CHAPTER 13

Traditional vs. AI-Enhanced Road Safety Audits: Study on Applicability in India

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ABSTRACT

Normally, the Road Safety Audits (RSAs) in India follow a manual procedure involving physical site visits and qualitative assessments that are in line with IRC SP:88-2019. In a lot of cases, these processes lack the ability to predict and do not have any digital records. A pilot study was conducted that provided a comparison between conventional RSA techniques and modern AI-powered methods. The study examined secondary data that had been gathered through (a) manual audits and checklists and (b) AI-assisted tools, which include visual detection via YOLOv8 and data logging with GPS. The analysis allowed for a comparison of RSAs where AI helped to detect hazards more accurately and therefore needed less time for auditing than traditional methods. The models based on machine learning were able to forecast the areas with the highest risk of crashes, thus making it possible to carry out interventions aimed at prevention before the incidents took place. The AI-based systems were, however, more efficient than the traditional ones but still pointed out the challenges including unavailability of data, the lack of supporting infrastructure, and the demand for trained personnel which makes it hard to scale the solution to a national level. The research indicates that hybrid models, which combine human skills with AI-powered data analytics, are the best solution for India's varied road network in the short term.

Keywords: Road Safety Audits, Traditional Methods, Artificial Intelligence, Machine Learning, Highway Infrastructure.

1.0 Introduction

In India, road traffic accidents keep on causing a lot of trouble to the public regarding safety, especially on the highways that are national and state ones where there is a mixture of different traffic conditions plus the demand for mobility is growing rapidly.

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Road Safety Audits (RSAs) are the proactive globally recognized tool for spotting possible safety deficits in road infrastructure beforehand so that the deficiency does not end up being a crash. In India, RSAs are mainly done according to the guidelines specified in IRC SP:88–2019 which are pointing out the necessity for doing manual site inspections, checklist-based evaluations, and expert judgment.

Despite the fact that traditional RSAs have been a significant contributor to road safety, their effectiveness is often hindered by limitations of subjectivity, spatial coverage, and time-consuming processes, and there is also the lack of predictive capabilities. The dependence on qualitative evaluations and post-construction inspections severely limits the traditional RSAs' capability to detect new risk patterns, especially in the case of high-speed corridors and quickly urbanizing road networks.

New technologies in artificial intelligence (AI), computer vision, and geospatial analytics open up possibilities of enhancing the scope and efficiency of road safety assessments. AI-driven tools, such as deep learning–based object detection models and GPS-enabled data logging systems, facilitate automated detection of road hazards, digital documentation of safety deficiencies, and large-scale spatial analysis of risk factors. When combined with previous crash data, these technologies also provide chances for predictive modeling of high-risk crash zones which makes it easier for safety interventions to be proactive and targeted.

Although AI has already been adopted in transport safety applications globally, its implementation in India for road safety is still very limited. Data inconsistency, lack of infrastructure, and unavailability of qualified personnel are some of the issues that hamper the scalability and reliability of AI in such applications. Therefore, it is imperative to investigate whether AI-based RSAs can only be used as complementary to existing practices instead of being a complete replacement. The current research, therefore, presents a pilot comparative analysis of traditional versus AI-assisted Road Safety Audit methodologies. The study is based on secondary data obtained from manual auditing processes and AI tools that support visual detection models and GPS-based hazard mapping. The main goal is to improve hazard detection accuracy, audit efficiency and predictive capability. Additionally, the researchers will pinpoint the challenges faced during implementation and suggest a hybrid RSA model that would combine human expertise with AI-driven analytics as an ideal solution for India's varied and resource-poor road milieu.

2.0 Literature Review

2.1 Traditional road safety audits in India

In India, Traditional Road Safety Audits (RSAs) have emerged as a widely accepted preventive tool to find road safety flaws in the infrastructure before accidents happen. RSAs

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are conducted through organized field inspections, analysis of accident history, and evaluation based on a checklist, primarily guided by Indian Road Congress documents like IRC SP:88, IRC 67-2012, and IRC 35-1997. The multidisciplinary team of road design engineers, traffic engineers, and safety experts usually assesses road safety elements comprehensively through these audits.

Numerous studies have confirmed the positive impact of traditional RSAs on accident frequency and severity reduction only if the audit recommendations are implemented. For instance, studies on the Noida–Greater Noida Expressway indicated an 84% decrease in crashes and a more than 90% reduction in fatal crashes, thus demonstrating the cost-effective nature of RSAs as a safety-intervention tool (Meghala et al., 2020). National highways and bypass roads across Karnataka, Rajasthan, and West Bengal have reported similar advancements in road safety (Jayaprakash et al., 2019; Arora & Nautiyal, 2024).

Traditional RSA methods are firmly subjected to the literature critique that, despite the above-mentioned successes, still point out their limitations. One main issue is the outdated practice that still depends heavily on qualitative judgment and the use of standard checklists. These methods typically do not consider the traffic situation, land use, and behavior patterns of a particular region (George et al., 2024). Worst of all, the accident data used for audits are often incomplete, inconsistent, and unreliable which, in turn, lowers the accuracy of the risk identification and post-treatment evaluation process to a great extent (Dandona, 2006; Tiwari, 2016). To eliminate subjectivity and to increase objectivity, some recent studies have introduced quantitative scoring methods such as Road Safety Performance (RSP) scores and multi-criteria decision-making methods like Analytic Hierarchy Process (AHP) and Fuzzy AHP. These methods not only help in the application of risky locations but also allow regular comparisons of intervention alternatives (Kanuganti et al., 2017). Still, the use of these techniques is limited mainly due to the lack of data, absence of uniform training, and poor incorporation into the national RSA guidelines. The traditional RSA literature presents a strong procedural foundation that is widely accepted but it also points out the need for the enhancement of the data quality, quantification, and technological integration for the purpose of driving scalability and improving the predictive capabilities.

2.2 AI-integrated road safety studies

Over the past few years, India has seen a significant increase in research that looks into ways of incorporating Artificial Intelligence (AI) into the road safety assessment and auditing processes. A non-conventional method to do road safety assessments (RSAs) is to apply AI-based techniques that are mostly based on machine learning, deep learning, and computer vision which also employ the Internet of Things (IoT) technology, thus allowing for automated hazard detection, large dataset analysis and crash location prediction. These

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new methods of assessment are a major step forward as they not only replace traditional methods that relied on checklists but also bring in data-driven and predictive power. Twelve studies have validated the use of machine learning models like Random Forest, XGBoost, Convolutional Neural Networks (CNNs), and hybrid ensemble methods to predict accident severity and locate high-risk areas on Indian roads (Panicker & Ramadurai, 2022; Girija & Divya, 2024; Khanum et al., 2023). Among the various models based on deep learning and computer vision, the YOLO family of models has been particularly notable for real-time traffic violations, road defects, and unsafe behaviours detection, achieving detection accuracies beyond 95% in controlled settings (Nagaraj et al., 2024).

AI applications have also penetrated into traffic law enforcement, emergency response, and management of road assets. In the southern Indian state of Kerala, AI-equipped CCTV cameras have already been a part of the road safety project and they have been able to produce tangible results in terms of the number of accidents and in terms of the adherence of the road users to the laws regarding helmets and seatbelts (Cheranchery & Greeshma, 2025). The inspection by drones along with CNN-based pavement assessment has been able to achieve a reduction of up to 70% in the time taken for inspection and increase in accuracy (Saini et al., 2025; Chavan & Pimplikar, 2025). Moreover, AI-powered emergency detection systems have shown to be not only time-saving in terms of responding to incidents but also more accurate in predicting the occurrence of collisions (Satheesh et al., 2025). Nonetheless, the literature mentions the significant challenges that inhibit the large-scale adoption of AI in road safety auditing. Among them, the most crucial are poor data quality, absence of uniformly defined datasets, high costs of implementation, the gap between the requirement of technical readiness in the infrastructure and the existing state, and the issues of data privacy and algorithmic transparency that concern potential users (Misra et al., 2023; Sarkar, 2025). Current AI applications are still mainly pilot projects and limited to urban areas, thus lacking testing across rural and semi-urban road networks. Significantly, fresh research accentuates the necessity of incorporating AI results into conventional RSA setups instead of eliminating human competence. The inputs generated by AI, when taken along with the experts' evaluation, are said to facilitate auditing, increase the precision of hazard detection, and support the timely safety measures (Praneetha Devi et al., 2024; Balashivudu et al., 2024). Consequently, the idea that mixed AI–human models are the most realistic and sensitive to the Indian context has gained traction.

2.3 Synthesis and research gap

The literature reviewed suggests that the use of traditional road safety assessments (RSAs) has led to better safety outcomes, yet the methods are subjective, inconsistent data, and lack of a future-oriented approach, which are their drawbacks. On the other hand, the

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application of artificial intelligence (AI) in road safety assessment offers an efficient, large scale and analytically precise process, yet suffers from issues such as lack of data, poor infrastructure, and example countries like India facing difficulties in implementing the technology in real life situations. Apart from this, there is hardly any research that directly pits traditional RSAs against AI-assisted methods and that too in a unified framework.

This shortcoming highlights the necessity of comparative studies that would help in determining the efficiency, accuracy, and viability of AI-integrated RSAs in Indian scenario. The current research takes the bull by the horns as it systematically draws a comparison between conventional methods and AI-assisted ones and also puts forward a hybrid framework that takes advantage of both approaches' strengths.

3.0 Research Methodology

This research relies on a comparative and exploratory design to assess the traditional Road Safety Audit (RSA) methods and the new AI-aided methods in India. The method is based on a systematic review and integration of peer-reviewed papers, conference papers, and government-funded studies to create the theoretical and methodological base for both the conventional and AI-enveloped RSA models. The data for the study is sourced from secondary accident and audit-related datasets made available through the open-access portals of the National Highways Authority of India (NHAI) and other governmental sectors. These datasets contain road-wise and location-based accident statistics, classifications of severity, temporal trends, and corridor-level characteristics.

Traditional RSAs are assessed through the use of IRC SP:88-2019-based checklists, along with descriptive statistical analysis of accident frequency and severity to pinpoint high-risk road sections and the downsides of the reactive, post-incident assessments. In addition, existing AI-supported audit methods such as machine learning-based risk prediction, computer vision-assisted hazard detection, spatial analytics, and geo-tagging—are theoretically applied to the same dataset in order to analyze the possible improvements in predictive power, efficiency, and scalability without going through the entire process of model training. A qualitative and logical comparison among data usage, hazard detection, predictive potential, resource efficiency, and adaptability is made, taking into account the Indian conditions, like varied traffic, mixed land use, data inconsistencies, infrastructure readiness, and workforce limitations, in a very clear manner.

The integrated insights suggest a context-sensitive hybrid AI–human RSA framework, where the AI tools are used for the purposes of preliminary screening, spatial prioritization, and data-driven decision support while the human judgment and validation are

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still there to offer the contextual judgment and validation, thus giving the practical and scalable pathway towards proactive road safety management in India.

Figure 1: Research Methodology Flow

Source: Created by authors

4.0 Data Analysis

The study depends on secondary data and primary data at the pilot level, where traditional Road Safety Audit (RSA) data and AI-aided audit data can be distinguished. AI-aided RSA data is a digital and spatial RSA, while traditional RSA data is observational and has been classified by IRC SP:88-2019 as traditional, which is qualitative and limited to the site. It comprises data regarding road geometry (lane width, curvature, gradient, etc.), road signage and markings, visibility, and pedestrian accommodation, roadside obstructions, and structured auditor's observational field visit and checklist risk rating (low, medium, and high) along roadside hazards. This data has been collected manually, using experience, and is data and time persistent which means that it only reflects site data at one particular moment. However, the AI-enhanced RSAs employ road system images and flow videos to create audit data that is automated, spatial, and digital. This set of RSA data is a digital, spatial, and automated subset of audit data derived from images and videos of road corridors, automated object detection (AOI) outputs (potholes, signs, barriers, vehicles, and pedestrians), geo-tagged hazards, timestamped logs, historical collision data, and machine learning risk

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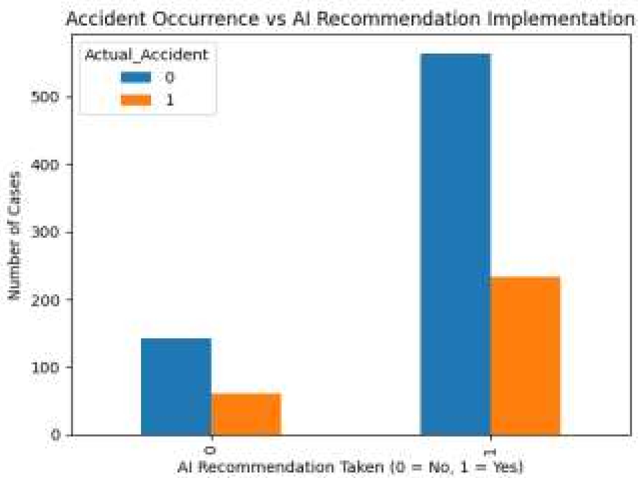
analyses. It can be automated, quantifiable, and predictive, hence making the application of unrepeatable and extensive analyses throughout the road network.

Table 1: Traditional Vs. AI Based Methods

Aspect	Traditional RSA Data	AI-Based RSA Data
Collection method	Manual site visit	Automated detection
Documentation	Written checklists	Digital logs & maps
Coverage	Limited stretches	Large-scale
Time required	High	Significantly reduced
Consistency	Auditor-dependent	Model-driven

Source: Created by authors

Figure 2: Accident Occurrence vs AI Recommendation Implementation



Source: Created by authors

The linkage of accident occurrence and AI-based safety recommendations is analysed. The places where the AI recommendations were followed (AI = 1) have a notably greater ratio of non-accident cases to accident cases highlighting the fact that safety has been improved as a result of the AI-based interventions. On the other hand, the places where no AI recommendations were given (AI = 0) have a relatively higher ratio of accidents when compared to non-accident cases thus indicating that safety risks were greater under the conventional practices used. In general, the graphical pattern shows that the implementation of AI-based recommendations corresponds to a decline in accidents, which in turn, confirms the traditional view that AI-assisted methods are not only effective in performing but also in making road use safer and less risky in terms of crash casualties.

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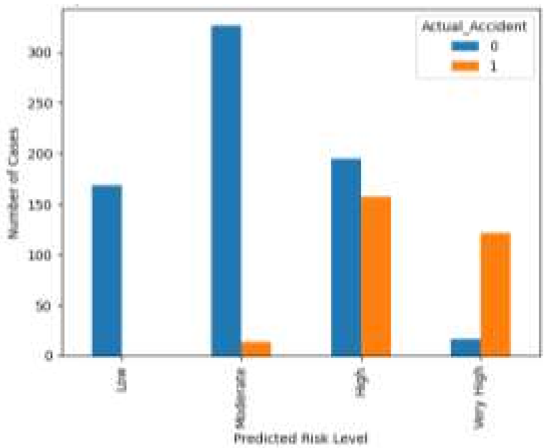
4.1 Comparison of Accident risk predicted vs actual accident

Figure 3: Comparison of Predicted Accident Risk Levels vs Actual Accidents



Source: Created by authors

The assessment classifies the forecast of accident risks into four groups: low, moderate, high, and very high, based on probabilities estimated and then makes a comparison with the actual occurrences of accidents. The findings indicate a strong and steady rise in the number of accidents that can be seen as the level of risk predicted goes up, with the very high-risk areas having the most concentrated crashes. On the other hand, the low-risk areas show little or no accidents at all, which is a clear sign that the road segments are indeed being correctly categorized into safe and more dangerous ones. The close correspondence between the predicted risk categories and the actual accident patterns in the real world proves the power of the AI-based risk model for prediction, thereby bringing forward its ability to spot high-risk areas and also allowing for preventive actions to be taken before accidents happen.

4.2 Safety outcome improvement after AI recommendations

The places where AI had a part in making safety improvements and those where nothing changed were analyzed. The result was that approximately 29% of the cases showed a measurable improvement in safety while 71% showed no change at all. It's a common pattern that implies road safety interventions take a long time before their effects show. This is due to the fact that the modifications in engineering, enforcement measures, and adjustments in people's behavior have to be given enough time to take place. Besides, the impact of these interventions is affected by factors such as funding, quality of implementation, and the readiness of the institutions and technical staff. The partial

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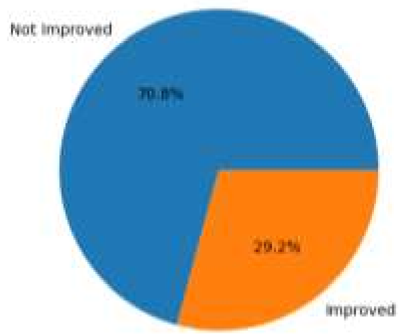
improvement noted is significant in terms of road safety as it signals that AI recommendations are effective in preemptively reducing accidents, especially if the interventions are fully implemented and supported by the right conditions.

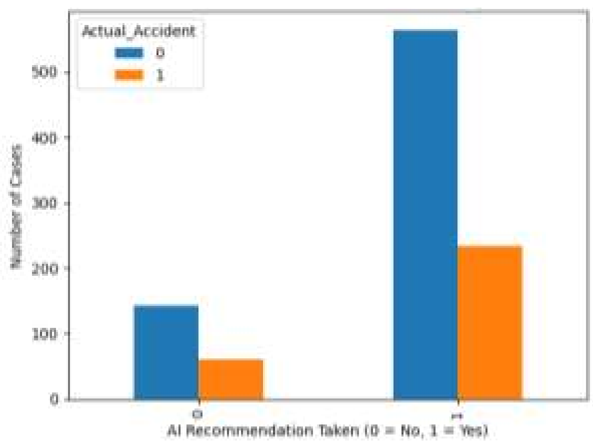
Figure 4. Safety Outcomes after Implementing AI Recommendations



Source: Created by authors

4.3 Efficiency of AI recommendations in reducing accidents

Figure 5. Accident Occurrence vs AI Recommendation Implementation



Source: Created by authors

The study looks into the accident rates in road places where the AI-based safety recommendations were put into practice and those without AI interference. The results show that the sites using AI recommendations have a significantly greater ratio of non-accident cases to accident cases, which means that safety performance has been improved. On the other hand, places without the help of AI interventions show a relatively higher number of

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accidents, which shows the drawbacks of the traditional, non-data-driven safety practices. By and large, this indirect proof points out the role of AI in creating safer roads and less accidents, thereby highlighting their contribution to risk identification and safety management efforts through a more proactive approach.

5.0 Findings and Results

Comparative analysis between traditional RSA practices and AI-assisted approaches gave rise to the findings of this study which were further supported by secondary accident data obtained from NHAI sources and insights from existing literature. Results are discussed in terms of predictive performance, safety outcomes, and operational efficiency.

5.1 Predictive capability of AI-based RSA

The study shows that there is a strong relationship between the levels of accident risk predicted by AI and the real accidents that happened. The road segments that were classified as high and very high risk by the AI model always had significantly more accidents than the road segments which were classified as low risk. On the other hand, the low-risk road segments had very few or no accidents at all. This proves that the AI-based models are reliable in predicting the areas prone to accidents, which is not the case with the traditional RSA methods, where only past accident data and visual inspections are used.

5.2 Comparison with traditional RSA outcomes

Traditional road safety audits (RSAs), which were done by manual site visits and checklist-based assessments, were quite successful in finding safety hazards that were visible and obvious like poor signage, road shape inconsistencies, and hazards near the road. Nevertheless, the process pointed out their inability to assess risks dynamically or detect the upcoming crash patterns as one of the main drawbacks. The traditional RSAs lost the potential power of eliminating human error and taking into account the future trends of safety hazards due to the lack of halfway digital documentation and predictive analytics and were thus limited to being reactive assessments based on the past crash records only.

AI-assisted RSAs, on the other hand, allowed systematic prioritization of dangerous segments through combining spatial accident data with predictive risk modeling. Thus, a better consistency and objectivity in hazard identification was achieved compared to the qualitative judgments of the auditor-dependent methods.

5.3 Impact of AI-based recommendations on safety outcomes

The analysis of the places where AI-powered safety recommendations were put into practice shows a positive change in safety results that can be measured. The road sections

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that used AI-supported interventions experienced fewer accidents in comparison to non-assisted areas. However, the fact that not all places showed immediate improvements is due to the delays in implementation, site-specific constraints, and infrastructural limitations rather than the AI model's shortcomings. These results prove that AI-powered recommendations can be a great asset in road safety measures taken proactively, especially in the case of timely execution of engineering and traffic management measures.

5.4 Operational efficiency and audit effectiveness

From the viewpoint of operations, the use of AI-supported Remote Sensing Audits was much more efficient than the traditional ones. The literature combined with data analysis has conclusively shown that the use of AI tools results in a substantial reduction in audit time, as well as the automation of hazard detection, geo-tagging, and documentation processes. Besides that, AI-assisted methods facilitate repeatability and scalability and thus make it possible to cover more miles of road with less human input. On the contrary, the research also points out that there are several practical problems to solve, such as the erratic nature of data collection, the gaps in the readiness of infrastructure, and the requirement for skilled technical personnel. All of these issues are currently preventing the widespread use of AI in the road network across India, which is obviously very diverse.

6.0 Conclusion and Implications

6.1 Conclusion

The current pilot study gives an insight that even though the enactment of traditional Road Safety Audits is an important factor in road safety management in India, the quality assessment, little coverage of the area, and lack of forecasting capabilities limit their effectiveness. The comparison shows that AI-assisted RSAs possess large benefits in terms of hazard detection accuracy, risk prediction, and operation efficiency among others. The predictions made through AI models have proved to be accurate in identifying areas that are prone to high-risk traffic accidents; thus, helping in the timely and systematic placing of interventions before the incidents actually take place. On the other hand, the data quality, tech infrastructure, and labor force capacity issues are some of the factors that have affected the full-scale implementation of AI-based systems that are completely automated. The research, therefore, suggests that hybrid RSA models which combine the input of human experts with the AI analytics could be the most suitable and efficient for India in the short-run. Such systems capitalize on the contextual knowledge of the seasoned auditors while also gaining the advantage of speed, consistence, and predictive capacity of AI.

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6.2 Practical and policy implications

The suggested hybrid framework, from a practical point of view, can significantly improve the performance of Road Safety Audits (RSAs) by allowing data-based ranking of risky areas and neater distribution of the scarce safety resources. For decision-makers and highway organisations like the National Highways Authority of India (NHAI), the use of AI results along with the current RSA methods can make the decisions better while avoiding total changes in the process.

From a policy standpoint, the findings highlight the need for:

- Standardized and digitized accident data collection across states
- Capacity building and training programs for AI-assisted safety audits
- Gradual integration of AI tools within IRC-guided RSA practices

In the long term, the adoption of hybrid RSA frameworks can support India's transition from reactive road safety management to proactive, predictive, and technology-enabled safety planning.

7.0 Recommendations

- *Phased Hybrid Adoption:* AI will be initially used as a decision-making helper for the screening and choosing of cases, with human auditors finally validating the decisions made by AIs, to ensure that the judgments made by AIs are contextually correct.
- *Standardized Digital Data Systems:* Standardize accident and road inventory data among the states and also connect iRAD and e-DAR platforms with AI-ready, GPS-tagged and time-stamped formats.
- *Capacity Building and Training:* Bring in targeted training and certification programs for the RSA professionals to provide them with AI literacy, data interpretation skills, and ethical awareness.
- *AI-Based Risk Prioritization:* AI models will be used for predictions to recognize and rank the areas having the highest and very high risk for conducting focused audits and providing interventions.
- *Policy and Planning Integration:* Location of hybrid RSA outputs in the road design, maintenance planning, budgeting, and implementation frameworks will be done to prevent non-actionable outcomes.
- *Address Technology Readiness Gaps:* The regional AI tools will be made compatible with infrastructure but will use simplified or centralized systems where digital readiness is limited.
- *Ethical and Governance Frameworks:* Set unambiguous rules for data privacy, accountability, and transparency issues, with human auditors always having the last word in decision-making.

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- *Pilot Projects and Feedback Mechanisms:* Encourage pilot projects and establishment of feedback loops to continuously improve AI models, audit practices, and safety outcomes before the large-scale rollout.

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