

An Operations Management Perspective on Human Organ Transplantation in India: Managing a Time-Critical, Perishable, and Demand-Constrained Service System

Sohan Dudala

Indian Institute of Management-Lucknow
Noida Campus, Noida, Uttar Pradesh, India
pgpwe21055@iiml.ac.in

Venkataramanaiah Saddikuti

Professor of Operations and Supply Chain Management
Indian Institute of Management-Lucknow
Noida Campus, Noida, Uttar Pradesh, India
svenkat@iiml.ac.in

Abstract

Human organ transplantation is among the most operationally demanding processes in modern healthcare. It combines a severely constrained supply, a highly perishable resource with limited viability windows, time-critical logistics, multi-stakeholder coordination, and complex allocation decisions made under uncertainty. This work examines organ transplantation in India through the lens of operations management, using the data published by the National Organ and Tissue Transplant Organisation (NOTTO), the apex body in India for organ registry and allocation. It maps the transplant pathway as a service-and-supply-chain system and identifies the principal operational bottlenecks: a structural dependence on living donors, a chronically thin deceased-donor base, acute regional concentration of donation, and fragmented logistics. Between 2013 and 2024 India's total annual transplants increased from 4,990 to 18,911, yet deceased donors stood at only 1,128 in 2024 and the deceased-donation rate remains below one per million population. The article argues that India's organ transplant gap is, to a substantial degree, an operations- and systems-design problem.

Keywords

Healthcare, Lean Operations, Organ Transplantation, Process Design, Product-Service System, Theory of Constraints, Time-Critical.

1. Introduction

End-stage organ failure is often only treatable by transplantation. Yet the demand for transplantable organs vastly exceeds supply - India being no exception. According to NOTTO, the national body in India responsible for overseeing, coordinating, and regulating the retrieval, allocation, and transplantation of organs and tissues across the country, total annual organ transplants grew from 4,990 in 2013 to 18,911 in 2024 (NOTTO, 2024), the highest figure on record. Globally, India performed the third-largest number of transplants in 2024 (18,911), behind only the United States (48,935) and China (24,684) (Global Observatory on Donation and Transplantation, 2024). Despite this scale, India's deceased-donor donation rate remains below one per million population, far behind world leaders. The paradox of high absolute volume and very low per-capita deceased donation defines the Indian transplant landscape.

Most analyses of this gap focus on awareness, culture, consent, or clinical capability, leaving a crucial dimension underexplored - transplantation is fundamentally an operations problem. An organ is a perishable unit of inventory whose viability clock starts at retrieval; the transplant pathway is a multi-stage process spanning two or more hospitals, traffic systems, and regulatory bodies; allocation is an assignment problem solved under time pressure; and the whole system is a service operation with tight capacity constraints on Transplant Intensive Care Unit (TICU) beds, operating theatres, and surgical teams. With this perspective, many losses in the system are operational losses - organs donated but not used, time wasted in coordination, and capacity idle in one region while demand goes unmet in another. This article attempts to apply operations management concepts to the Indian transplant system (Figure 1).

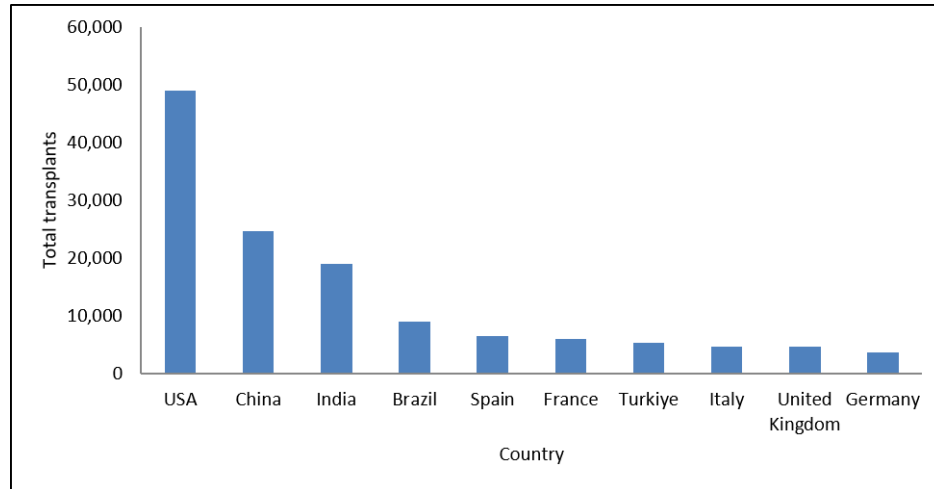


Figure 1. Top 10 countries by total organ transplants (2024)

2. Literature Review

The operations-management treatment of healthcare delivery has matured into a substantial literature, yet its application to organ transplantation in India remains thin. This section places the present work within four streams: managing perishable medical supplies and their constraints, extending organ shelf life through preservation, the clinical reasons an operations view matters, and methods for drawing conclusions from observational transplant data. The closest methodological precedent is the work on perishable medical-product inventory. Lowalekar and Ravi (2017) apply the Theory of Constraints (TOC) thinking process to an Indian blood bank and show that a cluster of seemingly unrelated problems - simultaneous shortage and wastage, ageing stock, high cost, and low product variety - originate in a single policy root cause: collecting blood in large, infrequent batches. Their recommendation, to collect in smaller quantities and collect more often, converts a push system into a responsive replenishment (pull) system and, in simulation, cuts shortages and wastage simultaneously. Their analysis is directly relevant because blood and organs share the defining features of a stochastic, perishable, life-critical supply; indeed, the explicit differentiator being that long transplant waiting lists are extension of their approach, where perishability is compounded by the need to match a specific organ to a specific recipient.

A second stream concerns the perishability constraint itself. In operations terms, cold ischemia time is the shelf life of the organ, and any technology that extends it widens the feasible matching and transport window. Hunter et al. (2025) reviewed advances in donor-organ perfusion and report that hypothermic machine perfusion reduces delayed graft function relative to static cold storage, particularly for kidneys recovered from marginal donors, while normothermic perfusion may permit real-time viability assessment before transplantation. From a systems-design perspective, perfusion is a lever that relaxes the binding constraint identified later (), improving both the utilization of scarce organs and the geographic reach of each donation.

A third stream establishes why the operational stakes are high. Grinyó (2013) explains that transplantation is the preferred therapy for end-stage organ failure on both survival and quality-of-life grounds, which means that every organ lost to operational failure carries a measurable cost in lives. Ekser and Fernandez (2025) survey xenotransplantation (transplantation from a nonhuman animal source into a human recipient) as a longer-horizon

supply-side response to the donor shortage, underscoring that even frontier clinical solutions are ultimately attempts to relieve the same scarcity that operations methods address from the demand- and process-side. Comparative system experience is also informative: Shah (2025) describes building a kidney transplant programme in Nepal, a low-resource setting, and identifies trained coordinators, political will, affordable immunosuppression, and a planned shift from living to deceased donation as the operational preconditions for growth - closely paralleling the constraints observed in the Indian system.

A fourth stream addresses inference. Because transplant outcomes are rarely studied through randomized trials, observational analysis dominates. Gomez-Montero et al. (2026) provide methodological guidance on propensity score matching (PSM) for kidney-transplant research, detailing covariate selection via directed acyclic graphs, balance assessment using standardized mean differences, and sensitivity analysis. This toolkit is relevant to the empirical agenda - quantifying the effect of operational interventions on transplant outcomes will require exactly such quasi-experimental methods.

This work builds on the aforementioned streams and is an integrative treatment that frames the Indian transplant system as a single end-to-end operation and locates the highest - leverage interventions across its stages.

3. Operations Management Perspective

Operations management studies how inputs are transformed into goods and services efficiently and reliably. The following map directly onto transplantation:

- Perishable inventory management: An organ behaves like extremely perishable stock with a short, organ-specific shelf life. It cannot be replenished on demand, cannot be substituted freely, and its shelf life (cold ischemia time) directly determines graft (transplant) success.
- Service operations and capacity planning: Transplant centres are capacity-constrained service systems: TICU beds, operating theatres, retrieval teams, and trained coordinators are the bottleneck resources. Queuing theory describes the waitlist, where patients wait for a scarce, randomly arriving resource.
- Supply chain and logistics: The journey from donor hospital to recipient hospital is a time-critical cold chain requiring synchronized, last-mile-sensitive transport - conceptually similar to emergency and humanitarian logistics.
- Assignment and optimization: Matching a donated organ to a recipient is a constrained assignment problem balancing medical compatibility, urgency, waiting time, and geography.

Rather than treating these as separate clinical challenges, the following sections frame the Indian transplant system as a single end-to-end operation and locate the highest-leverage interventions across its stages. Methodologically, the analysis draws on two complementary operations-management traditions: the Theory of Constraints, used to identify and prioritise the single binding constraint on the supply side, and lean logistics, used to compress time and eliminate waste along the flow from organ recovery to transplantation.

4. Institutional and Regulatory Context

Organ donation and transplantation in India is governed by the Transplantation of Human Organs and Tissues Act, 1994 (amended in 2011), administered by the Ministry of Health and Family Welfare. The Act regulates the removal, storage, and transplantation of human organs for therapeutic purposes and strictly prohibits commercial dealing in organs. Operationally, this legal frame defines who may donate, how brain-stem death is certified, and how organs may be allocated - each a constraint on the operating system.

Coordination is delivered through a three-tier network: the National Organ and Tissue Transplant Organisation (NOTTO) at the top, Regional Organ and Tissue Transplant Organisations (ROTTOS), and State Organ and Tissue Transplant Organisations (SOTTOs). This network functions as the system's coordination and information backbone. Recent reforms under a 'One Nation, One Policy' approach removed state-domicile requirements, upper age limits,

and registration fees for deceased-donor recipients, and an Aadhaar-linked digital pledge portal launched in 2023. These reforms reduce friction in demand registration and widen the matching pool - both operationally significant.

4.1 International comparison: India, Spain, and the United States

India's regulatory and operational model becomes clearer when set against the two systems most often cited as benchmarks: Spain, the long-standing world leader in deceased donation, and the United States, the largest transplant system by volume. The three differ on three operationally decisive dimensions - the consent regime, the coordination architecture, and the allocation method - and these differences, more than clinical capability, explain much of the performance gap.

Spain operates a presumed-consent (opt-out) framework under its 1979 Transplantation Law, but the consensus is that the law itself is not the cause of its success; in practice coordinators always approach families and abide by their wishes (Domínguez-Gil, in *The Lancet*, 2024). The decisive operational feature is the Spanish Model's coordination architecture: a dedicated hospital transplant coordinator - typically an intensive-care physician - embedded in every procurement hospital, whose core function is the early identification of potential donors. In operations terms, Spain attacks the conversion-rate bottleneck at its source, supported by donation after circulatory death and continuous professional training. The result is roughly 46 - 49 donors per million population, against India's sub one per million population.

The United States runs an opt-in system under the National Organ Transplant Act (NOTA) of 1984, coordinated through the Organ Procurement and Transplantation Network (OPTN), operated under federal contract by United Network for Organ Sharing (UNOS), with regional Organ Procurement Organizations (OPOs) performing recovery. Allocation is algorithmic - for each available organ, UNOS generates a donor-specific 'match run' ranking candidates by urgency, expected benefit, waiting time, and geography, with a one-hour acceptance window for each offer. This is a mature, IT-intensive assignment engine - though it too has faced criticism over equity and organs lost in transit. India sits between these poles and, in key areas, behind both. Like the United States, it uses an opt-in regime; unlike either Spain or the US, it has historically lacked both the embedded hospital-coordinator role that drives Spanish conversion and the uniform national allocation algorithm that drives US matching. The recent 'One Nation, One Policy' reforms move India toward the US model of national, domicile-blind allocation. The clearest operational lesson from the comparison is that neither a consent law alone (Spain shows presumed consent is not the active ingredient) nor volume alone (the US shows scale does not guarantee equity) closes the gap; what does is the combination of source-level donor conversion and a transparent, viability-aware allocation engine - both of which are operations-design choices rather than purely legal or clinical ones (Table 1).

Table 1. Regulatory and operational comparison: India, Spain, and the United States

Dimension	India	Spain	United States
Consent Regime	Opt-in	Opt-out	Opt-in
Governing Regulation	THOTA 1994 (amended 2011)	Transplantation Law 1979	National Organ Transplant Act 1984
Coordinating Body	NOTTO / ROTTO / SOTTO	ONT (Organizacion Nacional de Trasplantes)	OPTN, operated by UNOS; regional OPOs
Key Operational Lever	Emerging national policy; coordinator role still developing	Embedded hospital coordinator; early donor identification	Algorithmic national match run; IT-intensive allocation

5. The Transplant Pathway as an Operations System

The deceased-donor pathway can be modelled as a sequential process with strict time dependencies. Each stage adds delay, and delay reduces the value of the perishable unit: donor identification and brain-stem-death certificate; family consent and authorization (often the rate-limiting step); organ retrieval and preservation (the organ is flushed with a preservation solution and packed in a cold container); matching and allocation through the registry; transport by road or air, frequently using a "green corridor"; and recipient surgery with post-operative TICU care (Figure 2).

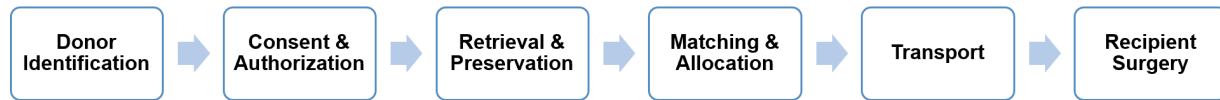


Figure 2. The deceased-donor transplant pathway

The binding operational constraint across this pathway is cold ischemia time (CIT) - the interval between interruption of the donor organ's blood supply and reperfusion in the recipient. The longer the CIT, the lower the probability of good transplant function. Viability windows differ sharply by organ, which makes the logistics problem organ-specific (Table 2).

Table 2. Indicative cold ischemia tolerance by organ

Organ	Approx. viability window	Dominant logistics implication
Heart	4 - 6 hours	Air transport / very short; failure margin is minutes
Liver	12 - 15 hours	Road or air; failure margin high but lower than heart
Kidney	Up to 36 hours	Most logistically flexible; can tolerate longer transfers

Because the heart and liver have the shortest windows, they are the organs for which India most often activates green corridors - traffic-cleared routes coordinated among hospitals, traffic police, and airport authorities to compress transit time. Documented transfers, such as organ movement between Pune and Mumbai in roughly 90 minutes (ZTCC Pune, n.d.), illustrate what synchronized last-mile logistics can achieve - and, by contrast, what is lost when such coordination is unavailable.

5.1 Contrast with corneal transplantation

Corneal transplantation offers an instructive contrast that sharpens the operations argument, because the cornea is an avascular tissue rather than a solid organ and therefore relaxes almost every constraint that makes solid-organ logistics so demanding. The contrast is also regulatory: the 2011 amendment to THOTA reclassified the cornea as a tissue rather than an organ, which allowed trained technicians - not only surgeons - to perform enucleation, and because corneas are recovered only from the deceased, the live-donor regulations were unnecessary. This single classification change widened the procurement workforce and is credited with substantial gains in tissue availability.

Operationally, the cornea differs from kidney, liver, and heart on the dimensions which have, in earlier sections, been identified as binding. Its viability window is measured in days to weeks under modern storage media rather than the hours of cold ischemia that govern solid organs, so the time-critical green-corridor logistics are largely unnecessary. It does not require blood-group or genetic matching in standard cases, collapsing the assignment problem that complicates solid-organ allocation. And it does not depend on brain-stem-death certification or ICU-based donor maintenance, removing the most fragile steps in the deceased-organ pathway. The corneal supply chain is thus closer to a conventional perishable-inventory system than to the emergency-logistics system that solid organs demand.

Most relevant to the present argument, India's corneal system already embodies the replenishment-style, source-level procurement logic. The Hospital Cornea Retrieval Programme (HCRP) - a proactive, opt-in model in which counsellors and technicians approach families at the point of hospital death - has become the dominant and most reliable source of optical-grade tissue, outperforming passive voluntary donation on both quantity and quality. In effect, the cornea system solved its conversion-rate bottleneck by embedding procurement into the hospital workflow, which is precisely the intervention that solid-organ donation in India still largely lacks.

The contrast is not wholly favourable, however, and it underscores that operational design, not biology alone, determines outcomes. Despite far easier logistics, India still meets only a fraction of its corneal need - utilization rates of collected tissue have historically hovered around half, less than half of the country's eye banks are fully functional, and a pledge to donate does not legally bind the next of kin. The corneal case therefore cuts both ways: it shows how

relaxing the perishability and matching constraints simplifies operations, yet also shows that without sustained procurement, quality control, and utilization discipline, even an easier supply chain leaves large unmet demand. For solid organs, where the constraints are far tighter, the operational stakes of getting these design choices right are correspondingly higher.

6. Diagnosing the Operational Losses

The NOTTO dataset (NOTTO, 2024) reveals where the system loses value. The pattern is rapid growth in total volume driven overwhelmingly by living donors, alongside a deceased-donor base that remains structurally thin (Figure 3) (Table 3).

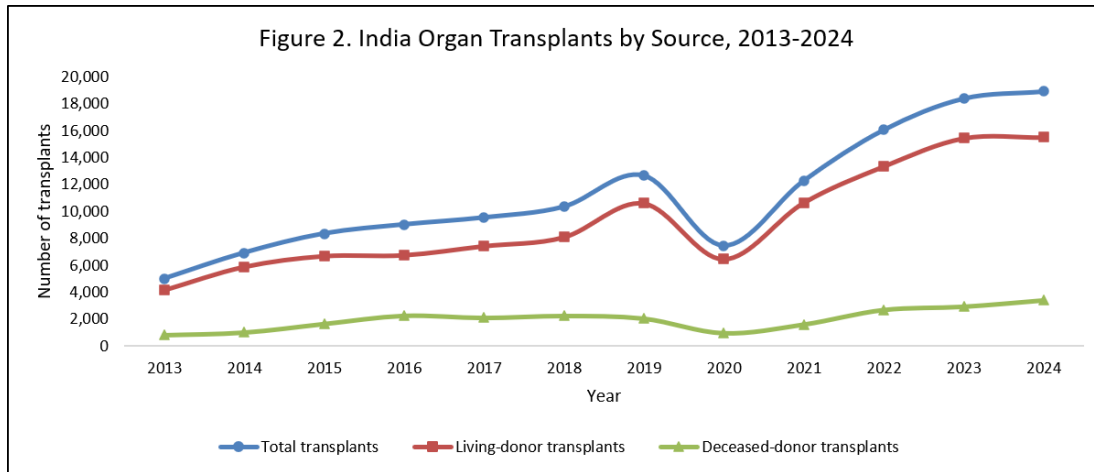


Figure 3. India organ transplants by source (2013 – 2024)

Table 3. Indicative cold ischemia tolerance by organ

Year	Total transplants	Living-donor transplants	Deceased-donor transplants	Deceased donors
2013	4,990	4,153 (83%)	837 (17%)	340
2014	6,916	5,886 (85%)	1,030 (15%)	408
2015	8,348	6,689 (80%)	1,659 (20%)	666
2016	9,022	6,756 (75%)	2,265 (15%)	930
2017	9,539	7,429 (78%)	2,110 (22%)	773
2018	10,340	8,085 (78%)	2,254 (22%)	875
2019	12,666	10,604 (84%)	2,060 (16%)	715
2020	7,443	6,457 (87%)	984 (13%)	351
2021	12,259	10,638 (87%)	1,619 (13%)	552
2022	16,041	13,338 (83%)	2,694 (17%)	941
2023	18,378	15,435 (84%)	2,935 (16%)	1,099
2024	18,911	15,505 (82%)	3,403 (18%)	1,128

6.1 Living-donor dependence and the demand-supply gap

Of the 18,911 transplants in 2024, living donors accounted for 15,505 and deceased-donor transplants for only 3,403. India is simultaneously the world's largest performer of living-donor transplants and one of the lowest in deceased donation. From an operations standpoint, a service system that depends on living donors is one whose supply is effectively rationed by whether a patient happens to have a compatible, willing relative. Patients without such a donor

join a long queue against a near-empty deceased-donor pipeline. The 2020 dip - total transplants falling to 7,443 from 12,666 in 2019 - also shows the system's fragility to external shocks such as the COVID-19 pandemic.

6.2 A thin and slow-growing deceased-donor base

The number of deceased donors rose only from 340 in 2013 to 1,128 in 2024, and it has been volatile rather than steadily increasing - peaking at 930 in 2016, falling to 351 in 2020, and recovering thereafter. One efficiency gain is visible in the data - the average number of organs transplanted per deceased donor rose from 2.43 in 2016 to 3.02 in 2024, meaning each scarce donor is now used more fully. This indicates a true operational improvement in yield per unit of supply, but it cannot compensate for the small number of donors (Figure 4).

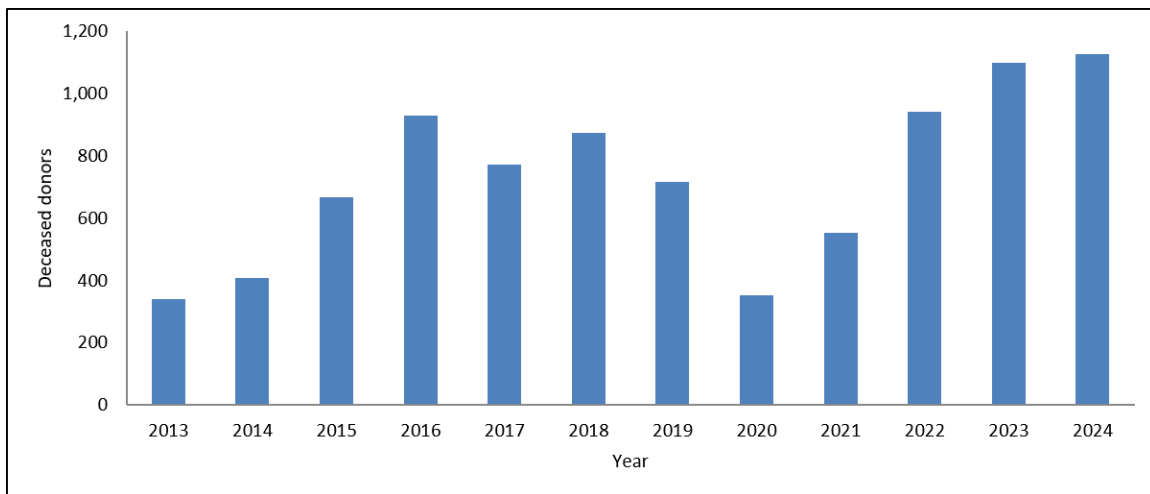


Figure 4. Number of deceased donors in India (2013–2024)

6.3 Potential Donors Lost in Conversion

India records well over one lakh road-traffic deaths annually, a substantial pool of potential deceased donors, yet realizes only around 1,100 deceased donations. The gap between potential and realized donation is, in process terms, a conversion-rate failure: the input exists but is lost at the identification, brain-stem-death certification, and consent stages. This is the single largest operational opportunity in the system, because it expands supply at the source rather than merely optimizing the handling of an already scarce resource.

6.4 Extreme regional concentration

Deceased donation is geographically concentrated to a degree that distorts the entire network. In 2024 the top five states for deceased-donor organ transplants were Tamil Nadu (860), Telangana (587), Karnataka (483), Maharashtra (466), and Gujarat (367), while the state-wise donor distribution shows a long tail of states contributing only single digits - several reporting just one donor. Living-donor activity is concentrated differently, led in 2024 by Delhi NCR (4,357), Tamil Nadu (1,987), Maharashtra (1,607), Kerala (1,471), and West Bengal (996). A network with such concentrated supply nodes and dispersed demand is operationally fragile: it cannot balance load, and organs cannot easily reach distant recipients within viability windows (Table 4).

Table 4. Top five states by transplant activity 2024

Rank	Deceased-donor transplants	Numbers	Living-donor transplants	Numbers
1	Tamil Nadu	860	Delhi NCR	4,357
2	Telangana	587	Tamil Nadu	1,987
3	Karnataka	483	Maharashtra	1,607

Rank	Deceased-donor transplants	Numbers	Living-donor transplants	Numbers
4	Maharashtra	466	Kerala	1,471
5	Gujarat	367	West Bengal	996

6.5 Organ-mix concentration

The transplant mix is dominated by kidneys and livers. In 2024 living-donor kidney transplants numbered 11,558 and deceased-donor kidney transplants 1,918, while living-donor liver transplants reached 3,946 against 952 from deceased donors. Higher-complexity organs remain rare: 253 heart, 228 lung, 44 pancreas, and 37 kidney-pancreas transplants. The thin volumes for thoracic organs reflect both supply scarcity and the unforgiving logistics of their short viability windows - precisely the organs most dependent on reliable green-corridor capability.

7. Operations Management Interventions

Mapping the losses to Operations Management levers yields a concrete improvement agenda spanning supply expansion, network design, process improvement, and decision support. Two operations-management practices structure this agenda, and they apply at different stages of the pathway. The Theory of Constraints (TOC) governs the diagnosis and the supply side: it directs attention to the single binding constraint rather than to improving everything at once, and the analysis above identifies that constraint as the failure to convert potential deceased donors into actual donations. TOC's logic and the replenishment, pull-based thinking that Lowalekar and Ravi (2017) used to transform a comparable perishable-supply system—motivates the supply-conversion and forecasting interventions. Lean logistics, by contrast, governs the flow side: once an organ is retrieved, the goal is to remove every avoidable hour and handoff between recovery and reperfusion, which motivates the network-design, process-improvement, and allocation interventions. The two are complementary rather than competing - TOC decides where to act first, lean determines how to make the chosen process fast and reliable - and the present work applies TOC to elevate donor conversion as the priority constraint while using lean methods to harden the time-critical cold chain behind it.

7.1 Expand supply through managed donor conversion

Because the largest leakage is the failure to convert potential deceased donors, the highest-return intervention is a standardized donor-conversion process embedded in every large trauma and tertiary hospital: routine identification of potential donors, protocol-driven brain-stem-death certification, and trained transplant coordinators managing the family-consent conversation. Treating donor conversion as a managed process with measured conversion rates - rather than an ad-hoc event - attacks the supply constraint at its source. The experience of building a transplant programme in a low-resource setting reinforces this priority: trained coordinators, affordable immunosuppression, and a deliberate shift from living to deceased donation were the operational preconditions for growth in Nepal (Shah, 2025).

7.2 Demand forecasting and registry analytics

A unified national registry enables forecasting of organ-specific demand by region, blood group, and urgency. Forecasts support proactive capacity planning - staffing retrieval teams, reserving ICU beds, and pre-positioning logistics - rather than reacting to each donation as a surprise event.

7.3 Network design: hub-and-spoke and load balancing

Given concentrated supply and dispersed demand, a deliberately designed hub-and-spoke network - regional retrieval and transplant hubs linked to feeder centres, with clear inter-state sharing rules - can balance load and widen each organ's reachable recipient pool. The reforms removing state-domicile barriers are the kind of network-design change that lets a unit of supply serve a national, rather than local, demand pool.

7.4 Lean process improvement on the time-critical path

Every hour removed from the pathway between retrieval and reperfusion raises transplant-success probability. Lean techniques - value-stream mapping of the donor-to-recipient process, eliminating coordination handoffs, parallelizing consent and recipient preparation, and standardizing green-corridor activation as a pre-agreed protocol - convert green corridors from heroic one-off efforts into a reliable, repeatable capability. The rising organs-per-donor ratio (2.43 to 3.02) shows yield improvement is achievable when handling is optimized. The same logic that moved blood banks from large, infrequent batch collection to responsive replenishment (Lowalekar and Ravi, 2017) applies to the

transplant cold chain: reliability comes from a standing, repeatable process rather than case-by-case heroics. Complementing process change, organ-preservation advances such as machine perfusion can extend the viability window itself (Hunter et al., 2025), widening the feasible transport radius for each donated organ.

7.5 Decision support for allocation

A uniform, transparent national allocation algorithm that weighs medical compatibility, urgency, waiting time, and expected transport time within the organ's viability window reduces both inequity and wastage. Embedding viability-aware logistics into the matching decision - so an organ is offered first to a recipient reachable within its CIT - aligns the assignment problem with the perishability constraint.

7.6 Information systems and traceability

Real-time tracking of organs in transit, digital pledge and waitlist registries, and live coordination dashboards reduce information delays that are themselves a source of operational loss. End-to-end traceability also supports quality assurance and outcome tracking, closing the feedback loop for continuous improvement.

8. Conclusion

Human organ transplantation in India is a high-stakes operations system constrained by a thin and geographically concentrated supply, a perishable product with unforgiving time limits, fragmented logistics, and historically inconsistent allocation. The NOTTO data show record transplant volumes built overwhelmingly on living donors, with deceased donation growing slowly and unevenly. The operational losses - unconverted potential donors, regional imbalance, avoidable transit delay, and inequitable matching - are large and addressable. Operations management offers a coherent toolkit: managed donor conversion, forecasting and registry analytics, hub-and-spoke network design, lean improvement of the time-critical path, viability-aware allocation, and real-time information systems. Framing the challenge as an operations-design problem reframes the path forward - most lives are saved not only by asking more people to donate, but by building a system that loses far less of what is already given.

These conclusions should be read alongside the study's limitations. This article draws on published national aggregates from NOTTO; it does not measure actual cold ischemia times, organ-discard rates, or centre-level capacity utilization, which national reporting does not yet fully capture. Future work would pursue primary data collection at transplant centres, discrete-event simulation of the donor-to-recipient pathway, queuing analysis of organ-specific waitlists, and optimization modelling of inter-state allocation and transport networks. Empirical estimation of donor-conversion rates by hospital type would help quantify the supply-side opportunity identified here. Because such evaluations rely on observational data, quasi-experimental methods would be needed to support credible causal claims about the effect of operational interventions on transplant outcomes.

References

- Domínguez-Gil, B. "Organ donation: Lessons from the Spanish model," *The Lancet*, Vol. 404, No. 10461, 2024.
- Ekser, B., and L. A. Fernandez. "Promise and pitfalls of liver xenotransplantation," *Nature Reviews Gastroenterology & Hepatology*, Vol. 22, pp. 527–528, 2025.
- Eye Bank Association of India (EBAI). "Procurement, storage and utilization trends of eye banks in India and the Hospital Cornea Retrieval Programme (HCRP)," *Indian Journal of Ophthalmology*, 2019.
- Global Observatory on Donation and Transplantation. "Data charts and tables: Total transplants by country, 2024," 2024. <https://www.transplant-observatory.org/data-charts-and-tables/chart/>
- Gomez-Montero, A., Garcia-Lopez, A., Cabas, S., Nieves-Rico, A. A., and Giron-Luque, F. "Methodological guidance on implementing propensity score matching in observational studies of kidney transplantation," *Scientific Reports*, Vol. 16, p. 1878, 2026.
- Grinyó, J. M. "Why is organ transplantation clinically important?" *Cold Spring Harbor Perspectives in Medicine*, Vol. 3, No. 6, p. a014985, 2013.
- Hunter, J., Hosgood, S., Moers, C., Leuvenink, H., Rabelink, T. J., and Ploeg, R., on behalf of the COPE consortium. "Improving outcomes in kidney transplantation through advances in donor organ perfusion," *Nature Reviews Nephrology*, Vol. 21, pp. 818–832, 2025.
- Lowalekar, H., and R. R. Ravi. "Revolutionizing blood bank inventory management using the TOC thinking process: An Indian case study," *International Journal of Production Economics*, Vol. 186, pp. 89–122, 2017.

- National Organ and Tissue Transplant Organisation (NOTTO). “Data for Organ Donation and Transplantation (2013–2024),” Directorate General of Health Services, Ministry of Health and Family Welfare, Government of India, 2024. <https://notto.mohfw.gov.in/>
- National Organ and Tissue Transplant Organisation (NOTTO). *Annual Report 2024–25*, Ministry of Health and Family Welfare, Government of India, 2025.
- Organ Procurement and Transplantation Network (OPTN) / United Network for Organ Sharing (UNOS). “The national organ donation and transplant system and the National Organ Transplant Act of 1984,” U.S. Health Resources and Services Administration, 2024. <https://unos.org/>
- Shah, D. S. “Insights from Nepal into implementing transplantation programmes in low-resource settings,” *Nature Reviews Nephrology*, Vol. 21, p. 812, 2025.
- Transplantation of Human Organs and Tissues Act, 1994 (Amended 2011)*, Ministry of Health and Family Welfare, Government of India, 2011.
- Zonal Transplant Coordination Centre (ZTCC), Pune. “Green corridor for saving lives: Cold ischemia time and organ preservation,” n.d. <https://ztccpune.org/>