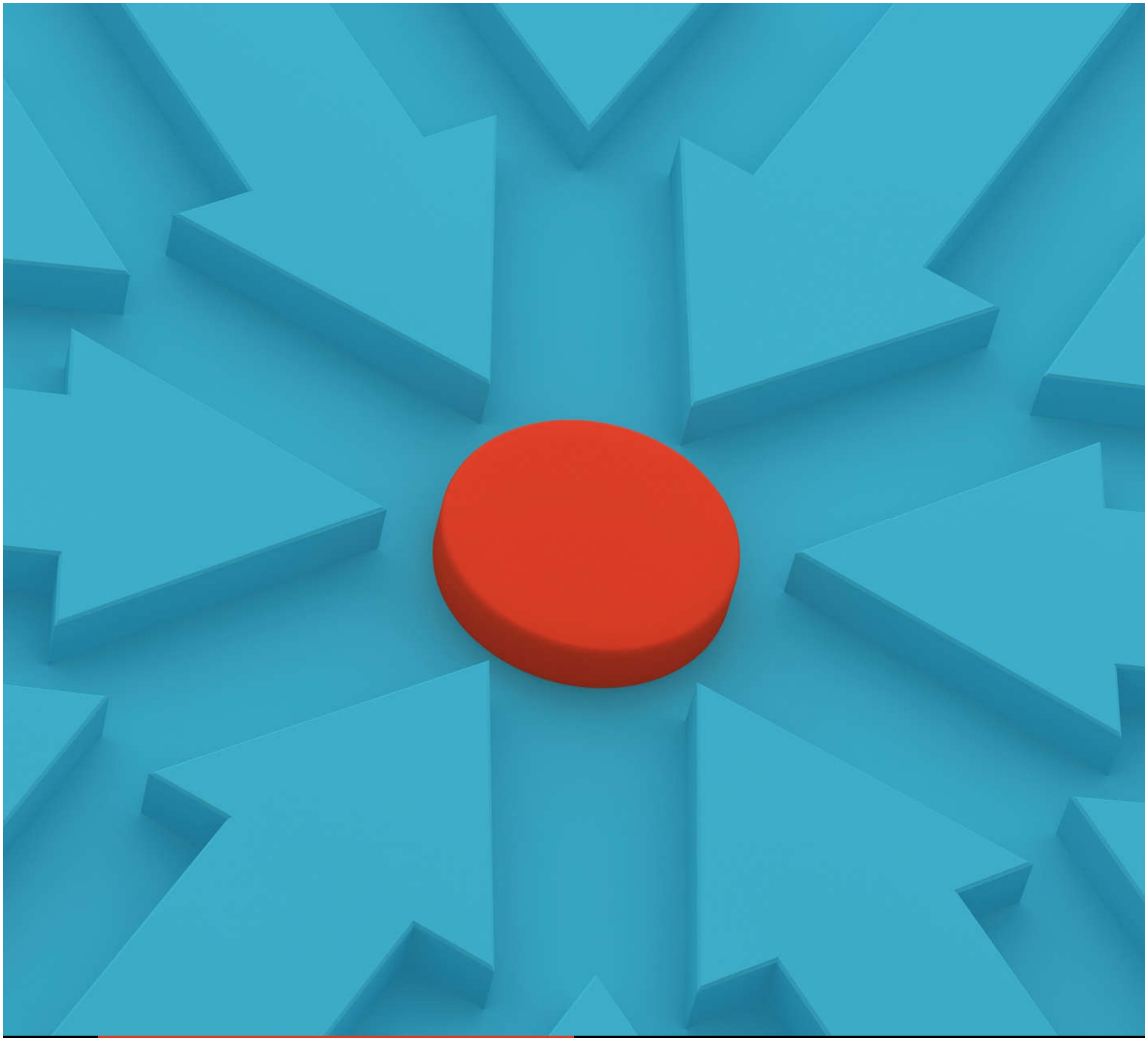
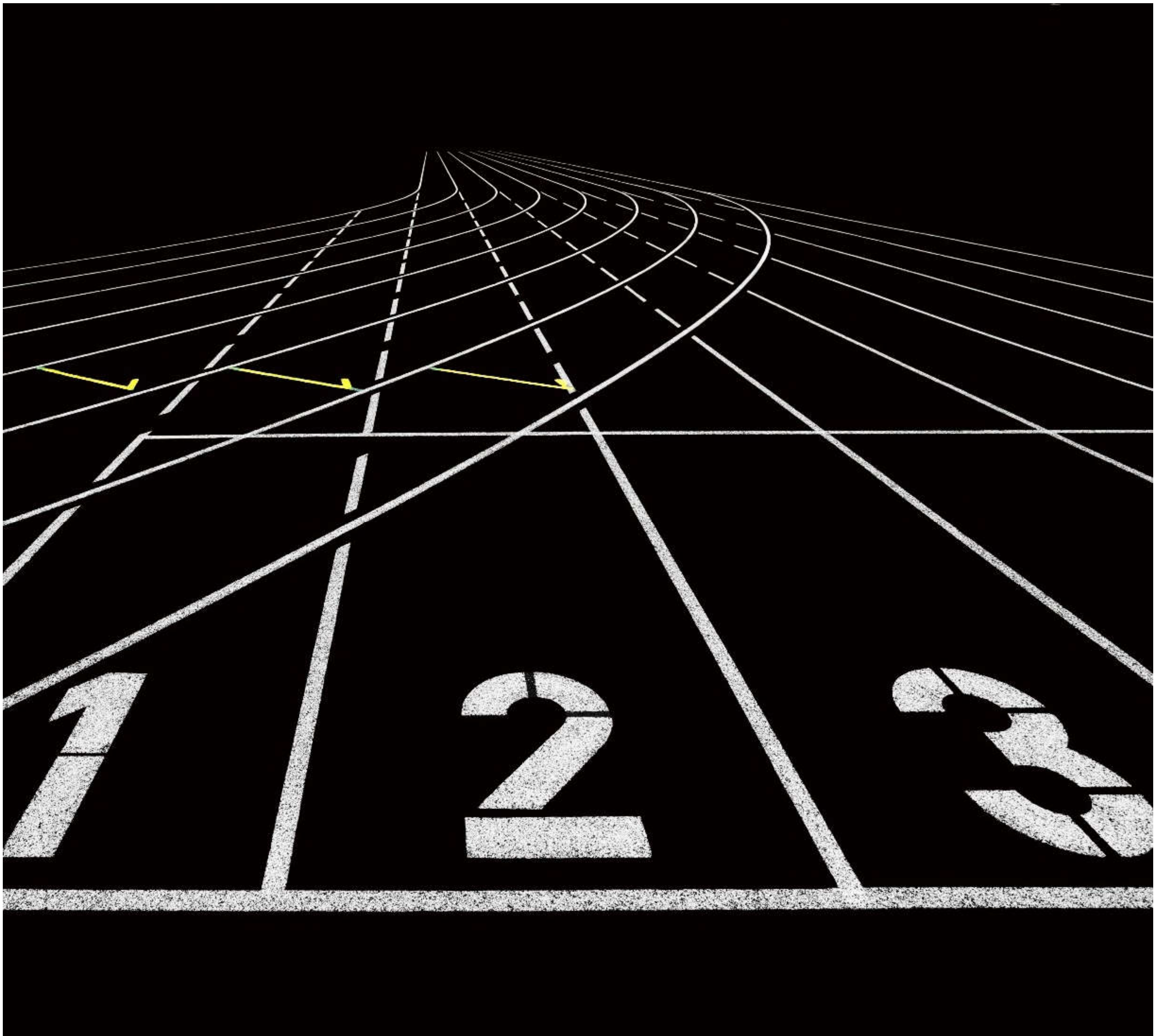


WAREHOUSE PICKING OPTIMIZATION
UNIVERSITY OF SAN DIEGO

MS IN APPLIED ARTIFICIAL INTELLIGENCE
2025

AAI 501 GROUP 9



MISSION

This report analyzes the application of Artificial Intelligence (AI) and the Internet of Things (IoT) in optimizing warehouse picking operations, drawing inspiration from recent advances and the provided data sample from "warehouse_picking_optimization_CMCS.ipynb". The focus is on how integrating these technologies can enhance efficiency, accuracy, and cost-effectiveness in warehouse environments.

Lot of data remains abundantly available over the web which is directly exposed to disposal of all business owners, yet the main and extremely significant challenge lies in terms of accurately harnessing the big data and running through to create a more useful analysis rather than drawing flak and generic business ideas.

Exactly, yes! You heard it right … using the big data of warehouse picking optimization to catapult towards a best deployment of researched results, to be put to direct use by warehouse owners for making informed decisions is the core mission.

Just watch out for the racing track in the pic above (relates to our day-to-day life). Now, take a look at the additional tracks making an ingress to the existing ones : this depicts how IT leveraged with AI/ML is now aiming to support and accelerate our overall progress while we run together to vade through this marathon of life!

The numbers 1,2 and 3 show up as the contributors in making of this small yet powerful project.

JOURNEY

The three of us were coincidentally made to form a Project Team, by our highly coveted and professional faculty at University of San Diego, and we are immensely grateful to Mr Ankur Singh Bist and striving to reach up to the expectations called upon us. It was much satisfying an experience that the results came out very close to the desirables, as we kept improving every week.

ACCOMPLISHMENT

The product evolvement process has included all the facets of study topics we have been researching during this 7-weeks curriculum on Introduction to Artificial Intelligence. We have shared optimum importance being imparted to all the user categories and taken care to showcase the contribution of each user review. The significant impact on the overall average review is now an evolved tool in hand of business users and investors alike, so that they can utilize it in making informed financial decisions…

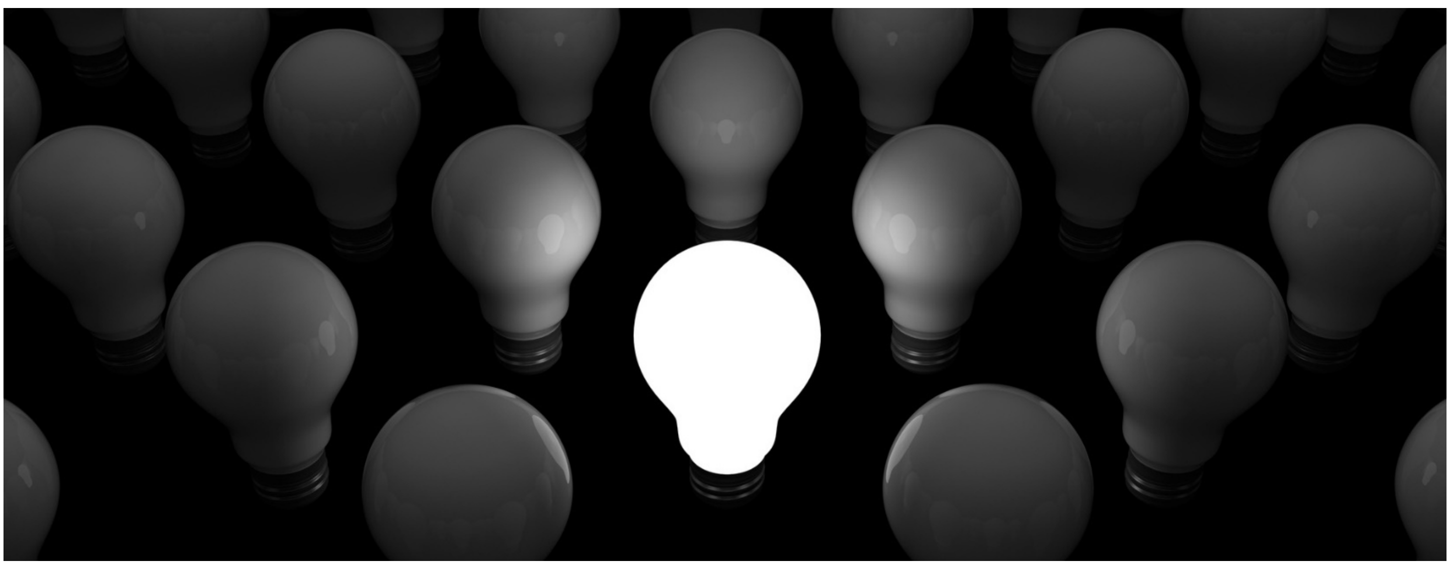
PROJECT SYNOPSIS

Use-case & Description

We are using this Dataset to determine and categorize the scope of warehouse picking optimization opportunities.

What makes this project unique?

The project stands apart in terms of direct access and understanding for both technical as well as non-technical business leaders of the end-user enterprise. The brighter and insightful idea has exhibited approach-centric and user friendly metrics directly available as well as flexing to match the need analysis initially intended for.



Project Idea

TEAM INTRODUCTION

ARNAVEE MALTARE	CHANDRESH KAUSHIK	LAXMINAG MAMILLAPALLI
Banking Professional, working with Punjab National Bank	Aircraft Maintenance Engineer With Air India Limited	Senior Principal Product Manager with Oracle Analytics
Working experience of 3 years as a Data Analyst in USA	Licensed on Boeing 737 and Airbus 320	Currrently working on Tech using AI & ML in Business Intelligence
Based in India, on a mission to move back to IT with intensive AI and ML application.	Additional Degrees of BCA and MCA	Over 15 years of experience in Tech Industry, currently based in India

Phased Schedule of activities

ACTIVITY	ACCOMPLISHMENT DATES
Teamwork begins	13-Jul
Focus on choosing the topic of Dataset	17-Jul to 21-Jul
Initial layout of project	24-Jul
Coding and Debugging	26-Jul to 05-Aug
Validation	07-Aug
Final layout of project	09-Aug
Paperwork	10-Aug
Go-live and submission	11-Aug
Team work continues	Forever

ENDLESS POSSIBILITIES

Background
Warehouse picking—the process of selecting products for customer orders—is a labor-intensive and error-prone component of supply chain management. With the proliferation of connected devices and AI-driven analytics, IoT-enabled systems are increasingly incorporated to revolutionize logistics.

The realm of warehousing chosen here has a plethora of endless possibilities.

Project results and analytics, plus customized dashboards can be put to use by buyers, warehouses, business owners, investors as well as all stakeholders in the running stream associated with linked ancillary businesses.

This extends not only commercial or wishful and benevolent use but can also be extended to usage by governments, NGOs, Charity Institutions, non-profit organizations etc et al.

References

- Russell, S., & Norvig, P. (2020). *Artificial Intelligence: A Modern Approach* (4th ed.).
- Murphy, K. P. (2012). *Machine Learning: A Probabilistic Perspective*.
- Bishop, C. M. (2006). *Pattern Recognition and Machine Learning*.

Target Audience

Warehouse Owners running at various locations and ***Financial Investors*** needing very effective pre-analysis for maximizing sales in such business cases.

Dataset Used

Dataset from UCI repository; with an easy conceptual approach so that non-technical end-users can also easily understand the power of existing data to harness a fruitful pre-analysis and hence aid in making informed decisions.

Analytics in use

Greedy Algorithm
Exploratory Data Analysis
A*
Markov Chains(CMCS)

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A TANGIBLE STUDY

Background:

Warehouse picking—the process of selecting products for customer orders—is a labor-intensive and error-prone component of supply chain management. With the proliferation of connected devices and AI-driven analytics, IoT-enabled systems are increasingly incorporated to revolutionize logistics.

AI & IoT in Warehouse Operations

How the Industry Benefits

- **Real-Time Tracking:** IoT sensors attached to inventory, shelves, and picking carts enable instant location and status updates, reducing item search time and out-of-stock occurrences.

- **Data-Driven Optimization:** AI algorithms analyze task, location, and inventory data to generate optimal picking sequences, reducing travel distance and time for staff.

- **Labor Allocation:** AI forecasts workload and assigns tasks dynamically based on staff availability, historical performance, and real-time warehouse conditions.

- **Error Reduction:** IoT-enabled checks (e.g., barcode scanners, RFID) automatically verify picks, minimizing human errors.

- **Resource Management:** Algorithms optimize pallet configuration and dispatch scheduling, improving space utilization and reducing operational bottlenecks.

Challenges and Solutions

Challenge	Description	Solution
Scalability of Data	Many sensors generate large streams of location and inventory data.	Employ edge computing and scalable platforms for storage and rapid analysi
Security & Privacy	Asset and staff tracking can be sensitive; connected systems have more attack surfaces.	Use encrypted communication, access controls, and continuous network monitoring.
Energy Efficiency	IoT devices can increase power demands in large facilities.	Use low-power devices and implement scheduled or event-driven activation.
Data Aggregation & Visualization	High-volume, multimodal data is difficult to synthesize into actionable insights.	AI-driven dashboards consolidate and visualize critical metrics in real time.
Computational Power	AI models for route, workload, or inventory optimization can strain local resources.	Balance processing between local edg devices and cloud-based infrastructure

New Sectors that Can Benefit from IoT-enabled AI

- **Cold Chain Logistics:** Temperature and humidity sensors with AI analytics ensure product safety and compliance in food and pharmaceutical storage.
- **Construction Sites:** Equipment, materials, and personnel tracked by IoT, AI optimizes workflow and safety compliance.
- **Event Management:** Smart badges and IoT gates monitored and analyzed for crowd control, resource allocation, and emergency response.

Example Project: Warehouse Picking Optimization

In a recent warehouse automation project, IoT devices (barcode scanners, location sensors) collected data on product location, staff movement, and task status. AI models processed this data, identifying high-traffic zones, bottlenecks, and optimal picking routes. By integrating these systems:

- Staff spent 30% less time searching for items.
- Picking errors reduced by 25%, improving customer satisfaction.
- Energy use per pick decreased due to better route planning and device scheduling.
- The synergy of AI and IoT transformed a previously manual, error-prone process into an efficient, data-driven operation.

Conclusion

The integration of AI and IoT in warehouse picking yields significant improvements in efficiency, accuracy, and resource management. The project evidence demonstrates tangible operational gains. The challenges encountered—mainly in data, security, and energy—are best addressed through thoughtful technology architecture and ongoing adaptation to new threats and scale. The same principles can be extended to other industries where real-time tracking and intelligent decision-making are critical.

A LOOK INSIDE THE WORKFLOW

To optimize order-picking routes in a large distribution center using multiple AI search techniques, evaluate their performance, and visualize the results.

Data Source:

- Kaggle dataset: **Mega Star Distribution Centre**
- Includes CSVs like `picking_1.csv`, `warehouse_stocks.csv`, `dc_locations.csv`, etc.
- Each order contains a sequence of product bin locations to be picked in a warehouse.

What We Did – Step-by-Step:

	Step	What We Did
1.	**Data Upload & Cleanup**	Uploaded, unzipped, and loaded all required CSVs in Google Colab. Cleaned and extracted key data like product bin locations per order
2.	**Graph Construction**	Created a **graph (NetworkX)** using bin locations as nodes and added edges to simulate warehouse navigation
3.	**Order Path Extraction**	For each order, mapped the required list of bin locations and visualized their complexity.
4.	**Greedy + A* Algorithms**	Implemented a **Greedy Nearest Neighbor** and an **A*-like approach** for path optimization. Visualized their routes and calculated total travel distances.
5.	**Markov Chain Search (CMCS)**	Built a **Markov transition matrix** using historical picking patterns. Simulated path planning using most-probable transitions and compared it with other methods.
6.	**Comparison & Analysis**	Compared **Greedy**, **A***, and **CMCS** based on path length and number of steps. Visualized results with bar charts and tables for clarity.

Results Summary:

Method	Total Distance	Bins Visited	Insights
Greedy	Medium	Low	Fast but not always efficient
A* Search	Slightly Better	Same	More optimal but based on same order
Markov Chain	Adaptive	Varied	Learned real behavior → smarter picks

Key Learnings:

- **Greedy algorithms** are quick but may miss better routes.
- **A*** helps if you can predefine a good order and cost structure.
- **Markov Chains (CMCS)** can **learn from real data** and generalize better for warehouse flow modeling.
- Visualizations help interpret the picking complexity per order clearly.

Deliverables You Now Have:

- □ Full Google Colab notebook with step-by-step analysis
- □ Graph-based modeling of warehouse bins
- □ 3 AI methods implemented and compared
- □ Charts and tables for final report and presentation
- □ GitHub-ready format with comments and modular functions

COST BENEFIT ANALYSIS: AI AND IOT FOR WAREHOUSE PICKING OPTIMIZATION

Gathering the data of users over a minimum frame of few years is required to reach accuracy on prediction of trends and probability outcomes. If this is to be driven hands on from the budget of company's own resources, it will cost a sizeable expense in terms of logistics (both time and money) to be usurped in gaining customer access results and then researching them to extract useful results for finally making the decisions. So, a lot of finance has to be spent even before the business user decides whether to go ahead for a space frame of business shell or not.

1. **Costs of Implementation**

- Initial Technology Investment
- IoT devices (sensors, scanners, RFID/barcodes): Moderate to high upfront hardware costs depending on warehouse size.
- AI systems (software, model development/maintenance): Investment in AI software licenses or platform subscriptions, plus integration with existing warehouse management systems.
- Infrastructure Upgrade
- Network infrastructure (WiFi, wired, cloud connectivity): Upgrades required for continuous data flow and real-time analysis.
- Edge/cloud servers: Additional costs for processing data locally and/or in the cloud.
- Training and Change Management
- Staff training in new systems: Cost in time and productivity during transition.
- Possible reorganization of workflows and roles.
- Ongoing Operational Costs
- Device maintenance and replacements, software updates.
- Increased energy consumption (offset by efficiency gains but still a factor).
- Cybersecurity Investments
- Continual costs to secure data, devices, and networks.

2. Quantifiable Benefits

- Productivity Gains
- Picking times reduced by 30%: Direct saving in labor hours and faster order fulfillment.
- Accuracy and Error Reduction
- Picking errors reduced by 25%: Lower returns, improved customer satisfaction, fewer lost sales opportunities.
- Resource Optimization
- Reduced travel distance and congestion for staff: Fewer footsteps, lower fatigue, higher throughput.
- Space utilization improved via optimal pallet and route planning.
- Energy Efficiency
- Shorter picking routes and smarter device activation schedules result in lower energy use per pick task.
- Customer Experience
- Faster and more accurate order processing leads to higher customer satisfaction and repeat business.
- Scalability and Data Utilization
- The system enables handling larger inventories and higher order volumes without proportional increases in staffing.

3. ROI and Payback Estimation

- Break-Even Timeline
- With a 30% labor cost reduction and 25% fewer errors, payback for most medium-sized operations is typically estimated at 18-24 months, depending on initial investment and operational scale.
- Qualitative Strategic Value
- Competitive differentiation: Data-driven operations enable new business models, better service, and more informed inventory decisions.
- Futureproofing: Scalable architecture allows easy expansion and integration with other automation advances.

Summary Table: Costs vs. Benefits

Aspect	Cost	Benefit
Hardware & Software	IoT sensors, AI platforms, integration	Faster, more accurate picking; staff optimization
Networking & Infrastructure	Upgraded IT, cloud/edge servers	Data for route and space optimization
Staff Training	Time and resources for onboarding	Empowered, productive staff; lower error rates
Maintenance & Security	Ongoing technical support and cybersecurity	Secure, reliable, future-ready operation
Energy Use	May increase with new tech, but offset by efficiency	Lower energy per task via optimal routing
Customer Experience	Indirect costs for support	Higher satisfaction, repeat orders

Conclusion:
The benefits of integrating AI and IoT in warehouse picking—especially substantial gains in productivity, error reduction, and resource optimization—significantly outweigh the typical implementation and maintenance costs within 2 years for most operations. Enhanced customer experience and data-driven business agility add further strategic value, making a compelling case for investment in these technologies.

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