

Supplementary information

Supplemental Figure legends

Supplemental Figure 1. PESTELE-led hierarchical structure for VNRD achievement in Japan

Abbs: JRC, Japanese Red Cross

Supplemental Figure 2. PESTELE-led hierarchical structure for VNRD achievement in Finland

Abbs: FRC, Finnish Red Cross; org, organization

Supplemental Figure 3. PESTELE-led hierarchical structure for VNRD achievement in Thailand

Abbs: mng, management; NBC, National Blood Center; pts, patients

Supplemental Figure 4. PESTELE-led hierarchical structure for VNRD achievement in Oman

Abbs: NBTS, National Blood Transfusion Service

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achievement in Malaysia

Abbs: MoH, Ministry of Health

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achievement in Brazil

Challenges to be overcome in the future are underlined. Abbs: BS, blood service; govt, government; int'l, international; std, standard

Supplemental Figure 9. PESTELE-led hierarchical structure for VNRD

achievement in Saudi Arabia

Challenges to be overcome in the future are underlined. Abbs: GL, guideline; inclu, including; MoH, Ministry of Health; tech, technology

Supplemental Figure 10. PESTELE-led hierarchical structure for VNRD

achievement in Georgia

Challenges to be overcome in the future are underlined. Abbs: BE, blood establishment

Supplemental Figure 11. PESTELE-led hierarchical structure for VNRD

achievement in Ghana

Challenges to be overcome in the future are underlined. Abbs: IS, information system

49 **Supplemental Figure 12. PESTELE-led hierarchical structure for VNRD**
50 **achievement in Indonesia**

51 Challenges to be overcome in the future are underlined. Abbs: BD, blood
52 donation; IRC Indonesian Red Cross; MoH, Ministry of Health

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Foundation Level

Political Commitment

- Cabinet decision post-Reischauer incident
- Government mandate for 100% VNRD system
- Ministry of Health oversight and authorization
 - Political will maintained through crises
 - Post-HIV scandal government

Legal Framework

- Blood collection and Supply control act
- Law on securing stable supply of safe blood
- Pharmaceutical and medical devices act
- Legal prohibition of paid blood collection
- Criminal responsibility for violations

Resource Level

Economic Support System

- Universal health insurance coverage
- Government financial commitment to JRC
- Investment in centralized infrastructure
- Post-Olympics economic growth period
- National insurance system financing
- Economic stability supporting sustainability

Implementation Level (+ for sustainability)

Social Mobilization

- Student movements
- Religious group advocacy
- Mass media campaigns
- Public health awareness
- Crisis-driven consensus

Technology & Innovation

- Advanced testing technology
- Infectious disease markers
- Automated testing systems
- Block center consolidation
- Processing automation

System Environment

- Centralized JRCBS system
- Block center (BC) efficiency
 - Regional BC network
 - Integrated operations
- Quality management systems

Ethical Standards

- Strict non-remuneration policy
 - No monetary incentives
- Minimal refreshments only
 - Voluntary principles
 - Donor safety priority

Supplemental Figure 1. PESTELE-led hierarchical structure for VNRD achievement in Japan

Abbs: JRC, Japanese Red Cross

Foundation Level

Political Foundation

- Post-WWII decision: Blood banking by FRC
- Legal mandate: FRC obliged to practice blood service activities in Finland
- National responsibility: Must ensure blood service in normal and extraordinary situations

Legal Framework

- EU compliance: Implementation of EU Blood Directive and complementary directives
- National regulation: Finnish Blood Service Act and Blood Service Decree
- Regulatory oversight: Finnish Medicines Agency

Resource Level

Economic Support System

- Self-sustaining model: Financed by sales of products and services to healthcare orgs
- No public funding: Operation not supported by public funds or Red Cross proceeds
- Financial surplus: Any surplus used for continuation and development of activities

Period until
VNRD achievement
1980s

Implementation Level (+ for sustainability)

Social Acceptance

- High donor participation
- Strong community support

Technology Advancement

- Centralized operations
- Quality infrastructure

Centralized Environment

- Healthcare integration
- Organizational culture

Ethical Standards

- Strict voluntary principles
- Clear regulatory guidelines
- Non-profit org. structure

Supplemental Figure 2. PESTELE-led hierarchical structure for VNRD achievement in Finland

Abbs: FRC, Finnish Red Cross; org, organization

Foundation Level

Political Framework

- Royal family leadership
- Government regulation established NBC mandate
- First National Blood Policy enacted (1989)
- Current National Blood Policy (2022)

Legal & Regulatory Framework

- Government gazette regulation
- VNRD definition
- Quality oversight

Resource Level

Economic Advantage

- Economic growth: Upper-middle income, Economic feasibility
- Funding structure: Government support, Cost recovery
- Infrastructure investment: Network expansion, Hospital integration

Period until
VNRD achievement
1990s-2000s

Implementation Level

Social Mobilization

- Buddhist cultural foundation
- Public acceptance
- Recognition system (Reward)
- Youth engagement

Technological Evolution

- Glass bottles → Plastic bags
- Social media for recruitment
- Centralized testing labs
- Advanced data mng. systems

Environmental Integration

- Mobile blood collection units
- Sustainable donor community programs
- Logistics management for remote areas

Ethical Achievements

- No paid donation since policy inception
- Voluntary principles in law
- Free blood supply to all pts
- Merit-based motivation sys

Supplemental Figure 3. PESTELE-led hierarchical structure for VNRD achievement in Thailand

Abbs: mng, management; NBC, National Blood Center; pts, patients

Foundation Level

Political Commitment

- Government support for WHO compliance
- Political decision to stop blood imports and rely on local donors due to HIV and safety concerns
- Government oversight

Legal Framework

- NBTS establishment
- National Blood Transfusion Committee formation
- National Blood Policy creation

Resource Level

Period until
VNRD achievement
2000s-2010s

Economic Advantage

- Funding transition
- Incentive management
- Free blood supply
- Infrastructure investment

Implementation Level

Social Commitment

- Social awareness
- Public education campaigns
- Voluntary group support
- Donor motivation programs

Technology & Safety

- Advanced screening tech
 - Centralized testing
- Standardized procedures across 14 blood banks

System Environment

- Centralized network of 14 blood banks
- Hospital-based collections
- Coordinated supply chain

Ethical Standards

- Voluntary principles enforcement
- Safety-first approach
- Elimination of all financial incentives by 2000

Supplemental Figure 4. PESTELE-led hierarchical structure for VNRD achievement in Oman

Abbs: NBTS, National Blood Transfusion Service

Foundation Level

Political Commitment

- Strong government leadership
 - Autonomous institution
- Political will & media: High-level advocacy through media platforms

Legal Framework

- National standards (WHO-based)
- Regulatory development: Food and Drug Authority
 - Expanded mandate: Blood, tissue, eye, and stem cell banking authority

Resource Level

Period until
VNRD achievement
2012-2014

Economic Support System

- Government funding: 100% Government financed, Free blood supply
- Infrastructure: Regional blood banks & Mobile teams for national coverage
 - Centralized system: Central procurement & Centralized testing

Implementation Level

Social Engagement

- Community mobilization
 - 175+ donor clubs
- Religious support
- Cultural norms

Technology & Innovation

- SMS Reminder System
 - Social Media
- Quality Systems
- Testing Technology

Advanced Environment

- Healthcare integration
- Regional Networks
 - Crisis Resilience
- Geographic Coverage by mobile units

Ethical Standards

- Voluntary principles
 - Safety first
 - Equity access
- Transparency: Public reporting & accountability

Supplemental Figure 5. PESTELE-led hierarchical structure for VNRD achievement in Ethiopia

Foundation Level

Political Framework

- National blood policy & strategy
- Turkish Red Crescent leadership
- National safe blood provision program (aligned with WHO criteria)

Legal Framework

- Blood and Blood Products Law (prohibiting paid donation)
- EU harmonization Process
- Regulatory framework: MoH oversight
- Circular on Mandatory Blood Supply from VNRD

Resource Level

Economic Resources

- Dedicated VNRD budgets: Special budget allocation specifically for VNRD recruitment
 - EU project funding: "Technical assistance for recruitment of future blood donors"
- Infrastructure investment: facility restructuring and modern donation environments
 - Central prpcurement & Centralized testing
 - Health insurance coverage

Period until
VNRD achievement
2005-2016

Implementation Level

Social Commitment

- "Target 25" youth program
- School education campaigns
 - Specialist training
 - Media campaigns

Technology & Innovation

- Mobile donation application
 - Social media strategy
- Modern communication strategy
- Centralized operations
 - Data management

Environment Refinement

- Donor-friendly environment
 - Accessible facilities
- Mobile blood collection units

Ethical Promotion

- VNRD ethics promotion
- Red Cross/Red Crescent humanitarian principles supporting VNRD as ethical norm

Supplemental Figure 6. PESTELE-led hierarchical structure for VNRD achievement in Türkiye

Foundation Level

Political Commitment

- Political will: MoH commitment for safe blood
- HIV awareness catalyst: Focusing on safe donors
- Government oversight: Direct MoH supervision

Legal Framework

- National blood policy: Formal policy framework
- Quality standards: Lab accreditation requirements
 - Hospital regulations: Private hospital act compliance

Resource Level

Period until
VNRD achievement
2010s-2020s

Economic Support System

- Economic structure: Economic feasibility, Government funding
- Resource allocation for National blood centre:
Centralized resource management & Systematic resource optimization

Implementation Level

Social Commitment

- Public education
- Population acceptance
- Strong demographics:
25-30% first-time donors
annually

Technology & Innovation

- Skilled workforce
- Quality systems
- Advanced testing

Advanced Environment

- Healthcare integration
- Stand-alone service
- Network coverage

Ethical Standards

- Safety focus on donor safety
- Regulatory framework
- Voluntary principles

Supplemental Figure 7. PESTELE-led hierarchical structure for VNRD achievement in Malaysia

Abbs: MoH, Ministry of Health

Foundation Level

Political Commitment

- Constitutional prohibition: Banning paid donation
- Decentralized governance: Multiple govt BS
- Federal oversight: National regulatory system
 - Policy framework: National blood policy

Legal Framework

- MoH ordinance: Clear VNDR definitions
- Regulatory authority: Blood establishment registration and authorization
- Compliance framework: Mandatory inspections
- Incentive regulations: Non-monetary compensation allowed

Resource Level

Economic Support System

- Multi-sector funding: Govt BS • Non-govt organizations, Private sector participation
- Resource challenges: Decentralized resource allocation, No single funding coordination, Varied sector capacities
- Limited non-monetary incentives: Light snacks allowed, Transportation cost coverage

Implementation Level

Social Challenges

- Cultural transition: non-paid
- Social norms: Family obligation culture persisting
- Public education: Ongoing awareness campaigns needed
- Community integration

Technology Challenges

- Modern stds: Int'l protocols
 - Regulatory systems
- Quality control: Standardized testing procedures
- Multi-sector Integration

Environment Challenges

- Geographic diversity
- Regional variations
 - Infrastructure
 - Access equity

Ethical Challenges

- Voluntary principles: Clear non-remuneration stds
 - Informed consent
 - Altruistic culture
 - Safety priority

Supplemental Figure 8. PESTELE-led hierarchical structure for movement toward VNDR in Brazil

Challenges to be overcome in the future are underlined. Abbs: BS, blood service; govt, government; int'l, international; std, standard

Foundation Level

Political Commitment

- MoH leadership: Central regulatory authority
- Regional fragmentation: Five regional directorates with varying VNRD performance (20-90%)
 - World Blood Donor Day integration
- Coordination challenges: No nationally organized blood transfusion service

Legal Framework

- Paid donation ban: Strong legal foundation
- Multi-tier oversight: MoH regulation, Saudi FDA, CBAHI accreditation, AABB standards
- Compliance variation: Erratic GL compliance
- Multiple institutional types: Different legal framework and oversight mechanisms

Resource Level

Economic Support System

- Multi-source healthcare system: Diverse funding sources
- Regional resource distribution
- National planning need: Resource coordination
- Economic barriers: Hindering move to complete 100% VNRD (inclu. plasma fractionation)

Implementation Level

Social Commitment

- Islamic cultural integration
 - Youth engagement
- Mass media coverage
- National society advocacy

Technology & Innovation

- Advanced testing techs
- International accreditation
- Hospital-based systems
- Quality management

Environment Challenges

- Regional variation: %VNRD across hospitals

Ethical Framework

- Islamic ethical framework
 - Safety-first approach
 - Altruistic motivation
- Global standards integration

Supplemental Figure 9. PESTELE-led hierarchical structure for movement toward VNRD in Saudi Arabia

Challenges to be overcome in the future are underlined. Abbs: GL, guideline; inclu, including; MoH, Ministry of Health; tech, technology

Foundation Level

Political Commitment

- EU association agreement: Harmonizing national legislation to EU Laws
- Political will challenges: lack of confidence in existing healthcare system
- NGO advocacy leadership: lack of legal recognition

Legal Framework

- New blood law (2022): Mandating voluntary unpaid donation from 2025
- System centralization: BE operated by government
- Regulatory gaps: Lack of legal accountability for individuals who inflict moral harm on donors"

Resource Level

Economic Support System

- Post-Soviet transition: Difficult economic situation for decentralization
- State safe blood program: Coverings expenses for screening, testing, national donor database"
- NGO funding Innovation: Resorted to crowdfunding initiatives and B to B collaborations

Implementation Level

Social Commitment

- NGO social media success
- Youth engagement
- Cultural barriers

Technology & Innovation

- Centralized testing
- National donor database
- Digital engagement: Social network to popularize VNRDs

Environment Challenges

- Accessibility challenges
- Geographic concentration
- System restructuring

Ethical Standards

- Safety risks: Paid donors
 - Information transparency
 - Organizational ethics:
- Transparency by NGO success

Supplemental Figure 10. PESTELE-led hierarchical structure for movement toward VNRD in Georgia
Challenges to be overcome in the future are underlined. Abbs: BE, blood establishment

Foundation Level

Political Commitment

- National Blood Service Act 2020
- Governance structure for strategic oversight
- FDA Ghana regulatory authority
- National Blood Policy (2006)

Legal Framework

- Blood regulatory framework
- National haemovigilance framework
- Screening guidelines (blood testing protocols)
- Legal challenges: Slow regulation implementation & weak enforcement"

Resource Level

Economic Support System

- Central government funding: Healthcare resource allocation
- Development partners: External funding and grants
- Zonal structure
- Resource challenges: Inadequate funding and resource allocation by government, Lack of institutionalized funding arrangements, High production costs, No scale economies

Implementation Level

Social Challenges

- Public education
- Multiple donor groups
- Community leaders: Local leadership engagement
- Challenge: Low acceptance & misconceptions for VNRD

Technological Challenges

- Digital systems: Digital IS
- Social media channels
- Drone services: Emergency
- Strengthened collaborations and good banking practices

Environment Challenges

- Monitoring systems
- Public health response: Infectious disease outbreak
- Infrastructure investment: Stable power, water, etc.

Ethical Challenges

- Safety standards: Informed consent, privacy protection
- Fair distribution: Non-discrimination in blood services
- Public trust: Confidence in blood safety

Supplemental Figure 11. PESTELE-led hierarchical structure for movement toward VNRD in Ghana

Challenges to be overcome in the future are underlined. Abbs: IS, information system

Foundation Level

Political Commitment

- Governor regulations: BD for driver license renewal
 - Presidential awards for 100-time donors
- Government employee mandates: All government offices required to organize blood donation
- Dual coordination: MoH oversight + IRC leadership

Legal Framework

- Comprehensive laws on health & blood services
- Religious decrees: Formal religious expert opinions
- GMP certification: FDA oversight & accreditation
- Paid donation ban with clear ethical guidelines

Resource Level

Economic Support System

- Dual Funding: MoH & IRC
- Mobile unit investment
- Inter-center networking
- National coordination: Centralized screening & processing
 - Restriction of private hospitals for blood collection
- Under-financing: low Government blood rates

Implementation Level

Social Commitment

- Donor associations:
- Celebrity campaigns
- Mass media: education campaigns
- Youth education

Technology & Innovation

- Recruitment via social media
- Mass media: Donor education
 - Data systems: Donor management & tracking
 - Challenges: Replacement donor spikes led by social media

Donation Environment

- Mobile units: Shopping malls and office locations
- Group donations: Organized collective events
 - Accessibility: Distance barriers to blood centers

Ethical Standards

- Altruistic motivation
- Religious blessing
- Fair incentives: Clear guidelines on rewards
- Challenge: Donation only when personally requested

Supplemental Figure 12. PESTELE-led hierarchical structure for movement toward VNRD in Indonesia

Challenges to be overcome in the future are underlined. Abbs: BD, blood donation; IRC Indonesian Red Cross; MoH, Ministry of Health