

EvacuWise: Optimization Of Indoor Earthquake Egress Routes In San Miguel National High School Using Dijkstra's Algorithm

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Abstract—This study developed EvacuWise, a static indoor earthquake egress-routing framework for San Miguel National High School using Dijkstra's Algorithm and measured building-pathway data. Forty-three physical buildings and facilities were represented through 42 weighted undirected graph models because Buildings 1 and 2 were treated as one connected model. Across these graphs, 935 vertices and 930 measured edges represented doors, corners, stairways, and designated exits. A Python implementation of Dijkstra's Algorithm computed the minimum-distance route from every door to the nearest reachable exit. The analysis generated 411 door-to-exit routes with distances ranging from 0.30 m to 69.85 m, with a mean (M) of 20.29 m and a standard deviation (SD) of 16.76 m. The longest route occurred from Door 65 of Building #10, Department of Education (DepEd) Standard School Building 4 (Laboratory), at 69.85 m. Model-derived travel-time estimates ranged from 0.23 s to 70.00 s using route-segment speed parameters embedded in the computational script; 233 routes (56.7%) included at least one stair segment. Route maps were generated to visualize the computed paths and their destination exits. The findings show that graph-based shortest-path analysis can convert measured school layouts into reproducible static egress plans and can identify buildings with longer or more complex indoor travel paths. The resulting maps are intended for preparedness planning and future supervised drills may help examine the effects of capacity, congestion, and bottlenecks on the computed routes.

Keywords—Dijkstra's Algorithm; indoor evacuation; weighted graph; earthquake preparedness; shortest path

I. Introduction

Public safety is one of the most fundamental aspects of human life, yet it is continuously threatened by natural hazards, particularly earthquakes that strike without warning. Globally, earthquakes are among the most destructive geophysical hazards, impacting millions of people through displacement and infrastructure damage [1]. These impacts extend beyond immediate effects to long-term disruptions of essential services, education systems, and livelihoods, with adverse socioeconomic consequences documented in multiple contexts [2]. Such realities highlight the need for effective, evidence-based evacuation strategies that enhance safety by providing clear and efficient routes from occupied spaces to safe exits during seismic events.

The Philippines is especially vulnerable to earthquakes due to its location along the Pacific Ring of Fire, a tectonically active zone with multiple subduction zones and active fault systems [3]. According to Rimando et al. [4], the 27 July 2022 Mw 7.0 northwestern Luzon earthquake demonstrated the complex tectonic activity associated with faults and plate convergence in Luzon. The Philippine Institute of Volcanology and Seismology (PHIVOLCS) reports that the country experiences an average of

20 to 30 earthquakes every day, equivalent to approximately 7,300 to 11,000 earthquakes annually [3]. These conditions establish the need for continuous research on earthquake preparedness and efficient movement of people to safety.

The high level of seismic activity in the Philippines is primarily associated with numerous active faults and tectonic boundaries [4]. Another major source of seismic hazard is the Valley Fault System, composed of the West Valley Fault and East Valley Fault, which traverse densely populated areas in Metro Manila and nearby provinces [5]. Luzon remains one of the regions facing considerable earthquake risk because several major active faults traverse the island. The West Valley Fault extends approximately 100 kilometers through Bulacan, Metro Manila, Rizal, Laguna, and Cavite and is capable of generating a magnitude 7.2 earthquake commonly referred to as “The Big One” [6]. Bulacan is particularly at risk because the fault passes through the municipalities of Doña Remedios Trinidad, Norzagaray, and the City of San Jose del Monte [6]. These conditions emphasize the importance of preparedness, land-use planning, and effective evacuation strategies.

Schools are among the most vulnerable places during earthquakes because they contain large numbers of students, teachers, and staff gathered in one area. During a strong earthquake, panic, damaged buildings, blocked exits, and limited movement can make evacuation difficult. Traditional preparedness activities such as “duck, cover, and hold” address immediate protective actions but do not evaluate the efficiency of routes leading from classrooms to building exits. Indoor egress involves movement through a sequence of connected spaces, including classroom doors, hallways, stair landings, and exits, whose accessibility determines overall evacuation performance. Because school buildings often contain constrained circulation paths, the design of efficient indoor routes becomes an important component of school safety planning [9].

San Miguel National High School, a public secondary institution in San Miguel, Bulacan, had 8,366 enrolled students from Grades 7 to 12 for School Year 2025–2026, in addition to teaching and non-teaching personnel [7]. The province lies within the influence zone of the West Valley Fault System, an active fault capable of generating significant ground shaking that extends through parts of Bulacan [8]. Consequently, San Miguel National High School provides a suitable setting for developing a systematic, data-driven indoor egress plan that considers the spatial arrangement of its occupied spaces, pathways, and exits.

Indoor egress routing focuses on the movement of occupants from occupied spaces inside a building toward available exits during an emergency. Unlike outdoor or city-scale evacuation models that typically analyze road networks and open spaces, indoor models must represent the connectivity of rooms, corridors, stairways, and exits within a single building. According to Astana et al. [10], graph theory provides a suitable mathematical framework for capturing these spatial relationships in school buildings. In this approach, key locations such as classroom doors, hallway junctions, stair landings, and exits are represented as nodes, while walkable connections between them are represented as edges. When actual measured distances are assigned as edge weights, the resulting structure becomes a weighted indoor network that can be analyzed computationally [11].

Applications of shortest-path algorithms have been used in evacuation planning at broader scales, while indoor environments require more detailed modeling of classrooms, hallways, intersections, stairways, and exits. Many existing evacuation planning studies focus on road networks or large outdoor areas using shortest-path and network optimization methods [12], whereas school environments require micro-scale modeling of classrooms, hallways, stairways, and exits [10]. This gap highlights the need to adapt shortest-path optimization to indoor and campus-level evacuation planning using measured distances and detailed building layouts rather than assumptions.

Dijkstra’s Algorithm is widely recognized as an effective method for computing shortest paths in weighted graphs with non-negative edge weights [13]. The algorithm systematically examines nodes and updates tentative distances until the minimum-distance path from a source to a destination is identified. When applied to indoor environments, it can determine the shortest-distance egress route from each selected classroom or occupied space to an available building exit. Astana et al. [10] applied the algorithm to design evacuation routes in a school setting by converting physical locations into nodes and connecting pathways into weighted edges. Gonzales et al. [14] also demonstrated the application of Dijkstra’s Algorithm to earthquake-related evacuation route optimization. These studies establish a scientific basis for using the algorithm to analyze movement through structured indoor spatial networks.

Although Dijkstra's Algorithm efficiently identifies minimum-distance routes, researchers have noted important limitations. Tang and Osaragi [15] demonstrated that evacuation planning after an earthquake may need to consider additional risks, such as post-earthquake fire spread, rather than relying only on distance minimization. The present study adopts a static approach that focuses on measured indoor distances as the primary optimization criterion. This design choice prioritizes computational clarity and remains suitable for preparedness planning rather than real-time navigation.

Despite these developments, a gap remains in evacuation planning, especially for Philippine public school buildings. Comparatively few investigations have addressed indoor earthquake egress routing using actual field measurements and Dijkstra's Algorithm. This gap is especially relevant for schools in seismically active areas such as Bulacan.

The present study addresses this gap by applying Dijkstra's Algorithm to a reconstructed indoor network of San Miguel National High School. Actual distances between connected indoor spaces are measured and used to construct a weighted graph. The algorithm then determines the shortest-distance egress routes from selected classrooms to available building exits. The resulting analysis offers a practical foundation for improving school-based disaster preparedness. A static indoor egress map based on the computed routes will be developed to support the school's disaster risk reduction protocols and provide a visual reference for navigating from occupied spaces to designated exits during earthquake emergencies, in line with Sustainable Development Goal (SDG) No. 11, which aims to make cities and human settlements inclusive, safe, resilient, and sustainable.

1.2 Research Question

This study aims to optimize indoor earthquake egress routes within San Miguel National High School (SMNHS) by applying Dijkstra's Algorithm to the school's actual building layouts and measured indoor pathways. It seeks to determine the shortest routes from individual rooms to designated exit points and present the results through graphs, tables, and visual representations.

Specifically, this study aims to answer the following questions:

1. How can the physical layouts of the buildings of San Miguel National High School be represented as undirected graphs consisting of rooms, pathways, intersections, and designated exit points with assigned unique labels and edge weights?
2. What are the optimal indoor egress routes and corresponding distances from each room to the designated exit point within the same building, as determined using Dijkstra's Algorithm?
3. How can the optimal indoor egress routes be visualized through maps or figures that clearly show the computed paths from rooms to designated exits?
4. How can a computational script implementing Dijkstra's Algorithm be developed and applied to the constructed indoor graphs to systematically compute the optimal egress routes?

II. framework OF THE STUDY

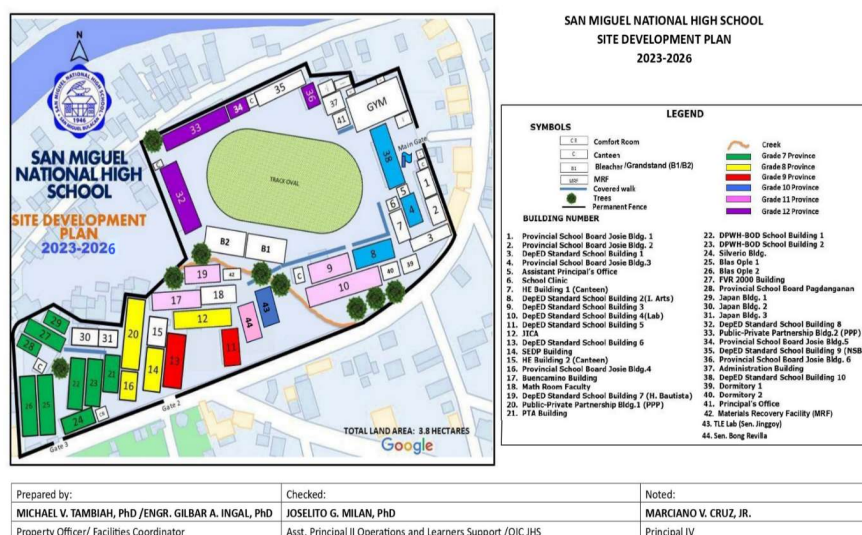
The process will begin with the inquiry of buildings and collection of relevant school references at San Miguel National High School, followed by the identification of indoor egress points and pathways. These identified features will then be converted into graphical representations, with corresponding distance data assigned as edge weights. A computational script implementing Dijkstra's Algorithm will subsequently process the graphical representations to determine the optimal paths. The resulting visualizations and optimal-path data will then be analyzed based on their calculated distances and pathway sequences.

III. MATERIALS AND METHODS

2.1 Inquiry of Buildings

This study primarily began by inquiring the school's facilities coordinator to obtain the necessary information regarding the overall layout of the campus. The inquiry helped identify the number of buildings within the school premises and it provided crucial references for the study. The information needed was then collected, alongside certain foundational guides, such as the Site Development Plan (School map), DepEd Standard School Building Guidelines, and other additional relevant details of each building, which served as the baseline for the next steps of the study.

Figure 1. Site Development Plan of San Miguel National High School (2023-2026)



2.2 Identification of Indoor Egress Points and Pathways

To identify the indoor egress points and pathways of each buildings, references from the school map was used. Smart cellular phones were also used to document and store the measurements or data of each building, as well as the identification and location of the nodes and edges which was useful for the representation of the physical layout of each buildings inside the premises of San Miguel National High School.

2.3 Graphical Representation of Buildings

The identified indoor egress points and pathways were converted into graphical representations of each building. Each building was modeled as a weighted undirected graph $G = (V, E)$, where V represents the set of vertices or points in the building, while E represents the set of edges or connections between them. The graphical representations were created and organized using the editing software Canva, this is used for the digital design and visualization of each building. Vertices were classified according to the shapes used in the field diagrams:

Each building layout was first analyzed to carefully identify the doors, stairs, corners, and exits that would serve as vertices in the graph. Each vertex was assigned to its own unique identification number (e.g., 1, 2, 3) to distinguish individual locations and their connections within the graph. The pathways connecting these vertices were represented as edges, shown as lines between connected points. The identified points and their corresponding pathways were then converted into a graphical representation for computational analysis. Figure 3 illustrates the physical locations within the building wherein identified points and pathways were

then converted into the graphical representation in Figure 4. Figure 4 illustrates how physical locations within the building were translated into vertices and how their traversable connections were represented as edges, with each vertex identified by the unique label given for computational processing.

2.4 Data Collection and Weight Input

On-site measurements were conducted to obtain the actual distances of the identified pathways within each building, including both standard and non-standard school buildings. Standard 10 meter tape measure was continuously used to measure the traversable distances along hallways, corridors, stairs, and other pathway sections through-out the measurement process. The measurements were recorded section by section, following the connections between the identified vertices such as doors, corners, turns, stairs, and exits. The measured distances were documented through digital notes to ensure that the collected measurements corresponded with the graphical representations of the buildings.

Figure 2. Sample Illustration of Distances Measured in a Building

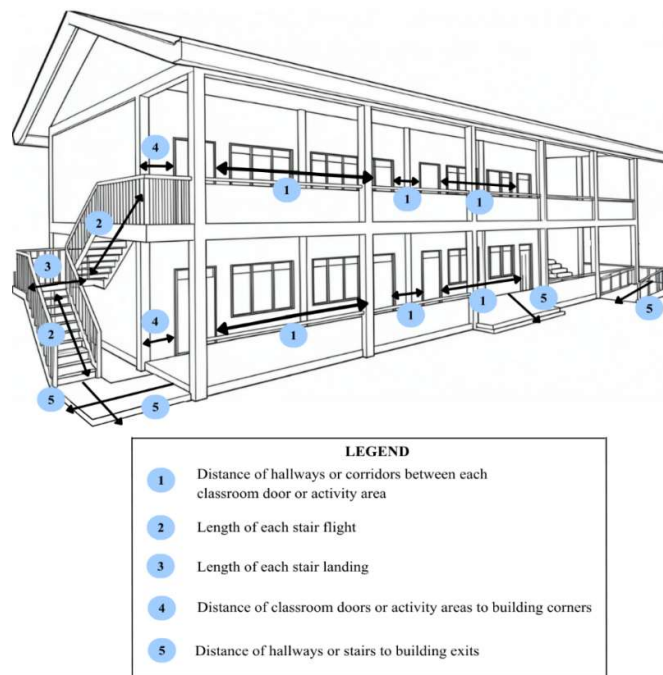


Figure 2 illustrates how pathway distances were measured between identified points within a building. The measurements represent the distances obtained along individual pathway sections and served as the basis for assigning numerical weights to the corresponding edges in the graphical representation of each building. Figure 6 presents the sample graph with edge weights, illustrating how measured distances along indoor egress paths are assigned to the corresponding edges. In the actual graphs, these measurements served as edge weights for Dijkstra's Algorithm to determine the shortest egress routes from identified starting points to exit points within each building. Operational assumptions were applied to features without directly measurable distances. The weight of 0.30 m was assigned to doors or corners that also served as exit points, while 3.00 m was assigned to canteens without doors. These researcher-defined values were used solely for graph construction and computational processing. Complete edge weights were necessary to maintain graph connectivity and exit reachability, as an unmeasured edge could prevent Dijkstra's Algorithm from computing a valid route.

2.5 Computational Implementation of Dijkstra's Algorithm

The computational script used was developed in Python to process the weighted undirected graphs and determine the shortest evacuation routes. The script accepted the identified nodes, edges, and measured distance weights as input. Dijkstra's Algorithm was implemented as the principal method for computing the minimum cumulative distance from each starting point (door) to the designated egress points.

The algorithm assigned zero distance to the source node and initialized all other distances to infinity. It then repeatedly selected the unvisited node with the smallest tentative distance, afterwards the distances of its neighboring nodes is updated whenever shorter paths was found, and the nodes are marked as visited until all shortest-path distances were finalized (Dijkstra, 1959). Because all edge weights were non-negative, the procedure guaranteed the minimum-distance path from each source to every reachable exit. The script subsequently selected the nearest exit for each starting point and reconstructed the corresponding route using the predecessor chain.

The routing procedure employed an adjacency-list representation of each graph together with a binary-heap priority queue. The computational complexity of the implementation was $O((V + E) \log V)$ per source vertex. For descriptive travel-time estimates, the script summed time by route segment using 1.3 m/s for level corridor or ground segments and 0.8 m/s for segments involving stair nodes. These values were adopted as operational model parameters rather than observed drill speeds; therefore, the reported times should be interpreted as scenario-based estimates only.

2.6 Validation of Graph Models and Computed Routes

The computational script used was developed in Python to process the weighted undirected graphs and determine the shortest evacuation routes. The script accepted the identified nodes, edges, and measured distance weights as input. Dijkstra's Algorithm was implemented as the principal method for computing the minimum cumulative distance from each starting point (door) to the designated egress points.

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2.7 Route Analysis

After the shortest paths were computed, the resulting routes were examined to identify the optimal evacuation path from each starting point to the nearest building exit. The total distances of the computed paths were compared to determine the most efficient routes. The analysis focused on identifying the shortest paths, evaluating path efficiency relative to the measured distances, and noting potential implications for school evacuation planning. The findings may serve as a basis for developing a static evacuation map to support the school's disaster risk reduction efforts.

III. Findings and discussion

The findings and discussion are presented according to the four Statements of the Problem (SOPs). For each SOP, the relevant numerical or visual evidence is presented first, followed by interpretation, implication for earthquake preparedness, and comparison or contrast with related studies. All numerical results were derived from the encoded graph data and the consolidated

output of the routing script. Because the study used a static shortest-distance model, the discussion refers to computed egress efficiency and does not claim observed reductions in actual evacuation time.

3.1. Representation of the Physical Layouts as Weighted Undirected Graphs

The physical layouts of San Miguel National High School were successfully represented as 42 weighted undirected graph models covering 43 physical buildings and facilities, with Buildings #1 and #2 encoded as one connected graph. The network consisted of 935 vertices and 930 measured edges, including 411 doors, 119 exits, 140 stairs, and 265 corners. Each vertex represented a specific indoor location, while each edge represented a traversable connection assigned a measured distance as its weight. As summarized in Table 2, this structure provided a consistent representation of the school's indoor spaces and pathways, allowing the physical layout to be processed as a measurable network rather than only as a floor-plan diagram. The use of measured distances also allowed each computed route to be traced to specific indoor pathway segments.

Table 1. *Summary of the Constructed Indoor Graph Network*

Network element	Count	Operational Role
Graph models	42	Building-level weighted undirected networks
Physical buildings/facilities represented	43	Buildings #1 and #2 combined in one graph model
Vertices	935	Doors, exits, stairs, and corners
Doors	411	Source vertices for route computation
Exits	119	Target vertices
Stairs	140	Vertical movement waypoints
Corners	265	Direction-change waypoints
Measured edges	930	Traversable connections with distance weights

This table representation also provided a reproducible spatial structure for the succeeding route computations. Doors, stairs, corners, and exits could be identified within the network, making it possible to examine how their locations and connections affected route distances. The approach is consistent with Gaitanis et al. (2023) and Astana et al. (2023), who also represented indoor spaces as graphs for emergency route planning and Dijkstra-based evacuation analysis. However, EvacuWise constructed its graphs from field-identified points and on-site distance measurements, rather than relying on automated floor-plan recognition. This made the model less automated but more directly connected to the measured geometry of the SMNHS buildings.

3.2. Determination of Optimal Indoor Egress Routes and Corresponding Distances

Table 2. Overall Descriptive Statistics of the Computed Door-to-Exit Routes

Measure	Minimum	Maximum	Mean	Median	SD
Distance (m)	0.30	69.85	20.29	16.66	16.76
Model-derived time (s)	0.23	70.00	19.64	15.58	17.36

Using the weighted graph network established in SOP 1, Dijkstra's Algorithm generated 411 minimum-distance door-to-exit routes within the school buildings. As presented in Table 2, route distances ranged from 0.30 m to 69.85 m, with a mean of 20.29 m, a median of 16.66 m, and a standard deviation of 16.76 m. The middle 50% of the routes ranged from 6.44 m to 30.61 m. The longest computed route was 69.85 m, connecting Door 65 to Exit 20 in Building #10, DepED Standard School Building 4 (Laboratory), with a model-derived travel-time estimate of 70.00 s. Route length differed across buildings because of variations in corridor length, number of floors, internal connectivity, and the location of exits relative to occupied spaces.

Table 3. Buildings with the Twelve Longest Maximum Computed Egress Routes

Bldg.	Building	Doors	Min (m)	Max (m)	Mean (m)
10	DepED Standard School Building 4 (Lab)	40	4.40	69.85	38.95
32	DepED Standard School Building 8	32	5.65	64.68	35.33
38	DepED Standard School Building 10	32	1.63	61.60	32.47
9	DepED Standard School Building 3	24	3.50	49.04	26.10
33	Public-Private Partnership Bldg. 2 (PPP)	21	3.90	44.24	23.09
17	Buencamino Building	20	1.34	41.47	16.68
8	DepED Standard School Building 2 (I. Arts)	14	1.39	38.57	21.25
13	DepED Standard School Building 6	24	3.27	37.48	21.43
1&2	Provincial School Board Josie Bldg. 1 & 2	16	2.56	36.88	17.71

11	DepED Standard School Building 5	16	3.27	36.74	21.41
20	Public-Private Partnership Bldg. 1 (PPP)	16	3.13	35.86	19.44
34	Provincial School Board Josie Bldg. 5	8	1.60	30.16	15.44

The building-level pattern in Table 3 further shows this variation, with Buildings #10, #32, and #38 having maximum computed route distances of 69.85 m, 64.68 m, and 61.60 m, respectively. In contrast, smaller offices and simple single-corridor buildings generally had shorter routes because exits were closer to the starting doors. Figure 3 also presents a right-skewed distribution, with most routes concentrated at shorter distances and fewer routes extending beyond 50 m. Of the 411 routes, 233 (56.7%) included at least one stair node, which affected the model-derived travel-time estimates because stair segments used a lower speed parameter than level pathways. These findings provide building-specific distance references for preparedness planning, while the computed times remain scenario-based estimates rather than measurements of actual evacuation duration.

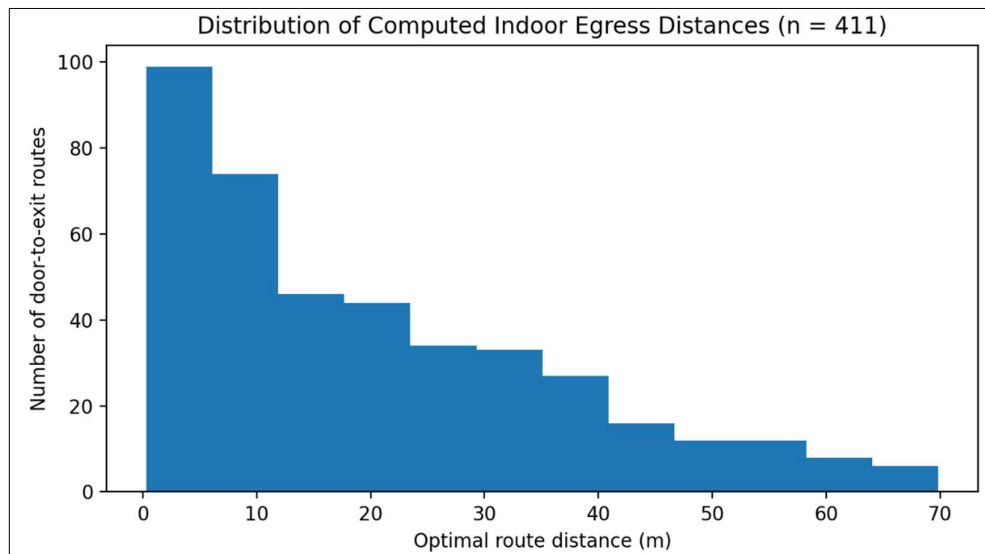


Figure 3. *Distribution of Computed Optimal Indoor Egress Distances*

3.3. Visualization of the Optimal Indoor Egress Routes

The computed routes were converted into static shortest-path maps for each graph model, with the original vertex labels and symbols retained. Each map overlays the route from every door to its selected nearest reachable exit, allowing the numerical route outputs to be viewed as actual indoor movement paths rather than only as route sequences.

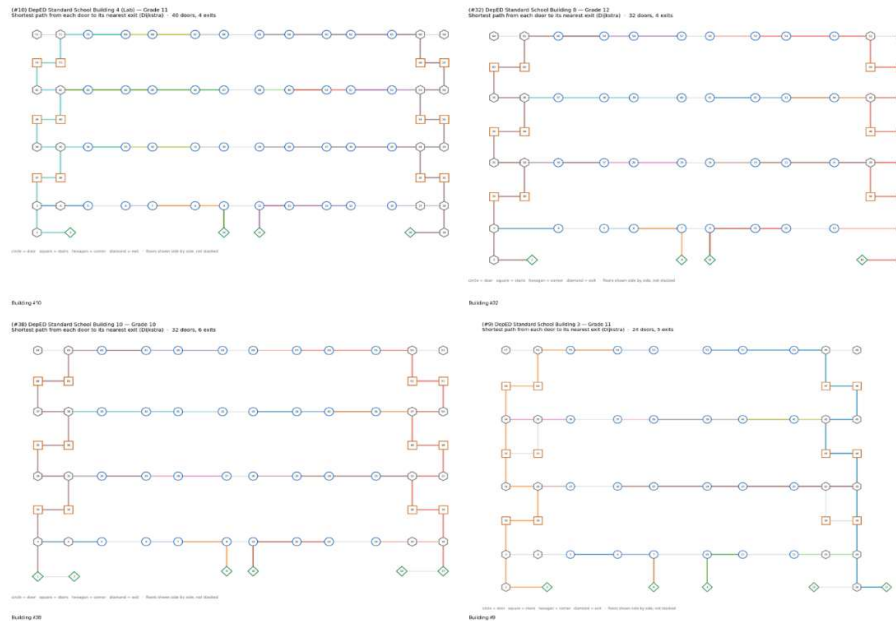


Figure 4. Representative Computed Route Maps for Buildings #10, #32, #38, and #9

Figure 4 presents representative route maps for Buildings #10, #32, #38, and #9, which contain some of the longer computed routes. Their larger and more complex layouts include multiple doors, corners, stairs, and exits, resulting in a greater number of possible paths. The route overlays provide a visual reference for reviewing and posting building-specific evacuation routes, while the complete graph diagrams are retained in the appendices for checking individual node sequences.

The maps remain static representations of the measured indoor network. They do not account for congestion, damaged corridors, blocked doors, debris, or changes in accessibility during an earthquake. Thus, the visualized paths serve as preparedness references that still require on-site review and validation through evacuation drills before actual use.

3.4. Development and Application of the Dijkstra Routing Script

The Python script was developed to apply the same Dijkstra routing procedure across all **411 door sources** in the constructed indoor graphs. For each source, the script built an adjacency list, calculated tentative distances using a binary-heap priority queue, selected the nearest reachable exit, reconstructed the route, and calculated its distance and model-derived travel time. The resulting building, door, exit, distance, time, and vertex sequence were then exported into a consolidated CSV file, making the routing process consistent across the analyzed buildings.

The script also included automated checks for **node-label completeness, orphan nodes, graph connectivity, and exit reachability**, together with a manual review of the encoded diagrams and edges. These checks supported consistency between the measured layouts, graph structures, and computed routes. Since Dijkstra's Algorithm produces the same shortest path for a fixed weighted graph, the workflow can be repeated when building measurements or access conditions are updated. However, the script uses a static network and does not account for congestion, structural damage, debris, or temporary blockages, so its outputs remain computational route references rather than predictions of actual evacuation behavior.

IV. Conclusion

EvacuWise demonstrated that the indoor layouts of 43 physical buildings and facilities at San Miguel National High School can be systematically converted into 42 weighted undirected graph models and analyzed through Dijkstra's Algorithm. Across 935 vertices and 930 measured edges, the system computed 411 shortest door-to-exit routes, identified substantial differences in route

length among buildings, generated interpretable static route maps, and applied a reproducible Python workflow for campus-wide processing. Taken together, the four SOPs show that graph-based shortest-path analysis can provide a measurable and transparent baseline for school earthquake egress planning. The resulting paths should nevertheless be treated as static preparedness references rather than predictions of actual human evacuation behavior because congestion, hazards, blocked routes, and structural changes were outside the current model.

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