International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

# A Data-Informed Framework for Reliability-Aware Emergency Ambulance Route Planning Using Graph Theory: A Methodological Case Study of Kurukshetra District, Haryana, India

**Advit Bhardwaj[1], Ananya Bhardwaj[2], Prof. Rupak J. Nath**

[1,2]Class XII, Wisdom World School, Kurukshetra, Haryana, India
[3]Research mentor, Applied Mathematics | Computer Science | Operations Research

**ARTICLE TYPE: METHODOLOGICAL CASE STUDY AND PUBLIC-DATA INVENTORY**

**Publication and evidence-status note**

This manuscript is presented as a completed methodological case study and public-data inventory, not as a completed empirical test of ambulance travel-time performance. The official public source inventory has been incorporated, but a geospatial road-network extraction, coordinate validation, route computation and traffic-scenario experiment have not been executed for this version. Accordingly, this paper reports no invented route times, percentage improvements, statistical significance, or claims of improved real-world ambulance response. It is suitable for consideration by a journal that accepts methodological or data-resource papers, subject to peer review and journal formatting. It must not be submitted as an empirical performance evaluation until the computational experiment described below has been run and its outputs inserted.

**Abstract:**

Emergency medical transport is influenced by road-network connectivity, travel-time uncertainty and the availability of appropriate receiving facilities. This paper develops a transparent, reproducible framework for studying reliability-aware ambulance route planning in Kurukshetra district, Haryana, India. The road system is represented as a directed weighted graph, with road segments assigned baseline travel-time estimates and scenario-dependent perturbations. Dijkstra's algorithm and A* search are specified as static shortest-path baselines. A reliability-aware route-selection criterion is formulated to balance expected journey time and travel-time variability across a finite set of candidate routes. To ground the case study in documented local healthcare infrastructure, the paper transcribes a government-published district list of 60 Ayushman Bharat–PMJAY empanelled facilities dated 16 December 2025: 24 public and 36 private entries. The register is supplied as a companion CSV. Empanelment is treated only as evidence that a facility appears in the scheme list; it is not taken as proof of 24-hour emergency capability, ambulance acceptance, clinical suitability or current operation. The paper specifies the geospatial inputs, simulation design, evaluation measures, reproducibility requirements and validation steps needed for a subsequent computational evaluation. Because coordinates and route outputs have not been verified and computed in this version, no local route-performance findings are claimed. The

contribution is a locally grounded, auditable research protocol and facility-data inventory that can support a subsequent empirical study.

**Keywords:** ambulance routing; emergency medical services; graph theory; Dijkstra algorithm; A* search; travel-time reliability; stochastic simulation; OpenStreetMap; Kurukshetra; healthcare accessibility.

## 1. Introduction

Emergency medical transportation is a time-critical component of healthcare access. The road route connecting an incident location to a receiving facility can influence transport duration, but route choice is only one component of emergency response. Dispatch delay, ambulance availability, crew capability, traffic regulations, clinical triage, receiving-facility capacity and patient condition also influence outcomes. A road-network model should therefore be interpreted as a transport-planning model rather than a complete emergency medical service (EMS) model.

Shortest distance does not necessarily imply shortest travel time. Road class, speed limits, one-way restrictions, junction geometry, access restrictions and congestion can change the relative performance of alternative paths. In addition, a route with a low mean journey time may have greater variability than a slightly slower but more predictable route. For emergency transport, this motivates explicit consideration of both expected travel time and reliability.

This paper focuses on the mathematical and computational structure required to compare static shortest-path algorithms with a risk-sensitive candidate-route selection method. Kurukshetra district provides a meaningful local context because public records identify a distributed network of public and private health facilities. The study deliberately separates verified administrative information from unverified operational assumptions.

### 1.1 Research question

How can a reproducible, reliability-aware graph-routing framework be specified and populated with publicly documented healthcare-facility data for a district-level ambulance transport case study in Kurukshetra?

### 1.2 Objectives

- Define a directed road-network graph and a consistent baseline travel-time weight.
- Specify Dijkstra and A* as static shortest-path reference algorithms.
- Formulate a route-level reliability score using mean travel time and travel-time variability.
- Compile a traceable register of district facilities appearing in the official AB-PMJAY list dated 16 December 2025.
- Define the coordinate verification, scenario generation, route evaluation and sensitivity-analysis steps required for empirical testing.
- Distinguish administrative facility listing, modelled road accessibility and actual emergency-care capability.

## 2. Background and related work

### 2.1 Shortest-path algorithms

Dijkstra's algorithm computes shortest paths in graphs with non-negative edge weights (Dijkstra, 1959). A* search orders exploration using $f(n)=g(n)+h(n)$, where $g(n)$ is the accumulated path cost and $h(n)$ is a

heuristic estimate of the remaining cost (Hart, Nilsson, & Raphael, 1968). For road routing, a straight-line distance divided by a defensible upper-bound speed can be used as a lower-bound time heuristic; the heuristic must remain admissible for optimality guarantees.

### 2.2 Open road-network data

OpenStreetMap (OSM) provides community-maintained geographic data. OSMnx enables the acquisition, construction, analysis and visualisation of street networks from OSM (Boeing, 2017). Network completeness, road classification, access restrictions, one-way attributes and speed data should be inspected. When speeds are imputed rather than observed, resulting travel times must be labelled as estimates.

### 2.3 Time-dependent and stochastic routing

Time-dependent routing considers travel costs that vary with departure time, while stochastic routing represents uncertainty in travel costs. Reviews by Gendreau, Ghiani and Guerriero (2015) and Adamo et al. (2024) describe the modelling challenges and algorithmic approaches associated with time-dependent routing. Lecluyse, Van Woensel and Peremans (2009) examine vehicle routing under stochastic time-dependent travel times. The present framework uses repeated scenario-based edge perturbations as a tractable first-stage model; it is not a fully time-dependent FIFO routing algorithm.

### 2.4 Ambulance system planning

Ambulance location, fleet composition, dispatch and routing are related but distinct decisions. Yoon, Albert and White (2021) use stochastic programming to study ambulance location and dispatch decisions. The present study isolates the road-route component and does not infer ambulance stationing, dispatch policy or clinical outcomes from route calculations.

### 2.5 Positioning of the contribution

The contribution is not a new shortest-path algorithm. It is a transparent local framework that combines established graph algorithms, an explicitly defined risk-sensitive route score and a source-traceable district facility inventory. Its empirical value will depend on verified coordinates, a documented road-network snapshot and measured or carefully justified travel-time assumptions.

## 3. Study area and public facility inputs

The case-study geography is Kurukshetra district, Haryana, India. The District Administration's public utilities page identifies district health services spanning a district civil hospital, community health centres, primary health centres and village sub-health centres. The Haryana Health Department publishes a facility directory dated 5 May 2025. In addition, the official AB-PMJAY district empanelment document dated 16 December 2025 lists 60 Kurukshetra facilities. The latter is used here as a reproducible administrative inventory, not as a definitive emergency-care destination list.

The 60 entries comprise 24 public facilities and 36 private facilities. The list includes primary health centres and community health centres as well as hospitals and specialist facilities. Some entries are generic or contain spelling/formatting irregularities in the source; the CSV preserves a readable transcription and flags that names and coordinates require verification. The source list does not itself provide geographic coordinates or establish 24-hour emergency receiving capability.

**Table 1. Administrative facility inventory from AB-PMJAY list (16 December 2025)**

| Facility category in source | Count | Interpretation |
|---|---|---|
| Public empanelled facilities | 24 | Administrative public-sector listing; operational emergency |

| | | |
|---|---|---|
| | | role not assumed |
| Private empanelled facilities | 36 | Administrative private-sector listing; operational emergency role not assumed |
| Total listed entries | 60 | Source inventory; duplicate/name/operational checks required |

A separate facility register is supplied as ERRM_Kurukshetra_Facility_Register.csv. It records the source transcription, facility type and explicit data-quality flags. Contact details have been excluded from the research input file because they are unnecessary for network modelling.

### 3.1 Destination eligibility rules

A facility should enter the final routing destination set only after its exact name, current operating status, latitude/longitude, facility level and emergency receiving capability have been checked using an official source or authorised confirmation. An AB-PMJAY entry is not sufficient evidence of emergency department availability. Eye-care-only facilities, for example, should not be treated as general emergency destinations without a clinical basis. The destination set should therefore be stratified by verified capability rather than indiscriminately using all 60 entries.

### 3.2 Road-network data

The proposed road network is a directed driving graph obtained from OpenStreetMap through OSMnx. The final empirical version should archive the OSM extraction date, study boundary, network query, OSMnx and NetworkX versions, graph simplification settings, edge attributes and the raw graph snapshot. The OSM data must be attributed to OpenStreetMap contributors and used in accordance with the Open Database License.

### 3.3 Origin sampling

Origins should represent a transparent sample of settlements or grid points distributed across the district. Candidate urban and settlement centres may include Thanesar/Kurukshetra, Pipli, Shahabad Markanda, Ladwa and Pehowa, but each origin coordinate must be independently verified and recorded with its source and date. A reproducible design should use at least five origins and a capability-verified subset of receiving facilities. No coordinate is fabricated in this paper.

## 4. Mathematical model

### 4.1 Directed road graph

Let $G=(V,E)$ be a directed graph, where $V$ is the set of road-network nodes and $E$ is the set of directed road segments. Each edge $e \in E$ has length $d_e>0$ and baseline estimated travel time $t_e>0$. For a route $P$, baseline travel time is $T_0(P)=\Sigma(e \in P)t_e$, and route distance is $D(P)=\Sigma(e \in P)d_e$.

### 4.2 Static shortest-path baselines

Dijkstra's algorithm minimises $T_0(P)$ over all feasible paths between an origin and destination. A* uses $f(n)=g(n)+h(n)$, with $g(n)$ equal to accumulated baseline time and $h(n)$ an admissible lower bound on remaining travel time. Both algorithms must use the same graph, edge weights and origin/destination snapping procedure. Their optimal route costs should agree within a declared numerical tolerance.

### 4.3 Scenario-based travel-time model

For scenario r, define a non-negative multiplier $M_{e,r}$ for each edge e. The scenario travel time is $t_{e,r}=t_e M_{e,r}$. A practical experiment may define normal, moderate-congestion and heavy-congestion regimes using explicitly declared multiplier distributions. A disruption regime may additionally remove a pre-specified fraction of eligible edges or close selected links. These are synthetic stress tests unless calibrated against measured local observations. A fixed random seed and saved scenario draws are required for reproducibility.

### 4.4 Route-level reliability score

For a fixed route P evaluated across R scenarios, let $T_r(P)=\Sigma(e\in P)t_{e,r}$. Let $\mu(P)$ be the sample mean of $T_r(P)$ and $\sigma(P)$ its sample standard deviation. The risk-sensitive score is:

$$\mathbf{J(P;\lambda) = \mu(P) + \lambda\,\sigma(P), \quad \lambda \geq 0}$$

The parameter $\lambda$ controls sensitivity to variability. $\lambda=0$ ranks routes by mean scenario travel time. Larger $\lambda$ values penalise variability more strongly. The selected route is the minimum-score route within a finite candidate set C_K generated from baseline shortest and alternative paths. Because C_K is finite, the method is a candidate-set heuristic and is not guaranteed to find a global optimum of the risk-sensitive objective.

### 4.5 Important modelling distinction

The proposed scenario evaluation computes route costs under a collection of static edge-weight snapshots. It does not model within-trip time evolution, departure-time-dependent congestion, queue spillback or FIFO travel-time functions. It should therefore be described as scenario-based stochastic route evaluation, not as a fully time-dependent routing algorithm.

## 5. Proposed computational protocol

**Step 1 — Freeze and document the network**

Download the district driving graph, archive the raw file, record retrieval date and software versions, and inspect missing or implausible edge attributes.

**Step 2 — Verify locations**

Prepare a location register with unique ID, name, facility class, latitude, longitude, coordinate source, verification date and emergency-capability status. Snap each point to the nearest eligible road node and manually inspect suspicious snaps.

**Step 3 — Establish baseline routes**

For each origin–destination pair, run Dijkstra and A* with identical non-negative baseline travel-time weights. Record route length, travel time, expanded nodes and runtime.

**Step 4 — Generate scenarios**

Generate normal, moderate, heavy and disruption scenarios with fixed seed and saved parameters. Use at least 100 replications per scenario where feasible; report the actual number used.

**Step 5 — Evaluate candidate paths**

Generate a declared number K of candidate paths per pair. Evaluate every candidate against the same scenario ensemble and calculate $\mu$, $\sigma$, 95th percentile and $J(P;\lambda)$ for pre-specified $\lambda$ values.

**Step 6 — Sensitivity analysis**

Vary congestion severity, closure fraction, K and $\lambda$. Report whether selected routes and rankings remain stable.

**Step 7 — Validate and archive**

Check disconnected pairs, route feasibility, graph connectivity, output consistency and reproducibility. Archive code, input register, network metadata, scenario seed and result CSVs.

## 6. Evaluation measures and analysis plan

- Baseline route distance (km) and estimated travel time (minutes).
- Mean scenario travel time $\mu(P)$, standard deviation $\sigma(P)$, and 95th-percentile travel time.
- Route reachability and number of disconnected origin–destination pairs under each disruption scenario.
- Algorithm runtime measured on the same hardware and software environment; report median and interquartile range across pairs.
- Route overlap or path-change frequency across scenarios and values of $\lambda$.
- Paired comparisons of route travel times under identical scenario draws; confidence intervals should be computed using an appropriate paired or bootstrap procedure.

The final empirical article should provide descriptive summaries for every scenario and $\lambda$ value, not only selected examples. Any inferential test should be justified by the sampling and simulation design. Simulation replications are not independent observations of real-world ambulance operations and must not be presented as such.

## 7. Findings supported by the present evidence

The completed work in this version is documentary and methodological. The official AB-PMJAY source supports an inventory of 60 listed district facilities, consisting of 24 public and 36 private entries as of 16 December 2025. The District Administration and Haryana Health Department sources establish that the district has a broader public healthcare network, including hospitals, CHCs, PHCs and sub-centres. These administrative sources do not provide the validated geospatial and operational variables required to calculate ambulance travel times.

No road-network graph was processed for this manuscript version. Consequently, no Dijkstra/A* route comparisons, scenario travel-time distributions, runtime measurements, reliability-score rankings, or percentage improvements are reported. The hypotheses concerning route differences and reliability trade-offs remain testable propositions rather than findings.

## 8. Discussion

The main methodological implication is that facility enumeration and route optimisation require different layers of evidence. A district facility list can identify candidate destinations, but routing requires coordinates and a road graph, while emergency suitability requires information about operating status, clinical services and ambulance acceptance. Treating every empanelled facility as an equivalent emergency destination would create a construct-validity problem.

The proposed risk-sensitive score offers an interpretable way to examine the trade-off between expected journey time and variability. Its usefulness depends on scenario calibration and transparent candidate generation. If the scenario multipliers are arbitrary, the results can only demonstrate algorithm behaviour under assumptions; they cannot estimate actual local travel-time reliability. A subsequent study should therefore distinguish uncalibrated stress testing from calibrated simulation based on observed traffic data.

The framework also highlights the limits of static route planning. Real ambulance operations may require departure-time-dependent routing, priority rules, dispatch coordination and facility capability constraints. These extensions should be introduced only when suitable data and operational expertise are available.

## 9. Limitations

- The facility inventory is an administrative AB-PMJAY listing and is not a verified list of emergency receiving facilities.
- Facility names in the source include spelling variants and generic entries; the supplied register preserves transcription but requires local verification.
- Coordinates have not been geocoded or independently checked in this version.
- No road-network snapshot or route computations are included.
- OSM data may be incomplete or outdated; imputed speeds are estimates unless supported by local observations.
- Synthetic traffic multipliers and closures cannot establish actual traffic distributions or real-world ambulance response improvements.
- The model excludes dispatch delay, fleet availability, ambulance-specific driving behaviour, emergency priority, clinical triage and hospital capacity.
- The candidate-path approach is restricted to a finite set and is not a global optimisation guarantee.

## 10. Ethics, attribution and data governance

The present documentary framework uses public administrative facility information and proposes public road-network data. It does not use patient records, patient-identifiable information or confidential ambulance GPS traces. No emergency-service operations should be interrupted for data collection. Interviews or primary data collection require school approval, informed consent and appropriate privacy safeguards. OpenStreetMap attribution and ODbL obligations must be followed. Facility contact information should not be republished unless necessary and authorised.

## 11. Conclusion

This paper establishes a data-informed, reproducible framework for reliability-aware ambulance route planning in Kurukshetra district. It combines established shortest-path algorithms with a transparent mean–variability route score and grounds the local case study in an official inventory of 60 AB-PMJAY-listed facilities published on 16 December 2025. The key result of the present paper is a verified administrative inventory and a clearly specified computational protocol, not a measured improvement in ambulance response. A subsequent empirical study must validate facility coordinates and emergency capability, extract and archive the road network, execute the route and scenario experiments, and report the resulting data before making performance claims.

## Author contributions

Proposed contribution statement, to be amended to reflect work actually completed: Advit Bhardwaj — graph modelling, algorithm implementation and computational protocol. Ananya Bhardwaj — facility register preparation, source verification and analysis design. Both authors — research question, literature

review, interpretation and manuscript approval. The final statement must accurately describe each author's actual contribution.

**Acknowledgements**
The authors acknowledge Wisdom World School, Kurukshetra, and Prof. Rupak J. Nath for research mentorship, subject to institutional approval and confirmation by the named individuals.

**Funding**
No external funding was reported for preparation of this manuscript. Amend if institutional or other financial support was received.

**Competing interests**
The authors should confirm the journal's required declaration. If accurate, use: "The authors declare no competing interests."

**Data and code availability**
The facility register accompanying this manuscript is derived from the official AB-PMJAY district empanelment list dated 16 December 2025. The road-network graph, verified coordinate register and route outputs are not included because they have not yet been generated. The experiment code should be deposited with a versioned repository before an empirical follow-up submission.

**Generative AI disclosure**
Generative AI assistance was used to support language editing, manuscript organisation and preparation of the facility-register transcription. The student authors and mentor must independently verify all source data, citations, mathematical expressions and any future computational results. The disclosure must be adapted to the target journal's current policy.

**REFERENCES:**

1. Dijkstra, E. W. (1959). A note on two problems in connexion with graphs. Numerische Mathematik, 1, 269–271. https://doi.org/10.1007/BF01386390
2. Hart, P. E., Nilsson, N. J., & Raphael, B. (1968). A formal basis for the heuristic determination of minimum cost paths. IEEE Transactions on Systems Science and Cybernetics, 4(2), 100–107. https://doi.org/10.1109/TSSC.1968.300136
3. Boeing, G. (2017). OSMnx: New methods for acquiring, constructing, analyzing, and visualizing complex street networks. Computers, Environment and Urban Systems, 65, 126–139. https://doi.org/10.1016/j.compenvurbsys.2017.05.004
4. Gendreau, M., Ghiani, G., & Guerriero, E. (2015). Time-dependent routing problems: A review. Computers & Operations Research, 64, 189–197. https://doi.org/10.1016/j.cor.2015.06.001
5. Lecluyse, C., Van Woensel, T., & Peremans, H. (2009). Vehicle routing with stochastic time-dependent travel times. 4OR, 7, 363–377. https://doi.org/10.1007/s10288-009-0097-9
6. Yoon, S., Albert, L. A., & White, V. M. (2021). A stochastic programming approach for locating and dispatching two types of ambulances. Transportation Science, 55(2), 275–296. https://doi.org/10.1287/trsc.2020.1023

7. Adamo, T., Gendreau, M., Ghiani, G., & Guerriero, E. (2024). A review of recent advances in time-dependent vehicle routing. European Journal of Operational Research, 319(1), 1–15. https://doi.org/10.1016/j.ejor.2024.06.016
8. District Administration, Kurukshetra, Government of Haryana. (n.d.). Public utilities: Health services in Kurukshetra district. https://kurukshetra.gov.in/public-utilities/ (accessed 22 November 2026).
9. Health Department, Government of Haryana. (2025). Details of health facilities as on 05 May 2025. https://haryanahealth.gov.in/infrastructure/ (accessed 22 November 2026).
10. National Health Authority / Government of India. (2025). List of empanelled hospitals of District Kurukshetra (Haryana) under AB-PMJAY as on 16 December 2025. Official district PDF: https://cdnbbsr.s3waas.gov.in/s3169779d3852b32ce8b1a1724dbf5217d/uploads/2025/12/20251219416725671.pdf
11. OpenStreetMap contributors. (n.d.). OpenStreetMap. https://www.openstreetmap.org/ (accessed 22 November 2026).
12. Boeing, G. (n.d.). OSMnx documentation. https://osmnx.readthedocs.io/ (accessed 22 November 2026).

**Appendix A. Facility register transcription**

The following register transcribes the 60 entries in the official AB-PMJAY Kurukshetra district list dated 16 December 2025. It is an administrative source list only. Before use in routing, reconcile spelling, duplicates, coordinates, current operating status and emergency receiving capability.

| No. | Facility name (transcribed) | Type |
|---|---|---|
| 1 | PRIMARY HEALTH CENTER PIPLI | Public |
| 2 | PRIMARY HEALTH CENTRE KALSANA | Public |
| 3 | PRIMARY HEALTH CENTRE (Dhural area; official list entry) | Public |
| 4 | PRIMARY HEALTH CENTER (Thaska Miranji area; official list entry) | Public |
| 5 | PRIMARY HEALTH CENTRE RAMGARH ROR | Public |
| 6 | PRIMARY HEALTH CENTER GUDHA | Public |
| 7 | Polyclinic Sector 4 | Public |
| 8 | PHC Amin | Public |
| 9 | PHC Khanpur Kolian | Public |
| 10 | Community Health Center Ladwa | Public |
| 11 | PHC Ismailabad | Public |

| | | |
|---|---|---|
| 12 | UPHC Krishna Nagar Gamri | Public |
| 13 | CHC Babain | Public |
| 14 | Community Health Center (Jhansa; official list entry) | Public |
| 15 | CHC Mathana | Public |
| 16 | LNJP Civil Hospital (listed as LNJPCIVILHOSPIAL) | Public |
| 17 | CHC Barna | Public |
| 18 | PHC Deeg | Public |
| 19 | CHC Pehowa | Public |
| 20 | PHC Thol | Public |
| 21 | PHC Siana Saidan | Public |
| 22 | PHC Tatka | Public |
| 23 | CHC Shahabad | Public |
| 24 | Primary Health Centre Kirmach | Public |
| 25 | Miri Piri Institute of Medical Sciences and Research | Private |
| 26 | Sant Ishar Singh General & Multispeciality Hospital | Private |
| 27 | Vardha Healthcare Multispeciality Nursing Home | Private |
| 28 | Pawan Surgical Hospital | Private |
| 29 | Saraswati Mission Hospital | Private |
| 30 | Dr Jain Neurocare and Multispeciality Hospital | Private |
| 31 | Shri Narayan Heart & Multispeciality Hospital | Private |
| 32 | Kurukshetra Nursing Home | Private |
| 33 | P D Memorial Chauhan Eye and Maternity Hospital | Private |
| 34 | Agarwal Nursing Home | Private |
| 35 | Shri Balaji Aarogyam Hospital | Private |
| 36 | Anand Orthopaedic Centre | Private |
| 37 | Manju Nursing Home | Private |
| 38 | S Mehta Surgical and Maternity | Private |
| 39 | Verma Hospital | Private |
| 40 | Nand Lal Hospital | Private |
| 41 | Hayer Hospital | Private |
| 42 | Bhaskar Hospital | Private |
| 43 | Vaid Sadhu Ram Memorial (name as listed) | Private |

| | | |
|---|---|---|
| 44 | Saini Eye Care Centre | Private |
| 45 | Kamboj Hospital | Private |
| 46 | Adesh Medical College and Hospital | Private |
| 47 | Soni Orthopedic Hospital | Private |
| 48 | Nagpal Multispeciality Hospital | Private |
| 49 | Apna Hospital | Private |
| 50 | Life Care Hospital | Private |
| 51 | Sobti Nursing Home | Private |
| 52 | Haryana Multispeciality Hospital | Private |
| 53 | Radhakishan Hospital | Private |
| 54 | New Apna Hospital (Red Road) | Private |
| 55 | Virk Hospital | Private |
| 56 | BS Heart Care and Multispeciality Hospital | Private |
| 57 | SIMSS Hospital Kurukshetra | Private |
| 58 | Balaji Hospital & Trauma Centre | Private |
| 59 | Shri Guru Nanak Dev Charitable Eye & Dental Hospital | Private |
| 60 | Sunita Nursing Home | Private |

**Appendix B. Minimum empirical follow-up checklist**

☐ Verify all facility names against the current Haryana Health Department and AB-PMJAY records.

☐ Obtain and verify latitude/longitude for each candidate facility and origin; record source and date.

☐ Confirm emergency receiving capability and exclude facilities not clinically appropriate for the use case.

☐ Download and archive the Kurukshetra driving-road graph; record OSM extraction date and software versions.

☐ Run at least five origins and a justified set of eligible destinations; report all included and excluded pairs.

☐ Run Dijkstra and A* on identical baseline weights and test cost equality.

☐ Run normal, moderate, heavy and disruption scenario ensembles with fixed random seeds.

☐ Evaluate candidate routes across pre-specified $\lambda$ values and perform sensitivity analysis.

☐ Generate route maps, travel-time distribution plots and complete output tables from actual runs.

☐ Replace this methodological paper with an empirical article only after results are reproduced, reviewed and independently checked.