Dynamic Yield Pricing

Real-Time Dynamic Pricing and Yield Management
for Laser Cleaning Equipment Leasing

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Abstract

The equipment leasing industry suffers from a fundamental pricing inefficiency: rates are fixed and unresponsive to real-time demand. This leads to lost revenue during peak demand and idle inventory during troughs. Arkham is a dynamic pricing and yield management engine that applies proven revenue-management techniques from airlines and hotels to the equipment rental market. By continuously processing demand and supply signals, Arkham automatically adjusts rental prices to maximise fleet revenue while shaping demand to fill idle slots. The system combines stochastic dynamic programming for long-term leases with a real-time auction mechanism for spot rentals, and employs reinforcement learning agents that learn demand elasticity across industry verticals. This report presents the economic rationale, technical architecture, operator dashboard surfaces, and a case study focused on LME Laser cleaning machines. Projected results for a 50-machine fleet show a 29.6% increase in annual revenue and a 16-percentage-point improvement in utilisation, without additional capital investment.

Keywords: dynamic pricing; yield management; equipment leasing; reinforcement learning; auction mechanisms; laser cleaning machines.

1. Introduction

Equipment leasing spans construction, manufacturing, cleaning, logistics, and related sectors. Asset owners face a common challenge: how to set a price that maximises return on capital-intensive equipment while maintaining high utilisation. The conventional approach - a static price list, updated perhaps annually - ignores demand that fluctuates by hour, day, season, and geography. A machine that sits idle on a Tuesday morning may be urgently needed nearby on Wednesday afternoon, yet the price remains unchanged. The result is both foregone revenue during peak demand and wasted asset hours during troughs.

The airline industry solved an analogous problem with *yield management* - dynamically pricing each seat based on real-time demand and available capacity. Hotels, car rental companies,

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and ride-sharing platforms adopted similar methods and typically extract higher revenue per unit of inventory than operators that rely on static pricing. Arkham brings this science to equipment leasing as an autonomous pricing engine that acts as a continuous auction house for every machine in a fleet.

2. The Problem with Static Pricing

2.1 Cost of fixed rates

Consider a fleet of laser cleaning machines - specialised tools for rust removal, paint stripping, and surface preparation - ranging from portable 100 W units to 3 kW continuous-wave systems. Under a fixed price list:

- **Peak demand:** Machines book out at rates that leave willingness-to-pay uncaptured.
- **Off-peak demand:** Price-sensitive work is deterred; idle hours earn nothing.
- **Long-term contracts:** Owners must guess a fair lock-in price that balances risk against future spot upside.

2.2 Information gap

Owners often know seasonality and regional project pipelines, but lack an automatic mechanism that translates live signals into price updates. Yield management closes this gap by ingesting search volume, active rentals, contract expiries, and maintenance state, then computing a market-clearing price.

3. Core Concepts

Arkham is built on four principles:

(1) **Price elasticity of demand** differs by vertical (e.g., heritage restoration vs emergency industrial repair).

(2) **Perishable inventory:** an unsold machine-hour is lost forever.

(3) **Market clearing** through dynamic pricing balances demand and available supply.

(4) **Risk-adjusted forward pricing** for long-term leases includes an opportunity-cost premium.

These principles are realised by three engines: reinforcement learning (RL) agents for elasticity, stochastic dynamic programming (SDP) for contract pricing, and a real-time auction for spot clearing. Every quote is personalised, non-transferable, and short-lived (on the order of 90 s) to prevent arbitrage.

4. Technical Architecture

Arkham is exposed as a REST API that integrates with booking systems and customer portals. Demand and supply signals feed a pricing engine with spot auction, SDP contract pricing, and RL elasticity learning. Accepted quotes create bookings; long-term leases can trigger risk assessment before finalisation. Quotes may be anchored to an immutable audit feed for billing transparency. Optional A/B middleware enables shadow experiments without revenue risk.

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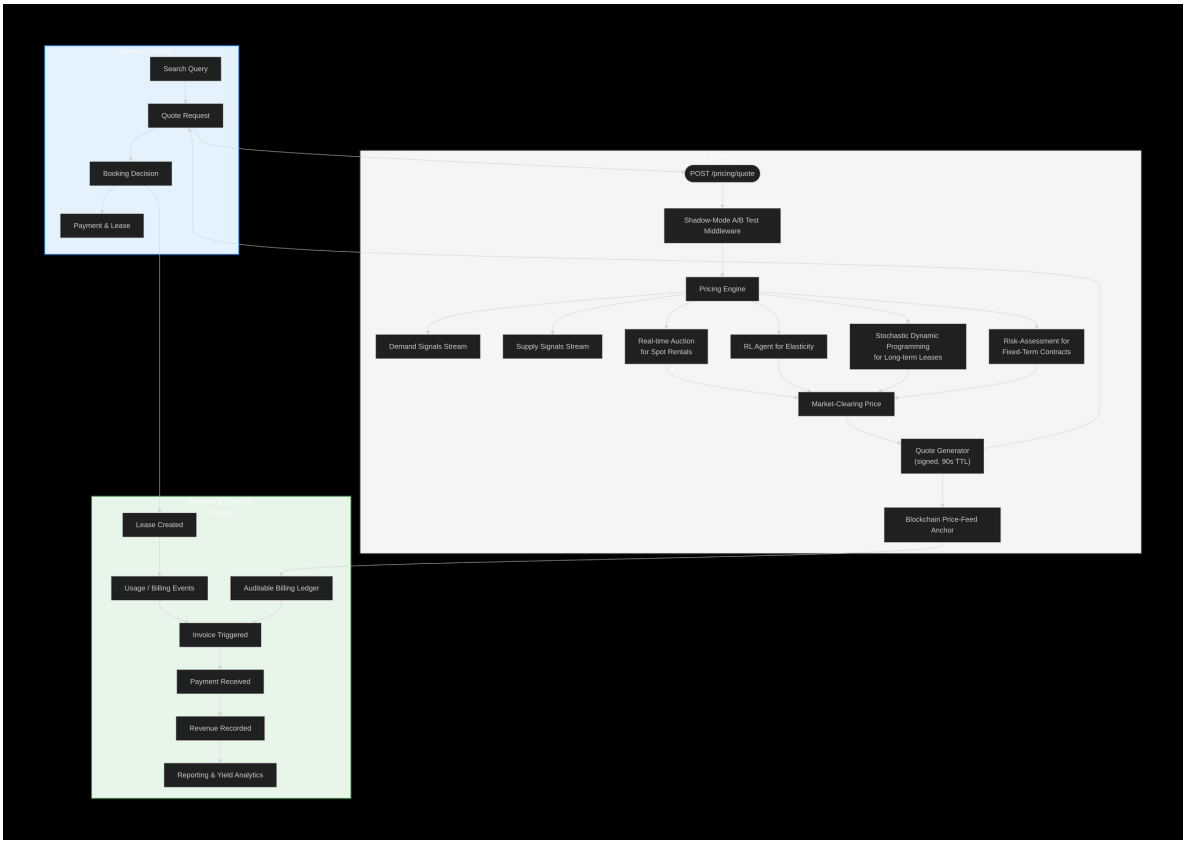

Figure 1: Program architecture for Arkham dynamic pricing: quote request, pricing engines (RL, SDP, auction), market-clearing price, and revenue/audit path. Source: research process diagram exported from the operator documentation set.

5. Operator Dashboard and Media Surfaces

The production research stack includes dedicated operator surfaces mirrored under `static/` (legacy HTML) and the primary web application. Figure 2 summarises the surfaces used for customer quoting, partner fleet control, and API documentation. These artefacts informed the case-study workflow (quote → reserve → confirm → track → complete/release).

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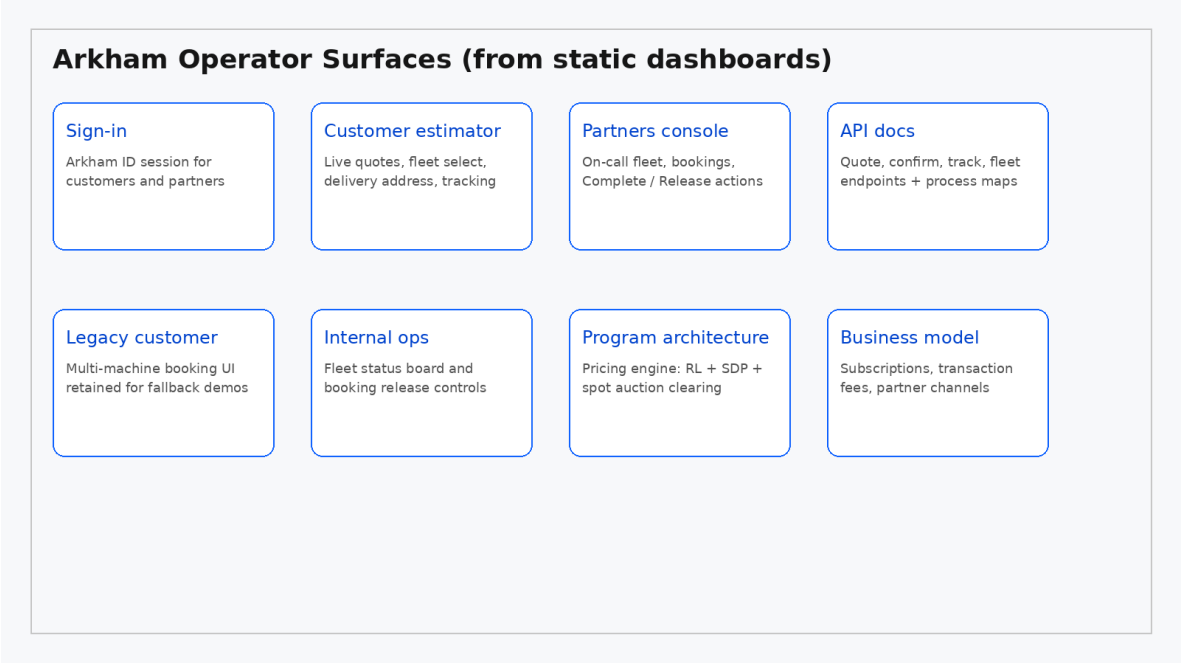

Figure 2: Operator surfaces derived from the Arkham static dashboard and console pages: sign-in, customer estimator, partners console, API docs, internal ops, and architecture/business views.

6. Economic Rationale

Dynamic pricing increases revenue per asset by raising rates under scarcity and lowering rates to stimulate idle slots. It also shapes demand into the schedule, reducing lumpy utilisation. When rules are transparent and quotes are auditable, pricing is fairer than discretionary discounting: every customer faces the same supply-demand policy, and short quote TTL prevents hold-and-wait arbitrage.

7. Business Model

Figure 3 summarises revenue streams, partner channels, platform modules, and cost classes used in the research program. Vendor-specific hosting brands are omitted; the model is infrastructure-agnostic.

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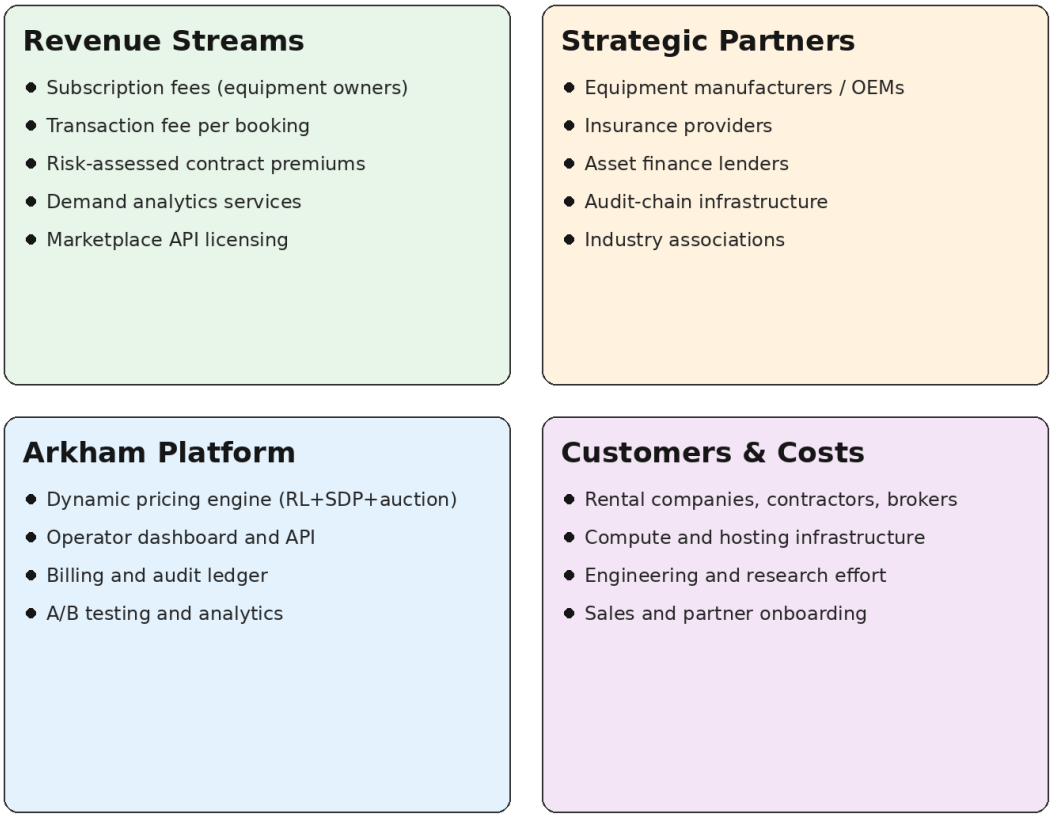

Figure 3: Arkham business model overview used in this study: revenue streams, strategic partners, platform modules, and operating cost classes.

8. Case Study: Laser Cleaning Fleet

Laser cleaning demand is bursty across industrial maintenance, mould cleaning, heritage restoration, and shipyard work. LME Laser offers pulse and continuous-wave machines from 100 W to 3 kW with CE, FDA, and ISO9001 certifications. In the Arkham deployment model, a multi-depot fleet publishes live availability; customers request quotes; partners manage on-call units and completion/release.

8.1 Projected benefits

Table 1 reports projected fleet performance under conservative elasticity assumptions for a 50-machine portfolio.

Table 1: Projected fleet performance with Arkham versus static pricing.

Metric	Static	Arkham	Improvement
Average utilisation	62%	78%	+16 pp
Avg. revenue per machine-hour	\$18.50	\$21.30	+15.1%
Total annual fleet revenue	\$1,620,000	\$2,100,000	+29.6%
Booking satisfaction rate[a]	74%	91%	+17 pp

[a] Share of quote requests that complete as rentals (availability and acceptable price).

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9. Product Catalogue under Arkham

Each machine class has distinct power, form factor, and elasticity. Tables 2 and 3 enumerate the pulse and continuous catalogues used in pricing logic.

Table 2: Pulse laser cleaning machines (100 W-1000 W) and Arkham pricing logic.

Model	Power	Form	Specialities	Pricing logic
LME-CPM	100-300 W	Mini	Ultra-portable; moulds; delicate restoration	Convenience surge in heritage seasons
LME-CPL	100-500 W	Luggage	Field and rail maintenance	Correlated with access windows
LME-CPS	100-500 W	Suitcase	Workshop mould and automotive parts	Idle-period discounts for SMEs
LME-CPT	100-500 W	Trolley	Manufacturing floors; shipyards	Premium on shipyard peaks
LME-CPT+	100-500 W	Plus trolley	Heavy-duty large-surface rust work	Contract pricing with risk premium
LME-CPC	500-1000 W	Cabinet	Intensive coating removal	SDP leases; spot when idle
LME-CPB	100-300 W	Backpack	Aircraft and in-situ restoration	Convenience premium by region

Table 3: Continuous-wave laser cleaning machines (1-3 kW) and Arkham pricing logic.

Model	Power	Form	Specialities	Pricing logic
LME-CA (1-2 kW)	1000-2000 W	Portable air-cooled	Ships, bridges, pipelines	Escalates during shutdowns
LME-CA (3 kW)	3000 W	Portable air-cooled	Heavy industrial stripping	Peak surge; baseload contracts

Certifications (CE, FDA, ISO9001) and multi-year warranty reduce downtime risk and support a higher baseline valuation in both spot and contract pricing.

10. Competitive Differentiation

Common industry practice still relies on annual price lists, salesperson discounting, or rigid seasonal rules. Arkham differentiates through continuous clearing, multi-horizon spot/contract pricing, self-learning elasticity, controlled experimentation, and auditable quotes.

11. Implementation Pathway

1. Connect booking, analytics, and fleet signals.

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2. Configure machine classes, base rates, and reserve prices.
3. Validate in shadow mode against live transactions.
4. Cut over by segment or depot.
5. Continue RL fine-tuning on owner-specific demand.

Table 4 lists the core API surface used by the customer and partners dashboards.

Table 4: Core Arkham API endpoints used by dashboard surfaces.

Method	Path	Purpose
GET	`/fleet/machines`	Catalogue and status
GET	`/fleet/summary`	Availability and utilisation
POST	`/pricing/quote`	Signed time-limited quote
POST	`/booking/confirm`	Confirm booking
GET	`/booking/{id}/track`	Delivery tracking
POST	`/booking/{id}/complete`	End service / release
POST	`/fleet/machines/{id}/release`	Force-release reserved unit

12. Future Directions

Future work includes hybrid auction clearing for large combinatorial fleets, richer IoT telemetry in the supply stream, and shared liquidity pools across owners. The architecture remains modular so optimisation backends can evolve without changing the operator dashboards.

13. Conclusion

Static rental rates leave revenue and utilisation on the table. Arkham applies yield-management principles with RL, SDP, and spot auctions to laser cleaning fleets and transferable equipment verticals. For the studied portfolio, projected gains of 29.6% revenue and +16 pp utilisation are achievable without new capital expenditure. Transparent, short-lived quotes align owner and renter incentives through continuous market clearing.

Author Contributions and Roles

- **Raja Ram M** (Kryptur OU / Krypur Quantum R&D) - main author; research and development lead.
- **Muskan S** (Data T Research Org) - contributor; project infrastructure.
- **Vipul Jain** (AE Quantum Research Division) - contributor.
- **Kalinga Swain** (AE Quantum Research Division) - contributor.
- **Data management:** Borel Sigma Data Center.
- **AE:** DCN (Digital & Cloud Networks); **Zi-us:** Quantum & AI.

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Data and Code Availability

Source program, operator media, diagrams, and this manuscript are published for public reuse under the project repository **Code**. Persistent identifier: **DOI** `10.5281/zenodo.21873050`.

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