller secondary hall.

In Figure 2, three red arrows are shown in the exit region. These arrows represent the most critical theoretical bottlenecks in the evacuation flow, based on the nightclub’s actual layout prior to the tragedy. These points were the environmental elements that, in principle, controlled and restricted the movement of people, at least during the initial moments of the incident.

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Except for the entrance, the building was acoustically sealed from the exterior; even the windows, including those in the restrooms, had been blocked, preventing air circulation with the outside environment. As a result, the limited oxygen supply confined the main fire to the ignition area and prevented it from spreading extensively throughout the structure. Consequently, most fatalities were caused by asphyxiation and inhalation of toxic gases, such as HCN and CO, produced by the burning of polyurethane foam (Antônio *et al.*, 2013; Bassi *et al.*, 2014; Avelar *et al.*, 2022).

The nightclub's entrance and exit were adjacent, and their operation was regulated by internal partitions, including metal railings that constrained circulation. These structures created funnel-like passages directing patrons toward service desks for entry and exit control. Although these railings were not part of the original 2009 architectural design (Silva *et al.*, 2013), they significantly altered the effective evacuation geometry.

Figure 3 presents a schematic of the entrance and exit area, highlighting walls and closed doors (black), railings (brown), service desks (green), and exit openings (yellow). The configuration resulted in narrow, channelized pathways that restricted simultaneous flow, contributing directly to the formation of critical bottlenecks. At the time of the fire, the centrally positioned opening, typically of secondary use, became an important escape route due to congestion at the primary exit.

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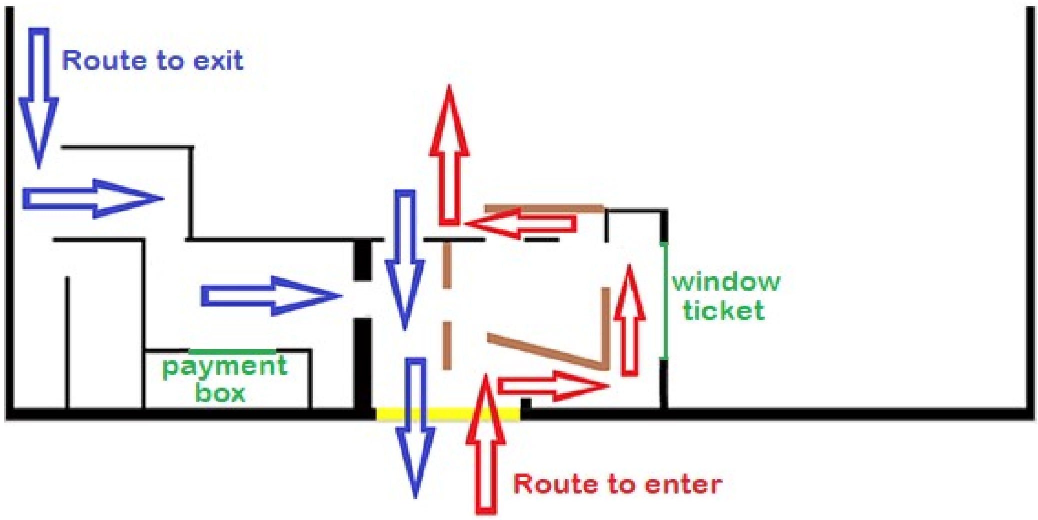
Figure 3 - Detailed schematic of the entrance and exit area indicating walls and closed doors (black), railings (brown), service control desks (green), and exit openings (yellow), illustrating the geometric constraints responsible for flow restriction (not to scale).



Source: Adapted from Braga and Moita (2017).

All entry and exit procedures were supervised by staff under normal operating conditions; however, during the emergency, the physical constraints imposed by the railings and layout geometry became the dominant limiting factors in evacuation.

4.3- Performance of the effective exit

Initially, considering a simplified environment with only the obstructions around the entrance/exit area, a complete evacuation of the nightclub was simulated with 1,000 agents, representing a physically plausible high-occupancy scenario for the environment. Although official figures for the number of occupants at the time of the fire remain uncertain, documented estimates reported in the literature indicate values in the range of approximately 691 to 771 people (Freitas; Rodrigues, 2026). The adoption of a larger simulated population provides a conservative basis for evaluating evacuation performance under increased demand conditions.

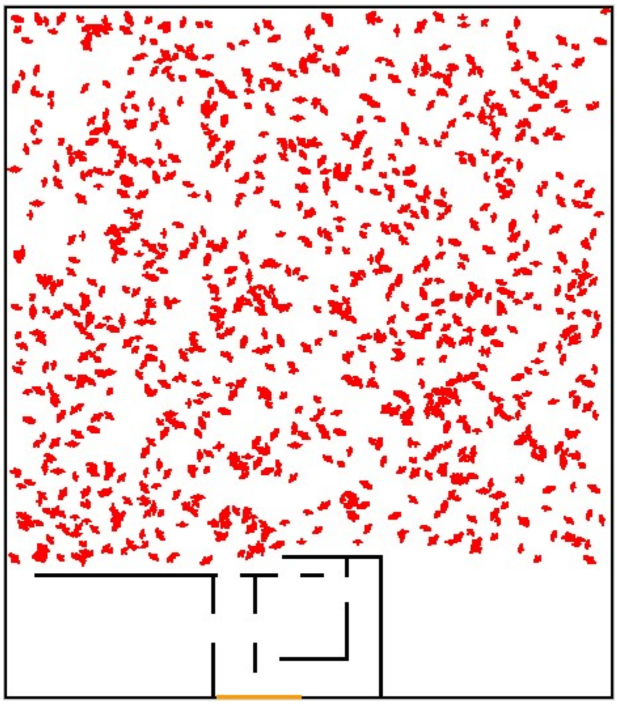
Agents were assigned random initial positions and orientations, always located beyond the entrance/exit area. Despite the random distribution, each simulation ensured that at least one agent started from the farthest point from the exit (top-right corner in the plan view), representing the worst-case evacuation distance.

In the modeling, agents were assumed to operate under pre-defined behavioral parameters within the limits of rule-based adaptive movement, representing an idealized evacuation scenario without panic-induced behavioral collapse. It is important to note that, in the real fire, adaptive behavior was quickly overwhelmed, giving way to chaos and panic. Therefore, the simulated evacuation times correspond to structured flow conditions and may be interpreted as a conservative baseline for analysis. Some of the metal railings that contributed to crushing were, in fact, torn down by the crowd in the process.

Figure 4 illustrates one of the simulations, with panel (a) showing the environment at the initial moment and panel (b) an intermediate stage. The simulation was repeated five times, yielding a total evacuation time of 421 ± 6 s.

Figure 4 - Simulation snapshots of the simplified nightclub layout: (a) initial stage with 1,000 randomly distributed agents; (b) intermediate stage showing flow formation toward the exit (agents in red, obstacles in black, exit in orange).

(a)



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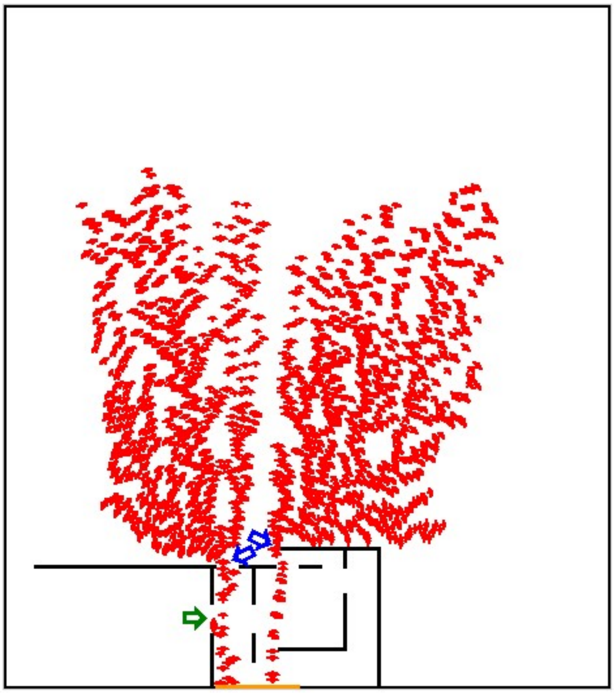
(b)



Source: Authors.

For a better understanding, Figure 4b highlights the formation and persistence of two distinct evacuation flows (blue arrows), in which only one agent per passage is able to move toward the exit at a time. In practice, this means that at most two agents can simultaneously proceed in parallel toward safety. The remainder of the population tends to accumulate at the entrance of these narrow channels, creating dangerous bottlenecks.

It is clear that this queuing condition, people waiting their turn to pass through the exit, represents a hypothetical structured evacuation scenario and does not reproduce the chaotic conditions observed during the real event. Nevertheless, the simulation provides insight into the physical conditions that may have contributed to the rapid breakdown of orderly behavior, particularly the high densities and restricted flow resulting from severe geometric bottlenecks.

Additionally, Figure 4b shows that the route leading from the cashier/payment area (green arrow) was only satisfactorily used at the very beginning of the evacuation, and thus remained underutilized. Even assuming that this passage had functioned effectively (which was not the case), in practice, at most three people could have exited the nightclub simultaneously. Therefore, the effective functional width of the emergency exit, given the nightclub's configuration at the start of the fire, was only 3 PU (passage units), equivalent to 1.65 m (as defined in NBR 9077 (ABNT, 1993), where 1 PU = 0.55 m).

In a non-adaptive situation, when the crowd behaves in a disorganized, impatient, and apparently chaotic manner (Ibrahim *et al*., 2017), as indeed occurred, a tragedy would be unavoidable, since it is unrealistic to expect people to calmly wait for space to open in order to escape. Moreover, this effective width of 1.65 m was significantly below the minimum legally required by NBR 9077 (ABNT, 1993), which prescribed 4.4 m (8 PU) for the venue.

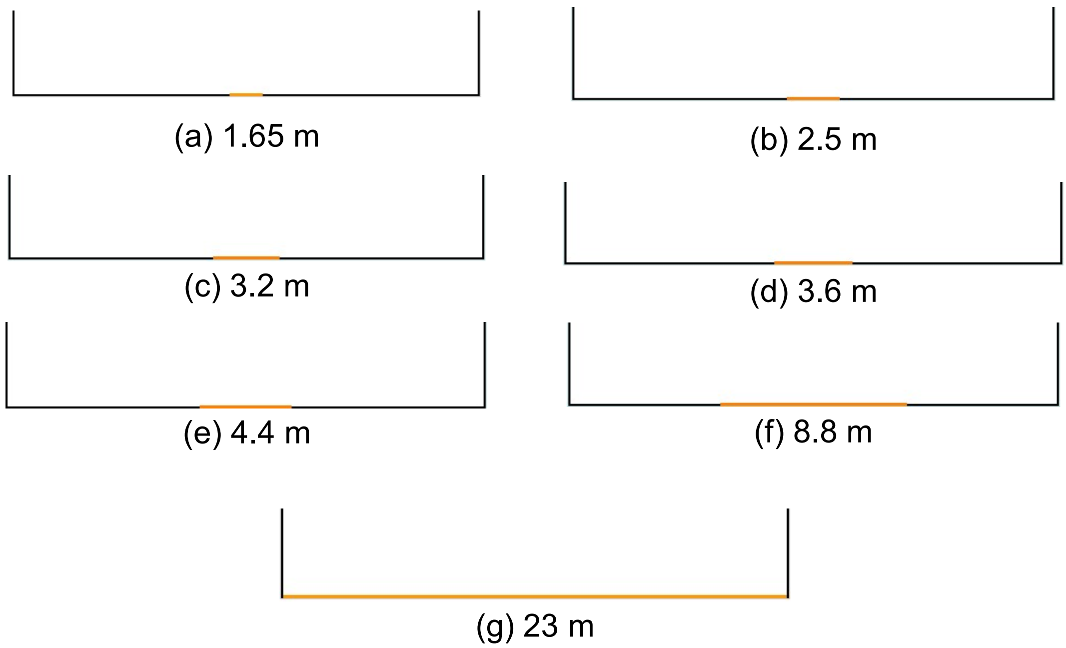
4.4- Impact of the exit width on the comparison between *RSET*and*ASET*

Additional simulations were carried out with the Fuga program to determine the effective emergency exit width that would have been necessary to prevent the tragedy from reaching its actual magnitude.

In these new simulations, exit width was varied from 1.65 m (the worst-case scenario, consistent with the conditions observed on the night of the fire) up to 23 m (the best-case scenario, assuming the entire lateral facade of the nightclub facing Andradas Street functioned as an exit).

As in the previous experiment, 1,000 agents were considered, with random initial positions and orientations in each simulation, all located behind the entrance area, and each with a maximum walking speed of 1.5 m/s. Since the goal was to isolate the influence of exit width on evacuation time, no internal obstructions were included in the model, not even those around the entrance area, to ensure they would not affect the results. Figure 5 shows the different exit widths tested, whileTable 1 presents the corresponding evacuation times as a function of total exit width.

Figure 5 - Frontal representation of the modeled environment facing Andradas Street, illustrating the different exit widths analyzed (highlighted in orange).



Source: Authors.

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Table 1 - Total evacuation time obtained from simulations for different emergency exit widths in the simplified nightclub configuration without internal obstructions.

Exit width (m)	Nº of PU (Passage Units)	Evacuationmovement time (s)
1.65	**3**	**423.3**
2.5	≈ 4.5	313.4
3.2	≈ 5.8	244.4
3.6	≈ 6.5	218.3
4.4	**8**	**180.5**
8.8	**16**	**89.2**
23	≈ 41.8	37.1

Source: Authors.

In this idealized scenario, where only movement time is considered and the safety factor *fes* is disregarded, the evacuation times in Table 1 can be interpreted as the corresponding *RSET* values. In contrast, under the rapid smoke development reported during the Kiss Nightclub fire, untenable conditions were estimated to develop within approximately 90 s (Braga; Moita, 2017), based on experimental observations of the foam ignition and smoke propagation. This value is adopted here as an indicative time window for available safe egress.

More recent fire-dynamics simulations indicate that smoke could fill the interior in under 70 s under realistic conditions, severely constraining evacuation opportunities (Freitas; Rodrigues, 2026). These estimates provide a reasonable range for plausible *ASET* values. Notably, the adoption of 90 s as a reference does not underestimate the severity of the scenario; if a shorter *ASET* is considered, the discrepancy between required and available safe egress time becomes even more critical.

Therefore, for *RSET* to at least match *ASET*, an emergency exit width of 8.8 m would have been required, double the width prescribed by NBR 9077 (ABNT, 1993). With respect to the Kiss Nightclub environment, it becomes clear that even a width compliant with the prescriptive minimum would not have ensured a safe evacuation under the conditions of the tragedy. For the legally prescribed width of 4.4 m, the *RSET* obtained from the simulations was 180.5 s, approximately twice the reference *ASET*. This indicates that, even if the original layout had been maintained in strict compliance with the standard, a catastrophic outcome would still likely have occurred, albeit potentially on a smaller scale than that actually observed.

It is important to emphasize, however, that this does not necessarily indicate a shortcoming in the regulation itself regarding this specific parameter (minimum total width). Rather, the combination of circumstances at the nightclub created a critical situation far beyond what the standard could reasonably have anticipated. This highlights the crucial importance of other control measures.

In the case under study, beyond the emergency exit dimensioning, several factors were involved. Among them, the failure in controlling finishing materials stands out, as this parameter has been recurrent in many major fire disasters. For instance, deficiencies in the control of interior finishing materials have systematically appeared in several significant fires (Santos; Vieira, 2021). Notably, the two largest fire disasters in Brazil, the Panamericano Circus tragedy in Niterói (Knauss, 2007) and the Kiss Nightclub tragedy, both illustrate the critical impact of inadequate control over such materials.

Finally, an additional point of concern is that the two emergency exits in Kiss Nightclub were partially located side by side (Figure 6). The absence of any requirement in NBR 9077 (ABNT, 1993) regarding the independence and spatial separation of exits is noteworthy and contradicts well-established lessons learned from previous nightclub fires (Duval, 2006; NFPA, 2018).

Figure6 - Facade of the Kiss Nightclub illustrating the spatial proximity of the two adjacent entrance/exit doors.

Source: Google Street View, Andradas Street, Santa Maria, Brazil, image captured in October 2012 (adapted by the authors).

Such a configuration is extremely hazardous, since an incident compromising the escape route in that area may leave no viable alternatives. Moreover, adjacent exits do not significantly reduce average evacuation time, which can only be achieved by ensuring adequate spacing between them (Braga; Moita; Almeida, 2019).This remains an important open issue that deserves further discussion and should be addressed in future studies.

5 - FINAL CONSIDERATIONS

The computational modeling performed in this study indicates that, under urgent evacuation conditions at the Kiss Nightclub, safe egress within the available safe egress time would not have been achievable given the existing geometric constraints. Under the modeling assumptions adopted herein, for the majority of occupants to evacuate within this time frame, the main exit and its associated escape route would have required a minimum width on the order of 8.8 m, approximately double the value prescribed by ABNT NBR 9077:1993 (4.4 m). This estimate should be interpreted as a parametric result within the defined geometric and behavioral simplifications; variations in *ASET* assumptions or occupant behavior could further increase the required width. Rather than indicating an inherent deficiency of the standard itself, the results suggest that the combination of unfavorable factors on the night of the tragedy produced a critical condition beyond the assumptions typically considered in prescriptive design.

The nightclub’s actual layout further aggravated this situation by creating severe bottlenecks. In the modeling, this condition was represented through an effective exit width of approximately 1.65 m, corresponding to the restricted flow configuration documented at the onset of the fire. Although this representation simplifies the complex physical interactions that occurred during the event, the resulting *RSET* values were substantially higher than the estimated *ASET*, reinforcing the conclusion that geometric constraints alone were sufficient to produce a critical evacuation scenario.

Additionally, although ABNT NBR 9077:1993 requires more than one exit for certain occupancies, it does not explicitly emphasize functional independence and spatial separation between them. This omission may permit configurations in which exits are positioned adjacently, as occurred in the Kiss

Nightclub, a layout that increases flow interference and contradicts widely recognized international fire safety principles.

In summary, the simulations provide quantitative evidence that compliance with prescriptive requirements alone may not guarantee adequate safety margins under extreme occupancy and unfavorable geometric conditions. The results obtained herein, while dependent on the defined modeling assumptions, indicate that geometric constraints can critically influence evacuation performance even in the absence of behavioral deterioration or panic dynamics.

These findings highlight the importance of critically reassessing Brazilian regulations, not only regarding exit width and spatial separation, but also in relation to finishing materials and occupancy control, and reinforce the role of computational simulation as a performance-based decision-support tool in fire safety design. Future studies should extend this approach by incorporating behavioral variability under high-stress conditions and by examining additional building typologies, thereby expanding the analytical robustness of the methodology.

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