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WORLD CUP 2014: CROWD ACCOMMODATION POLICY EVALUATION IN A SOCCER STADIUM BLEACHERS USING SIMULATION

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ABSTRACT

This case of study applied to the sports context (Grêmio Arena Soccer in Brazil) has the objective to measure dynamically the time spent during the accommodation of fans in a stadium bleacher. The metric used to evaluate it was the occupation time. In this study it was considered four different occupation scenarios of the bleachers characterizing ways to drive fans to their seats. The selected scenarios were: (1) random entry, (2) entry driven by a dispatchers, (3) numbered seats; (4) numbered seats with dispatcher. Building experiments using the simulation software SIMIO it was observed that the policy based on the dispatcher results in a shorter total occupation time. Additionally, the research analyzed factors that could make difference, such as physical feasibility to support the large number of people, as well as cultural aspects.

1 INTRODUCTION

Crowd environment became increasingly common in most of humans routine. Such types of situations are remarkably observed in the resident life of great centers in activities such as taking a subway, watching a football match, enter a row at the theater for a movie premiere, or to entry a great musical concert. A common point in all events mentioned above is the austere behavior, and sometimes aggressive, when people tries to occupy a confined and restricted space in a short period of time. Although in recent years several studies (Rodrigues 2011) have been conducted on the behavior of people during the evacuation process of confined spaces under a risky situation, few have investigated the arrival process of the crowd.

In Brazil, due to cultural and sporting tradition, an event that routinely movements crowds are soccer tournaments. Those events eventually are surrounded by risky and dangerous situations. A lot of people are exposed weekly to danger during the championship season. To avoid accidents related to the crowd and maintain the physical integrity of the fans and players, FIFA issued safety guidelines (Federation Internationale de Football Association 2013). This document delegates specific responsibility to organizers of the event, so that stakeholders (including the team supporters) are aware of their safety roles before, during and after the matches.

Despite of this safety manual, there is no straight recommendation to be followed during the occupation of the bleachers. The Recommendation Guideline from Brazilian Sports Ministry, created in partnership with Fundacão Getúlio Vargas (FGV), recommends that the fans should receive attention from the moment they enter the influence zone of the stadium. The same document remains unclear in defining such zone, yet. Hence, the arrival of the supporters and their occupation of a stadium can be considered a public

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problem from the organization authorities perspective, since there are many risks associated with this process. Violent behaviors can be reported in many events during the world cup championship.

Given the crescent interest in creating mathematical models to help decision makers to analyze a complex situation, we developed a simulation model using SIMIO to identify the best policy to drive the team supporters at the beginning of a soccer match. These efforts aim to provide the international community a proper and safety environment to receive the visitors during the 2014 World Cup.

2 LITERATURE REVIEW

2.1 Operational Research and Simulation

Starting from the foundations, Winston (Winston and Goldberg 1994) defines Operational Research (OR) as a method created from the use of mathematical models and algorithms with the goal of finding the best (optimum) option to solve complex problems in the resource allocation available within organizations. The Operational Research has two main areas: (1) Deterministic; and (2) Stochastic. The simulation, method used in this work, belongs to the stochastic segment and is traditionally counting on the extensive use of modeling operational and managerial problems, due to their flexibility and practicality of developing a model. Simulation involves the uses of computers to mimic the operation and functioning of a system and obtain records of their performance (Hillier and Lieberman 2001). A simulation model aims to capture the real behavior of a system and represent it as a computational model, being able to demonstrate random phenomena with data obtained through observations of the phenomenon (Chwif and Medina 2006).

2.2 Agents

As defined by Russell et al. (1995), an agent is an entity able to perceive the environment in which it is placed and interact with it. This perception is performed by sensors and their interaction with the environment is done by the actuators. A generic agent according to (Shoham 1993) can be exemplified in Figure1.

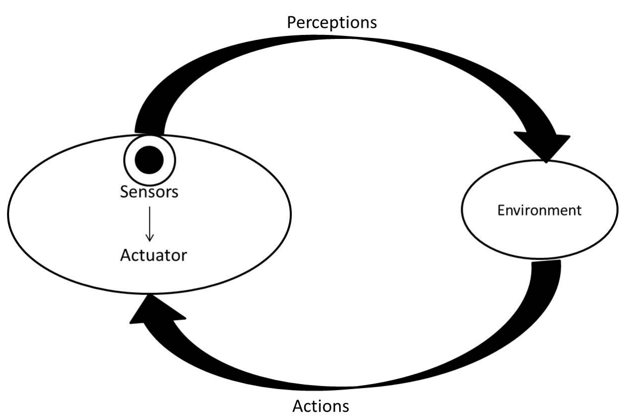

Figure 1: Conceptual model of a generic agent proposed by Russell.

According to Russell et al. (1995), during the development of an Agent-Based model, the modeler has the task to identify the activities of each agent, the possible behaviors, insert them in a certain environment and establish connections. The Agent-Based simulation brought those concepts into a mathematical modeling perspective.

2.3 Crowd Simulation

When such actuators and sensors are incorporated into the social perception, and employed into a human, the simulation model can be classified as crowd simulation. It can be developed with two major objectives: (1) to simulate behaviors focused on the validation of real-world events, in order to represent them as close as possible to the reality; (2) to simulate crowds graphically (as in film productions and electronic games), where the behavior is not the most important, but rather, the graphic quality presented (Thompson and Marchant 1995).

2.4 Physical Structure of Stadiums

Based on FIFAs Safety Guide (Federation Internationale de Football Association 2013), the assigned area to the fans should be divided into sectors properly identified in order to ensure fast recognition for each ticket location. Each sector should be limited by barriers that avoid the movement of a fan between sectors, ensuring that everybody will occupy the correct place. The Recommendation Guideline from Brazilian Sports Authority (Ministerio dos esportes 2010) suggests maintaining an easy and clear path between the seats, allowing the movement of spectators along the rows of seats. The same document also defines that the dimensions of the areas designed for people with special needs must be in accordance with Brazilian's accessibility standards regulations. Additionally, the circulation areas must provide well-being and security to the fans, with easy access to their seats, avoiding them to lose part of the game finding their place. The dimensions of the assets (chairs, stairs, isles) must be adequate to prevent risk situations due to a blockage. The number of fans inside the stadium must be determined by national, international authorities, or government agencies.

To help in the organization of the stadium during the match, there are agents called dispatchers. They are in charge to support the organization and security from the moment of opening the stadium until the events end. It is required that the dispatchers has reached the legal age and has experience in activities related to the work of dispatchers, especially in soccer matches. These agents should wear the same uniform, which should be easily identifiable, and have reflective strips so that they can quickly give support to fans. To ensure the safety and organization of the event inside the stadiums, the number of dispatchers to be employed in each match should be based primarily on physical factors of the stadium (e.g. entrances and exits, emergency gates).

2.5 Behavior in Crowds

Characterized by a large group of individuals confined in the same physical environment, a crowd shares a common goal and demands special attention of the staff (Roloff 1981). When individuals begin to move in the environment, targeted to specific destinations, there is a complex interaction between them, which may cause conflicts when trying to occupy the same space (Henderson 1971). Regarding the behavior of crowds, the main features are presented by Still (2000) and Helbing et al. (2001). In normal situations, the following characteristics in crowds and individuals were observed:

- Typically a crowd choose the fastest route to their next destination, but not necessarily the shortest. If there is more than one path with the same length, the pedestrian will choose the one that allows them to move varying the speed and direction as minimum as possible.
- They prefer to walk with a comfortable speed. This corresponds to the speed of walking with the lowest energy consumption.
- Maintain a distance from others and limitations, such as streets, walls and obstacles. As increases the density of pedestrians in a place, decreases the interpersonal distance.
- They usually do not follow a behavioral strategy in all situations, but act almost automatically. This is evident when they cause obstructions trying to enter a location even when other people are still coming out.

3 METHODOLOGY

This paper was partially based on theoretical assumptions since it is a projection of how the soccer arena will be built. On the other hand, the agents' behavior could be inferred by past studies, as well as data gathering of similar situations. Hence, field data collection was the basis for many parameters used to configure the model such as the agents' velocity. To investigate the problem it was developed a model based on Arena Grêmio to provide a mechanism for authorities to find mitigation policies for risk management during a soccer match.

3.1 Conceptual Model

The system simulated was the soccer stadium named "Arena Grêmio", located in Porto Alegre, Brazil (Figure 2), with 192,652 m^2 of built area (229 m x 187 m) and capable to receive about 60,000 supporters. This stadium is divided into four sectors (north, south, east and west) with a symmetric architecture, and perfectly adequate according to FIFA standards. For the scope of the present study, emphasis is given to the South sector, the fourth level, leaving room for the incorporation of the other three sectors for future work.

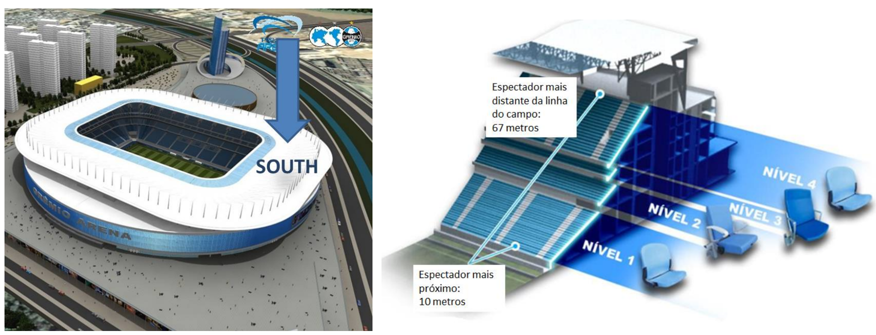

Figure 2: Arena Grêmio and its levels.

The fourth level was chosen with no generality loose, since it has a central entrance to the bleachers, and an equivalent number of chairs for both sides (right and left). The region to be simulated is called "partition" and it is prepared to accommodate 501 fans. This partition was divided into two "sub-partition": (1) right hand side, taking the entrance and the stairs as a reference, it was modeled using a matrix with 21 rows, and 10 cols with each cell representing a seat for a fan; (2) left hand side, using the same concept of the matrix. Details of the partitions and sub-partitions can be analyzed in Figure3.

Special assumptions were used for the central area of the sub-partitions, since there were cells (representing seats) which were not available for fans (the entrance region), as well as the first row (which figured extra seats). Such special cases were properly tackled in the mathematical model.

3.2 Mathematical Model

As a classic simulation study, this model was composed by entities, resources, attributes, and variables exchanging information to mimic the desired system. They can be translated into real world objects as follows:

- Entity: soccer supporters
- Resources: dispatcher, seats, isles, stairs
- Attributes: velocity, tickets number
- Variables: bleachers, scenario

Such objects interact according to the scheme shown in Figure 4.

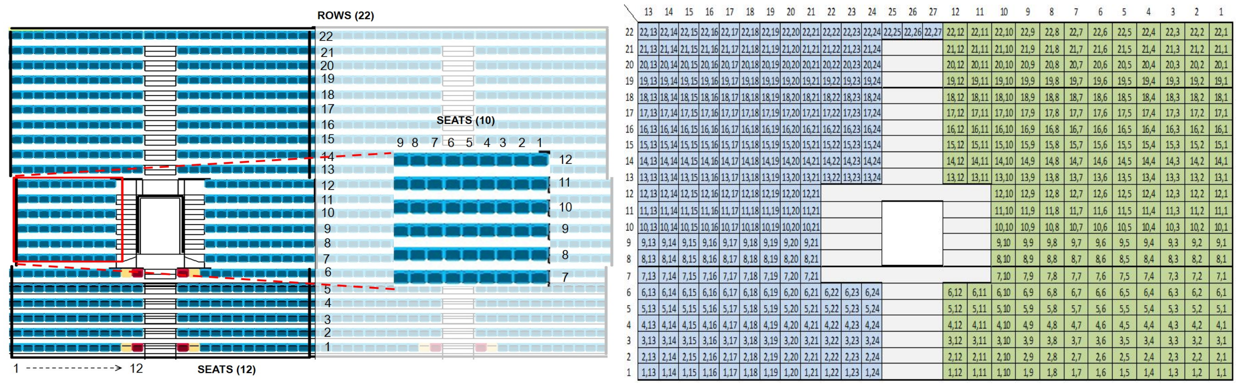

Figure 3: Partition and sub-partitions (conceptual and matrix).

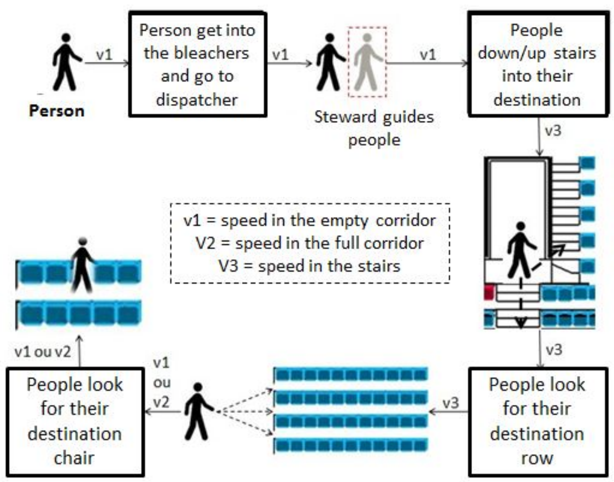

Figure 4: Conceptual entity steps of the model developed.

Each seat has an index (ticket number) according to its position and this index needed to be translated into a cell named (r,c) representing r = row; c = column. This translation is realized by the linear transformation in Equation 1.

$$c = ID - (r-1) * Cpl \tag{1}$$

Where:
r = row assigned to the fan (1 to 22)
l = column assigned to the fan
ID = index of the seat chosen by the fan
Cpl = capacity of the row

As a natural constraint of the system, the central seats of the beaches (seized by moving area) needed to be handled in a particular way. In the matrix, there were 594 cells to be assigned; however, 93 of those should be blocked because of the moving area. Under a modeling stand point, it was necessary to create logics to dispose the 93 fans assigned to such area. Hence, the supporters that were assigned to a valid index number enter to the system and look for its seat. The way a supporter will find its seat is the decision variable of this study. Each difference corresponds to a particular scenario, according to Figure 5, and how the organization who handles it configures a policy.

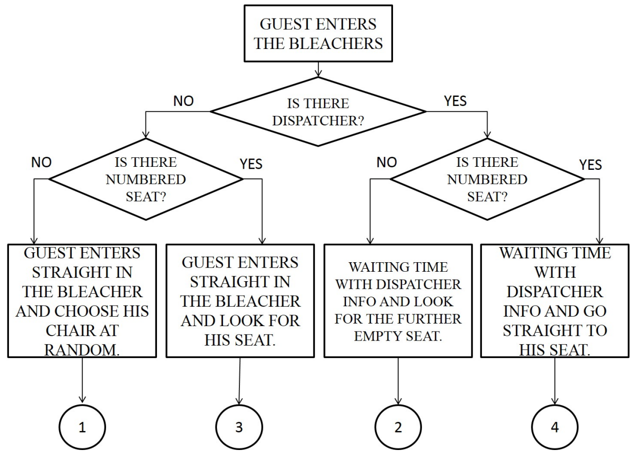

Figure 5: Disposal flowchart to apply constrained seats.

3.3 Data

The data used in this study can be classified in two groups: (1) physical data (stadium infra-structure); and (2) movement data (fans attributed). The physical data accounts for the dimensions of the stadium, such as the distances, number of seats, distance between seats, width of the isles and number of steps (Figure 6).

Figure 6: Dimension details of the stadium.

On the other hand, the movement data was based on de Gouveia and Etrusco (2002). In their work, they define a relationship between the velocity a person moves in the stairs and the size of the stairs itself. Such relationship can be seen in the Table 1.

Hence, the parameters used in the model are presented (Table 2). There is a set of relevant assumptions observed in the model that indicates the necessity of such data. In terms of the supporters, the model considers each supporter from the entrance to the gate until the final accommodation on its assigned seat. This assumption guarantees the impossibility of a supporter to decide to walk through the system for visiting the restroom, or buying snacks at the bar. Additionally they go straight to its assigned seat not moving toward different directions randomly. Hence, each isle is considered ”one-way” direction movement. Another important assumption is the consideration that the lower region of the bleachers are preferable if comparable with the other region (mathematically, the lower row indexed seats are preferable than the high indexed seats). Finally, disabilities seats was not considered to maintain the homogeneity

Table 1: Velocity of movement in stairs.

Hight(m)	Width (m)	Maximum velocity (m/s)
0.20	0.25	0.85
0.18	0.25	0.95
0.17	0.30	1.00
0.17	0.33	1.05

of the entities. Since all of those assumptions create a relaxed environment, those constraints could be included in the model for further investigations.

Table 2: Movement parameters used in the model.

Parameter	Value	Unit
Velocity of motion in stairs	0.85	m/s
Velocity of motion in plane	1.35	m/s
Width of the access gate	1.80	m
Width of isles crossing the access gate	0.85	m
Width of isles parallel the access gate	0.90	m
Width of isles of the seats	1.40	m

In order to complement the data provided by Gouveia's (de Gouveia and Etrusco 2002) work, an experiment was conducted using a group of students in an auditory with stairs to identify the velocity used in the model. It was collected the velocity of the walkers in the free isle, and concluded that this variable has a normal distribution with average of 0.93 and standard deviation of 0.08 (p-value > 0.150), and the velocity of a busy isle was also normally distributed with average of 0.56 and standard deviation of 0.07 (p-value of 0.065). In both cases it was considered a 95% of confidence.

3.4 Computational Model

This model was developed using the software SIMIO, which was considered by the research team the most capable to handle the environment of agents moving into a constrained system. Hence, each entity has a built-in logic to identify whether a seat is seized or not, or which is the path to find the assigned seat.

3.5 Scenarios

Scenarios were planned to investigate the lead-time of a supporter in the system. Obviously the term lead-time was adapted from the manufacturing context meaning the movement duration of a fan from the gate to the seat. Such analysis could be realized based on four scenarios.

3.5.1 Scenario 1 - No Numbered Seats, Without a Dispatcher

In this scenario, each person chose freely where to seat, deciding the way it should move. Since the occupation order is randomly chosen by the fan, the probability of occurring a block is higher, slowing down the movement of the supporters and taking longer to accomplish the occupation of the bleacher.

3.5.2 Scenario 2 - No Numbered Seats, With a Dispatcher

In this scenario, each person is assigned to a seat by the dispatcher. This staff member is responsible to assign sequentially a seat, leaving few room for a decision taken by the supporter. He will follow the filling of a row, directing the person for the next row as soon as it is full. This attitude avoids the time wasted in switching the rows.

3.5.3 Scenario 3 - Numbered Seats, With No Dispatcher

In this scenario, each person carries its own ticket with the seats previously assigned. Hence, as soon as the person cross the gate, it demands a slight time looking around and trying to identify where its seat is located.

3.5.4 Scenario 4 - Numbered Seats, With Dispatcher

In this final scenario, each person carries its own ticket, but he is helped by the dispatcher who supports him to identify the location of the seat. It avoids the time wasted trying to find the place, but do not avoid the blocking situations inside the seating isle.

4 RESULTS

The simulation created by this study outputs the complete occupation time of a bleacher by team fans before the beginning of a soccer match. This time is composed by the summation of the time every single person takes from the entrance gate until the seat accommodation. To ensure the validity of the model, it was validated according to classic concepts.

4.1 Validation

According to Chwif and Medina (2006), the validation is tight to the conceptual model because it is the project step where assumptions are checked, as well as the detail level of the model. Three possible mistakes can be incurred during a validation effort: (1) type I: reject a model when it is valid (also known as alpha error); (2) type II: fail to reject a model, when it is not valid. This type of error (known as beta error) is very common since the simulation is a relatively recent knowledge field, and many model developers are learning the concepts; and finally (3) type III error (particular to simulation models), where the model is valid, it is considered valid, however they do not reach the expected objectives in answering the investigated questions. Based on the ”turing test”, the model was validated by the comparison of the second scenario and a hypothetical deterministic scenario. The deterministic scenario was built by the summation of the following equation (Equation 2) for each entity.

$$Lead-time = \sum \frac{\mathrm{d}_c}{\mathrm{v}_c} + \frac{\mathrm{d}_e}{\mathrm{v}_e} \tag{2}$$

Where:
d_c = distance moved in the isle
v_c = velocity moved in the isle
d_e = distance moved in stairs
v_e = velocity moved in the stairs

As a reference, it was built an extra scenario using the average velocity as deterministic and the distance measured in the real stadium, the total occupancy time was 6,504.42 seconds, or 108.41 minutes. The scenario number 2, with the times as random variables the result, and 120 replications, the results converged to 6,469.42 resulting in a relative error of 0.54%The results of next scenario can be verified in Figure 8. As a practical rule, a relative error less than 5% can classify a model on valid, because it makes hard to identify which result is originated by the model and which one comes from the reality.

With the model considered valid, the next important decision is the identification of the number of replications that is necessary to conduct the experiments. According to Medina (Chwif and Medina 2006), a replication is defined as the repetition of the execution of a model using the same input parameters, but with a different random generation number seed. The method used to identify the number of replication was an iterative method proposed by the author, where multiple experiments were conducted until the studied random variable do not change if the replication number increase. The method can be seen in the following figure (Figure 7). Additionally, it can be observed convergence by the reduction of the confidence interval, as the number of replication increase.

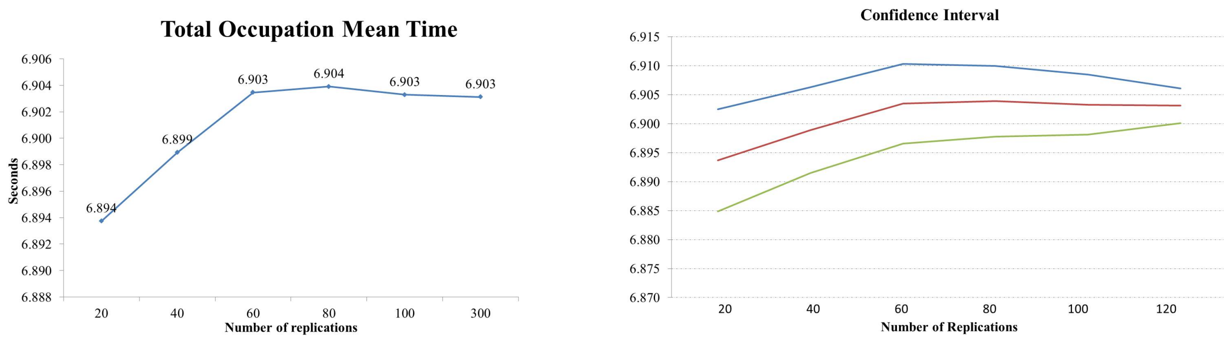

Figure 7: Convergence method of finding the replication number.

The same methodology was conducted in all four scenarios in order to draw the conclusions in the next section.

4.2 Scenario Analysis

Using the output tools of SIMIO it was possible to visualize the box-plot chart and the histogram at the same time of the studied random variable of interest in this study (Figure 8). All four scenarios could be compared visually in terms of position (average, mode), as well as dispersion (range, standard deviation).

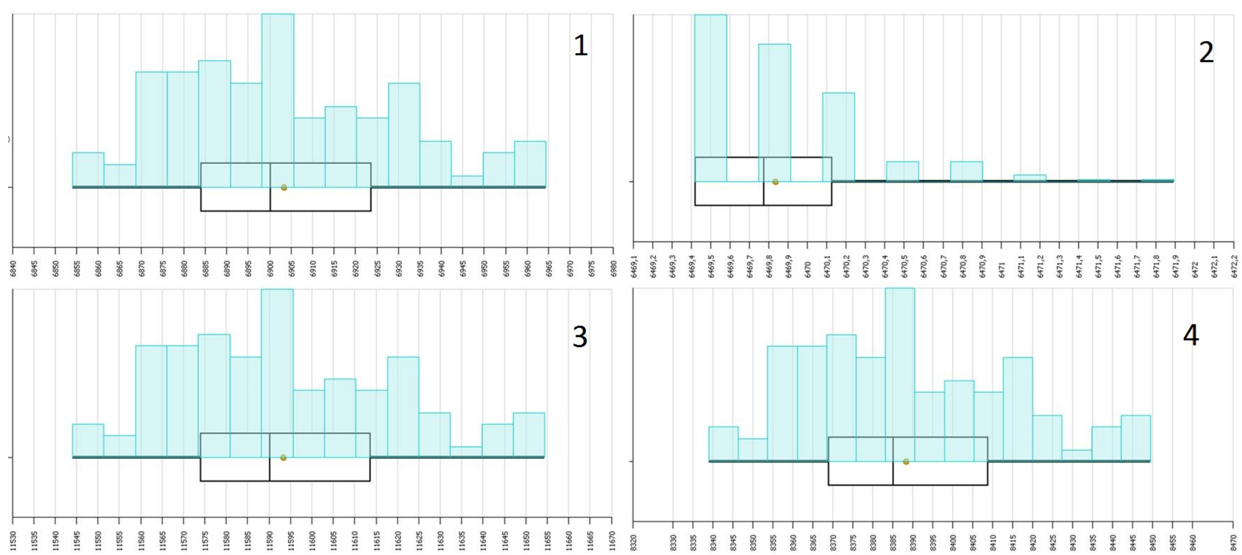

Figure 8: Histogram of all four scenarios.

The results could be observed in Table 3.

5 CONCLUSIONS AND DISCUSSION

By the analysis of the scenarios, it could be identified that scenario 2 was the best with the shortest total occupancy time, meaning that all 501 soccer fans have taken about 1 hour and 47 minutes to accomplish the occupation process. In contrast, the worst scenario was the number 3, which resulted in 3 hours and

Table 3: Results of all scenarios.

Scenario	Total occupancy time Seconds	Minutes
Scenario 1	6,903.3	115.0
Scenario 2	6,469.8	107.8
Scenario 3	11,590.2	193.2
Scenario 4	8,388.2	139.8

13 minutes for the same process. This result indicates that an existence of a dispatcher organizing the occupation can make the population occupy a bleacher in about half of the time.

The benefit of the dispatcher can be intuitively explained because they leave no room for delays during the process, however the numbered seats without a dispatcher policy makes the system much slower (scenario 3). For the research group it sounded counter intuitive at first, but also makes sense since the soccer fan do not know where the seat is located. Consequently, this time was wasted in searching the seat, ”learning” the logic of the place. Moreover, it incurs in the crowd an instability due to short delays generated all over the place. Hence, an immediate conclusion drawn is the fact that investing in pre-assigned tickets without having a dispatcher is an erroneous policy that can drive the crowd into danger. Beyond those analysis, a more qualitative one can be realized, leaving room for deeper investigation. Such qualitative considerations can be summarized into the Table 4. In the table, each X mark represents an association between the scenario and the qualitative dimension.

Table 4: Qualitative analysis of all scenarios.

Scenario	Description	Numered	Dispatcher	Blocking	Localization Delay	Dispatch Delay	Security	Cultural Influence
1	Random			X				
2	Ordered		X				X	X
3	Numbered Seats	X		X	X			
4	Numbered Seats + Dispatcher	X	X	X		X	X	

Under this perspective, it can be observed that scenario 1 resulted in the second shortest occupancy time, so there was a reduction on the total occupancy time. Additionally, there was a cultural advantage considered in a soccer arena in Brazil: the fact that the fans can freely chose a seat (policy adopted today in the majority of the arenas). In this way, they are free to decide the position to watch the game. On the other side, there are two disadvantages in such scenario: (1) lack of security due to the lack of formal organization to find the seat, and (2) the frequent blocking generated by the person who is already sitting, and need to be disturbed to the other person find his seat.

As seen previously, such disturbance can drive the crowd into danger, whereas scenario 2, obviously, represents the most beneficial set of characteristics. The supporters receiving directions from the dispatcher can generate more organization and comfort. Security is guaranteed during the occupation process. Nevertheless, it can be observed advantages in the reduction of the blocking occurred by a person previously sitting in the bleachers avoiding the necessity to wait until the path is released. On the other hand, under the practical standpoint it can be observed a hard culture change effort to implement such policy. The reason is the discipline to receive the dispatcher direction and follow it with no argument of complaint. In some countries, such as Brazil, this practice can be hardly accepted. Scenario 3 remains the worst option because of the long occupancy time and the lack of the dispatcher as well. The possession of the ticket can confuse the supporter once they will need to find their seat with no professional help leading. It can lead the crowd into a feeling of lack of security. This scenario brings only one positive aspect: the lack of necessity to find a seat with better view, because the seat number was decided previously. Finally, scenario 4, even though it was not the fastest, can be considered the most rational and organized one due to the pre-assigned seats with the dispatcher support. Among all scenarios explored, this can be considered the one that maximizes the comfort and safety of the team supporters. Of course such performance should be reached if the dispatchers are well trained; otherwise queue would be formed to be helped by them. Hence, based on this analysis, the recommendation for the infrastructure built in soccer stadiums is the use of scenario 2 policy if cultural elements allow it to work, meaning that people are already used to it and no negative consequence can be raised by such policy. It delivers more efficiency, organization, security, and comfort. On the other hand, the fourth scenario also represents organization, safety, and comfort. However, it brings together the disadvantage of a delay in the occupation time due to the necessity to be oriented by the dispatcher.

Infrastructure decisions are expensive and a deep analysis into the system is mandatory to avoid wasting money in erroneous decisions. Tacit knowledge is important but is not enough for such analysis. In this type of decision, simulation demonstrated to be extremely important. Simulating real life systems before building can lead the decision maker to challenge assumptions never challenged before, leaving less room for fundamental mistakes that cannot be worked around after the construction is finished. Using a simulation tool you can effectively see the system running in the screen of the computer. This practice implies into lower costs, lower mistakes, and more efficiency, hence more success in those types of projects. A natural extension of this study is the incorporation of all four segments of the stadium. In terms of results, there will be no much change. However the occupation time of a complete stadium can be a benchmark used by authorities. In addition, further investigation can be realized in the process before the gate, and this means that the queue formed outside of the stadium could be theme for research because if supporters arrive too early, it can be used as an advantage to have a constant flow into the stadium, diving even more security to the fans. Another idea is the relaxation of the constraint which states that all person needs to be oriented by the dispatcher. There are regular fans that know well the stadium and do not need the dispatcher orientation. In this case, the occupation time can be reduced even with the presence of the dispatcher, and it will increase the safety as well.

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