



***NORTHROP GRUMMAN***

DEFINING THE FUTURE

# Supply Chain Analytics for Humanitarian Logistics Transformation

Rockefeller Foundation Conference  
Humanitarian Logistics: Networks for Africa  
7 May 2008  
Bellagio, Italy

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Northrop Grumman Corporation

# Perspective

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**Ya hay un español que quiere  
vivir y a vivir empieza,  
entre una España que muere  
y otra España que bosteza.  
Españolito que vienes  
al mundo, te guarde Dios.  
Una de las dos Españas  
ha de helarte el corazón.**

**Antonio Machado, 1875-1939  
Proverbios y Cantares, 1917**

# Outline

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- **Value Proposition**
- Humanitarian Assistance
- Humanitarian Relief Organizations
- Humanitarian Logistics
- Supply Chain Analytics
- Performance Measures
- Example Application
- Conclusion

# Humanitarian Assistance Donor Economics

- **Total of \$9.2B** in 2006 from DAC (Development Assistance Committee) donors of the OECD (Organisation for Economic Cooperation and Development)
- Does not include local response and remittances from family members and Diaspora communities
- Breakdown by Country of Donor (\$8.5B total)

Country of Donor	Aid (US \$ M)	Percent
USA	3032	33
EC & EU member states	4237	46
Norway	380	4
Canada	278	3
Switzerland	196	2
Japan	199	2
Australia	197	2
Other	700	8
<b>Total</b>	<b>\$9.2B</b>	<b>100</b>

Source: Global Humanitarian Assistance 2007/2008, Development Initiatives

# Humanitarian Assistance Donor Economics

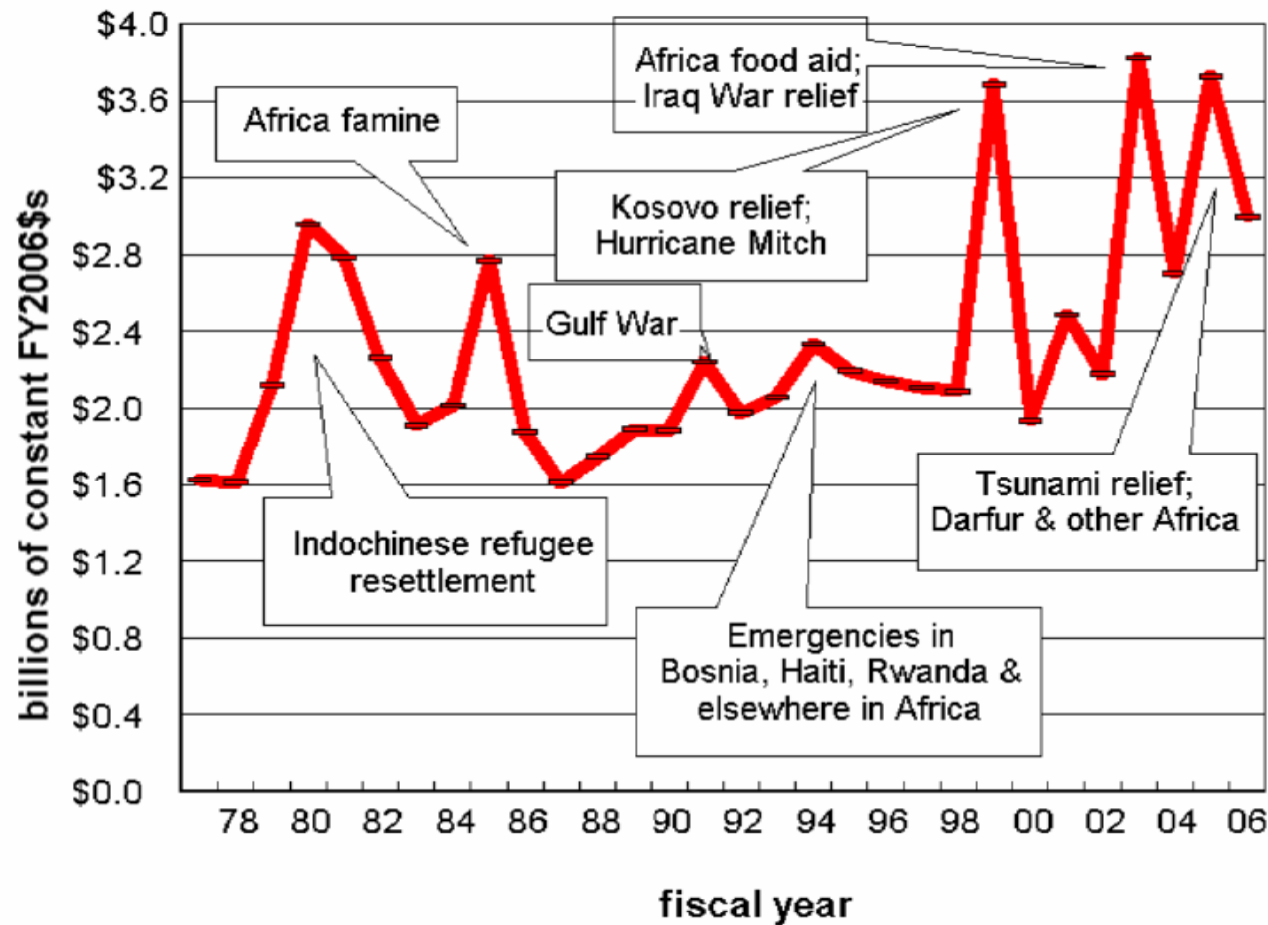
- GHA guesstimate of global humanitarian assistance 2006:

<b>Source</b>	<b>Amount (US \$ B)</b>	<b>Percent</b>
HA from non-DAC donors	0.435	3
Voluntary contributions to Red Cross/Red Crescent and UN agencies	0.470	3
Voluntary contributions to NGOs	1.840	13
Humanitarian activities that are not ODA-eligible	2.411	17
Multilateral HA	2.471	17
Bilateral HA from DAC donors	6.751	47
<b>Total</b>	<b>\$14.4B</b>	<b>100</b>

Source: Global Humanitarian Assistance 2007/2008, Development Initiatives

# Humanitarian Logistics Economics

## Historical US Disaster Relief Contributions



Source: CRS Report for Congress, International Crises and Disasters: U.S. Humanitarian Assistance, Budget Trends, and Issues for Congress, updated May 3, 2007

# Humanitarian Assistance Recipient Economics

<b>Recipient</b>	<b>2006 Aid (US \$ M)</b>	<b>Percent</b>
Sudan	1201	18
Palestine/OCT	701	10
DRC	374	5
Pakistan	370	5
Indonesia	367	5
Lebanon	346	5
Ethiopia	314	5
Afghanistan	296	4
Somalia	275	4
Uganda	214	3
Kenya	202	3
Iraq	151	2
Burundi	136	2
179 others	1956	29
<b>Total</b>	<b>\$6.9B</b>	<b>100</b>

Source: Global Humanitarian Assistance 2007/2008, Development Initiatives

# Humanitarian Assistance in Africa

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- **Humanitarian assistance to Africa grew from \$946 million in 1997 to just over \$3 billion in 2003.**

source: Development Initiatives (2004–05) 'Global Humanitarian Assistance', Update. Cited in Causing Hunger: an overview of the food crisis in Africa, Oxfam briefing paper, 24 July 2006

- **African farmers produce 83% of what Africans eat**

source: J. Devries & G Toenniessen of the Rockefeller Foundation, Securing the Harvest: Biotechnology, Breeding and Seed Systems for African Crops, p.33, CABI International, New York, 2001

- **Note that consumption provides a lower bound on demand**



# Food aid

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- **Emergency food aid**
  - the dominant response to food crises
  - constitutes over half of all UN consolidated emergency appeals
  - 17 per cent of non-food needs identified in the recent UN appeal for Kenya, for example, were funded, compared to 46 per cent of food needs
  - food aid exacerbates food insecurity if it harms farmers' livelihoods
  - Imported food aid can take up to 4-5 months to arrive
  - Food aid may cost as much as 50% more than local food, and may be nutritionally limited and culturally inappropriate.
  - In 2004, Canada spent up to 40% of its food aid budget on transportation, before policy change
  
- **Vested interests partly drive in-kind food-aid donations**
  - useful way to offload agricultural surpluses
  - provides commercial benefits to agricultural and shipping companies
  - 79% of food aid is sourced in donor countries
  - Is a form of domestic subsidy – can actively harm farmers in the developing world
  - US (biggest donor) sources 99% of food aid domestically
  - Denmark, France, and Italy largely source food aid domestically

source: Causing Hunger: an overview of the food crisis in Africa, Oxfam briefing paper, 24 July 2006

# Multilateral food aid channels

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- **About half of all food aid**
- **UN World Food Programme (WFP)**
  - handles ~98% of multilateral food aid
  - US is largest donor by far

source: J. Devries & G Toenniessen of the Rockefeller Foundation, *Securing the Harvest: Biotechnology, Breeding and Seed Systems for African Crops*, p.33, CABI International, New York, 2001

- main UN agency responsible for delivering food aid
- receives 48% of its food from the USA
- buys up to about 30% of its food aid locally
- receives the majority of its contributions from governmental donors in kind rather than cash
- some US NGOs have a conflict of interests regarding commodity food aid, since they rely on sales of food aid to finance development programs

source: *Causing Hunger: an overview of the food crisis in Africa*, Oxfam briefing paper, 24 July 2006

# US Food aid

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- **USAID – cost of transportation is 65% of the total expenditure for emergency food**

Source: GAO report to Congressional Committee on Agriculture, Nutrition and Forestry, 21 March 2007

- **Buying locally saves approximately 50% of total cost**
- **About 10% of aid is cash**
- **US is mainly alone in selling food aid. Most other donors buy food aid locally**
- **US food aid system set up to benefit US business interests, rather than to deliver aid effectively**

- source: Sophia Murphy & Kathy McAfee, US Food Aid: Time to Get It Right, Institute for Agriculture and Trade Policy, July 2005, <http://www.tradeobservatory.org/library.cfm?refid=73512>

# Supply Chain Analytics: Value Proposition

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- Savings are typically **10-25%** of supply chain operating costs
- Improved life-cycle costs, efficiency, dependability, reliability, feasibility, throughput, quality, profitability, cost avoidance, utility, timeliness, flexibility, responsiveness, mission success, mission effectiveness, availability, failure rate and/or any other quantifiable or non-quantifiable objective, over the given planning horizon

# Value Proposition

- **US – \$3B annually**
  - 65% of USAID food aid budget goes to transportation
  - **local buying** saves approximately **half** of total cost
  - **\$1.5B local-buying savings** opportunity
  - About 10% of aid is cash (assume buy local)
  - 15% for local transportation (includes locally-bought and shipped-in)
  - 10%-25% **transportation savings** yields **\$45-113M**
- **DAC (non-US) – \$9.2 – \$3.0 = \$6.2B annually**
  - 30% for transportation  $(65\% - 50\%)/(100\% - 50\%)$
  - 10%-25% **transportation savings** yields **\$186-465M**
- **DAC & Non-DAC (non-US) – assume \$14.4 - \$3.0 = \$11.4B annually**
  - 30% for transportation  $(65\% - 50\%)/(100\% - 50\%)$
  - 10%-25% **transportation savings** yields **\$342-855M**
- **Note: savings from “local buying” confounds food price differentials and international transport costs**
- **If food is cheaper locally than in the USA, then the 30% figure and the stated savings opportunities are conservative**
- **40%-50% figures may be more reasonable**

# Supply Chain Analytics Value Proposition

Amounts in US \$M	US	DAC but not US	DAC & Non-DAC, but not US
Total aid	\$3,000	\$6,200	\$11,400
Food	\$1,050	\$4,340	\$7,980
International transport	\$1,500		
Local transport	\$450	\$1,860	\$3,420
Local buying Savings opportunity	\$1,500		
Transport savings opportunity lower bound – low estimate	\$45	\$186	\$342
Transport savings opportunity lower bound – high estimate	\$113	\$465	\$855

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- **Humanitarian Assistance**
- Humanitarian Relief Organizations
- Humanitarian Logistics
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# Humanitarian Assistance

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**“The annual labor of every nation is the fund which originally supplies it with all the necessaries and conveniences of life which it annually consumes, and which consist always either in the immediate produce of that labor, or in what is purchased with that produce from other nations.”**

Source: An Inquiry Into the Nature and causes of the Wealth of Nations, Adam Smith, 1776. Opening words of Book One.

**Humanitarian Assistance is needed when a nation’s supply chain cannot support the lives of its people.**



# Humanitarian Assistance

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## Objectives:

- save lives, alleviate suffering and maintain human dignity during and in the aftermath of man-made crises and natural disasters,
- Prevent and strengthen preparedness for such situations.
- **Guided by**
  - the humanitarian principles of humanity, meaning the centrality of saving human lives and alleviating suffering wherever it is found
  - impartiality, meaning the implementation of actions solely on the basis of need, without discrimination between or within affected populations
  - neutrality, meaning that humanitarian action must not favor any side in an armed conflict or other dispute where such action is carried out
  - independence, meaning the autonomy of humanitarian objectives from the political, economic, military or other objectives that any actor may hold with regard to areas where humanitarian action is being implemented
- **Includes**
  - protection of civilians and those no longer taking part in hostilities
  - provision of food, water and sanitation, shelter, health services and other items of assistance
- **Undertaken**
  - for the benefit of affected people
  - to facilitate the return to normal lives and livelihoods
- Source: Principles and Good Practice of Humanitarian Donorship, Stockholm, 17 June 2003, <http://www.goodhumanitariandonorship.org/>

# Humanitarian Assistance Classification

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- **Disasters – result of a vast ecological breakdown in the relationship between man and his environment, a serious (sudden or slow) disruption on such a scale that the stricken community needs extraordinary efforts to cope with it**

(source: WHO 2003)

(source: Sundnes & Bimbaum, Health Disaster Management: Guidelines for Evaluation and Research in the Utstein Style. Prehospital Disaster Med 17 [Suppl 3:1:1-77], 2003)

- **Complex emergencies – conflict-generated emergencies caused by the breakdown of the state and its replacement by a political culture which reinforces and condones the use of violence to secure and maintain power**

(source: Unicef, State of the World's Children, 2003)

- **Sudden vs. slow onset**

# Classifying Disasters by Cause

- **Natural**
    - Seismic – Earthquake, Volcanic, Tsunami, Celestial collision
    - Climatic/Meteorological
      - Wind, precipitation, lightning, temperature
      - Flood, avalanche, erosion
      - Drought, desertification
  - **Mixed (natural + man-made)**
    - Drought, desertification, flood, erosion, landslides, mudslides, fire, epidemics
  - **Man-made**
    - Technological
    - Conflict
      - Armed – war, civil strife, complex emergency, terrorism
      - Unarmed – sanctions
- Source: Von Schreeb, Needs Assessments for International Humanitarian Health Assistance in Disasters, thesis for doctoral degree, Karolinska Institutet, Stockholm, 2007.
- Economic (supply-based)
    - Trade barriers
    - Price dynamics
    - Bullwhip effects/dynamics in supply chain
  - Population Dynamics (demand-based)

# Relief – Development Continuum

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- **Systemic problems**
  - cause man-made crises
  - cause inability to respond to natural crises
- **Relief and development are inter-dependent**
- **Ideally relief feeds into ongoing development efforts, rather than just saving lives**
- **Prevention and preparedness to build local capacities to deal with disaster. For example, agricultural investment vs. food aid**
- **Food crises can be caused by food shortage OR food prices**

# Price-induced food crises

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- **The EU and USA damage rural livelihoods in Africa by supporting their own farmers with over \$300 billion a year in subsidies; then dumping the output on world markets, which depresses prices.** Source: 'Cultivating Poverty: The Impact of US Cotton Subsidies on Africa', Oxfam Briefing Paper, 2002.
- **Increased prices due to bio-fuel production negatively affect developing countries' ability to feed themselves.** Source: Washington Post, 26 April 2008.
- **Conjecture: price increases and decreases both affect the dynamics of local food production**
- **Conjecture: volatility in commodity prices has a disproportionate effect on poorer populations**

# Disaster Definition

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- **CDR – Crude Death Rate (per 10K persons per day)**
- **U5DR – Under-Five Death Rate**
- **Emergency: if CDR doubles**
- **Extreme emergency: if CDR quadruples**
- **Thresholds depend on baseline CDR**
- **Thresholds differ by country/region**

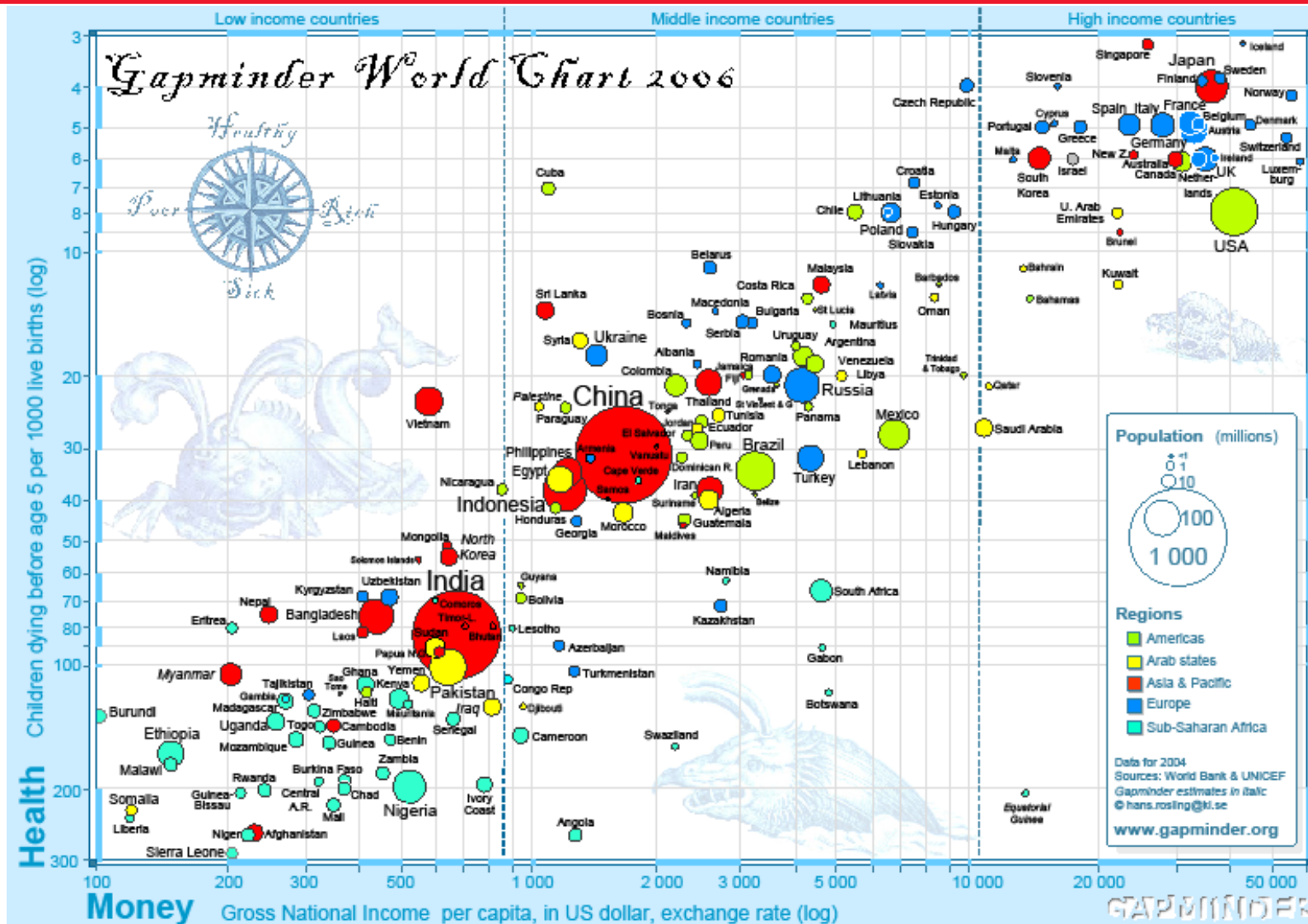
Source: Medecins Sans Frontieres, Refugee Health, An Approach to Emergency Situations, MacMillan Education Ltd, London, 1997; and Salama Spiegel et al, Lessons Learned From complex Emergencies Over the Past Decade, The Lancet 364 (9447): 1801-1813, 2004

# CDR Threshold Examples

Region	Baseline CDR	Threshold CDR	Baseline U5DR	Threshold U5DR
Sub-Saharan Africa	0.44	1.0	1.14	2.3
Middle East & North Africa	0.16	0.3	0.36	0.7
South Asia	0.25	0.5	0.59	1.2
East Asia & Pacific	0.19	0.4	0.24	0.5
Latin America & Caribbean	0.16	0.3	0.19	0.4
Central & Eastern Europe	0.30	0.6	0.20	0.4
High Income Countries	0.25	0.5	0.04	0.1
Middle Income Countries	0.25	0.5	0.53	1.1
Low Income Countries	0.38	0.8	1.03	2.1
World	0.25	0.5	0.48	1.0

Source Unicef, State of the World's Children, 2003

# U5DR & Per-capita Income



Source <http://www.gapminder.org/>

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# UN and IFRC

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- **Have legal mandate**
  - **UN Organizations (partial list)**
    - **World Health Organization (WHO)**
    - **UNICEF**
    - **World Food Program (WFP)**
    - **United Nations High Commissioner for Refugees (UNHCR)**
    - **Organization for the Coordination of Humanitarian Assistance (OCHA)**
  - **IFRC (International Federation of Red Cross and Red Crescent Societies)**
    - **Many member societies**
- Source: Von Schreeb, Needs Assessments for International Humanitarian Health Assistance in Disasters, thesis for doctoral degree, Karolinska Institutet, Stockholm, 2007.

# Humanitarian Relief NGOs

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- **Thousands of active societies**
  - More than 300 international NGOs active in Aceh province after 2004 Tsunami (source: B. Canny, Ed., A Review of NGO Coordination in Aceh Post Earthquake/Tsunami, International council of Voluntary Agencies (ICVA), 2005.
- **No legal mandates – own goals and objectives**

# A Few Humanitarian Relief NGOs

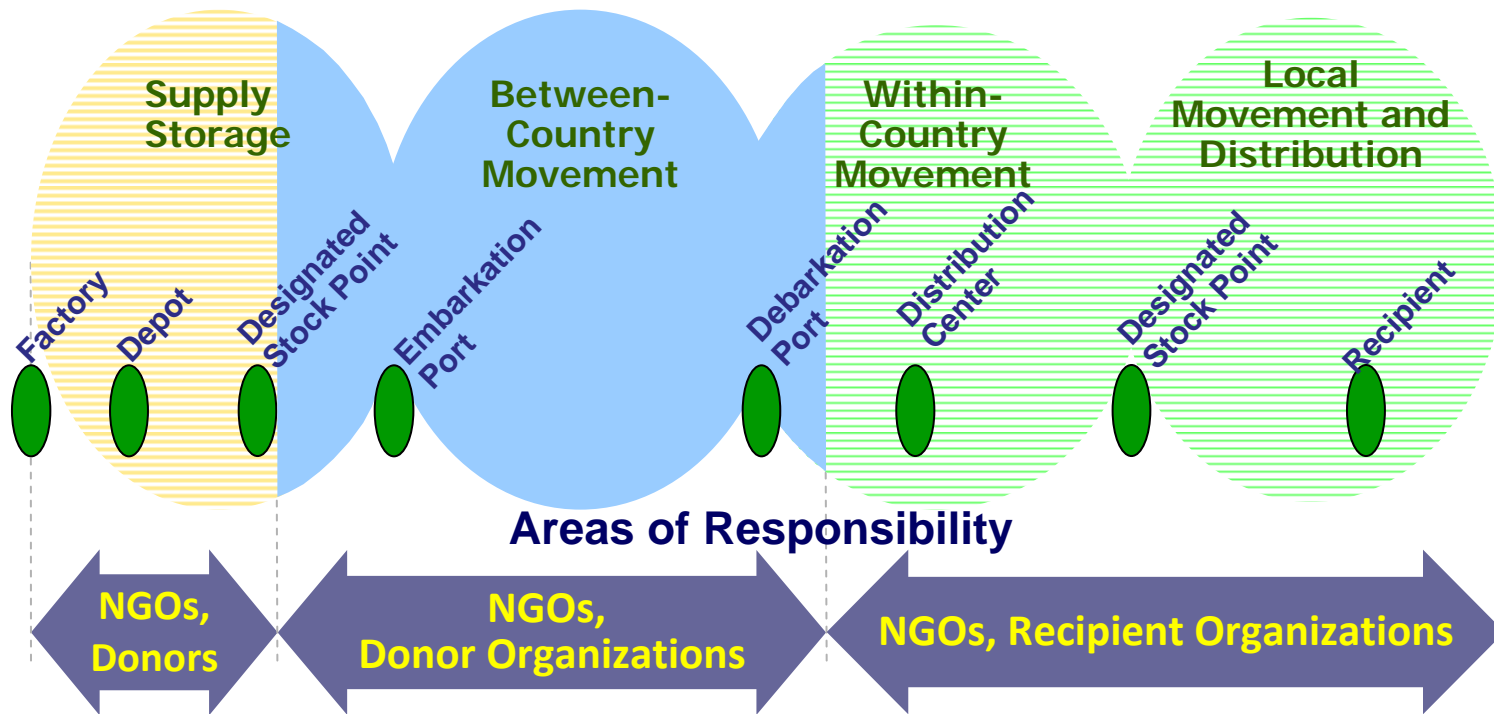
- **ACDI/VOCA**
  - **Action Against Hunger**
  - **Adventist Development and Relief Agency**
  - **American Friends Service Committee**
  - **American Jewish Joint Distribution Committee**
  - **American Jewish World Service**
  - **American Red Cross**
  - **American Refugee Committee**
  - **Baptist World Aid**
  - **CARE**
  - **Catholic Relief Services**
  - **Christian Children's Fund**
  - **Christian Reformed World Relief Committee**
  - **Church World Service**
  - **Concern Worldwide**
  - **Doctors of the World**
  - **Episcopal Relief and Development**
  - **Heifer Project International**
  - **International Aid**
  - **International Catholic Migration Commission**
  - **International Medical Corps**
  - **International Orthodox Christian Charities 44**
  - **International Rescue Committee 45**
  - **Lutheran World Relief 49**
  - **Mercy Corps International 51**
  - **Mercy USA for Aid and Development 52**
  - **Oxfam America 54**
  - **Physicians for Human Rights 55**
  - **Relief International 56**
  - **Save the Children 58**
  - **United Methodist Committee on Relief 60**
  - **United Way International 62**
  - **US Fund for UNICEF 63**
  - **World Relief 65**
  - **World Vision 66**
- Source: Efforts of Interaction Member Agencies in Kosovo, Disaster Response Unit of InterAction, American Council for Voluntary International Action, 2001

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# Humanitarian Assistance Supply Chain View



# Logistics & Supply Chain Commercial Sector View

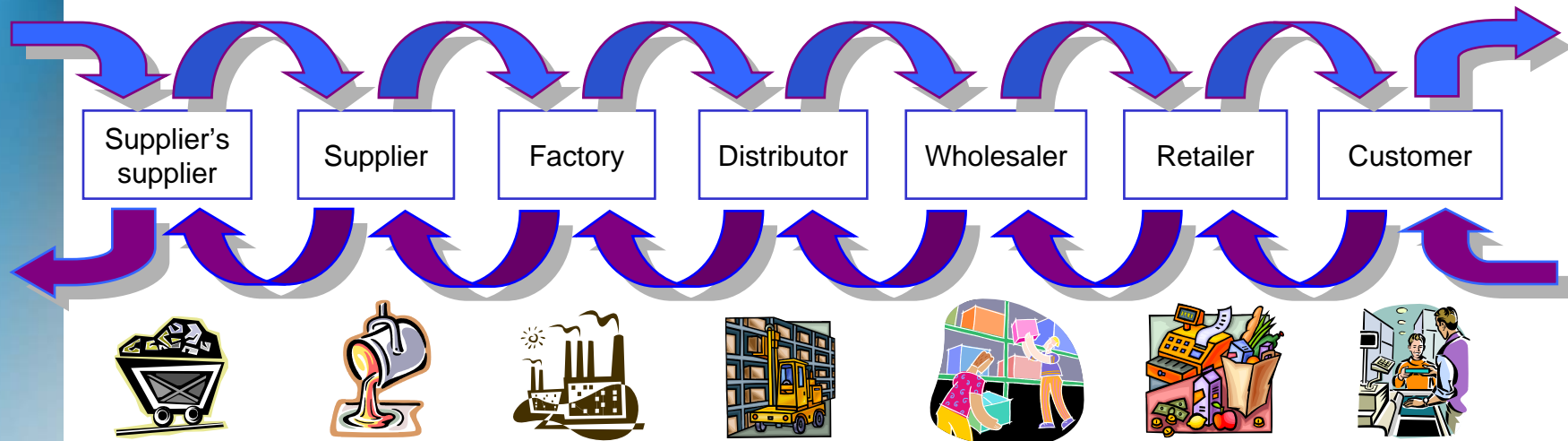
## SUPPLY CHAIN:

- The system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer.\*
- Transforms natural resources, raw materials and components into a finished product delivered to the end customer. \*
- Includes Logistics functions plus procurement & returns

\* source: Anna Nagurney: Supply Chain Network Economics: Dynamics of Prices, Flows, and Profits, Edward Elgar Publishing, 2006

## LOGISTICS:

- SC Activities within a company or organization
  - Inbound Logistics
  - Production Logistics
  - Outbound Logistics



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# Logistics & Supply Chain Military View

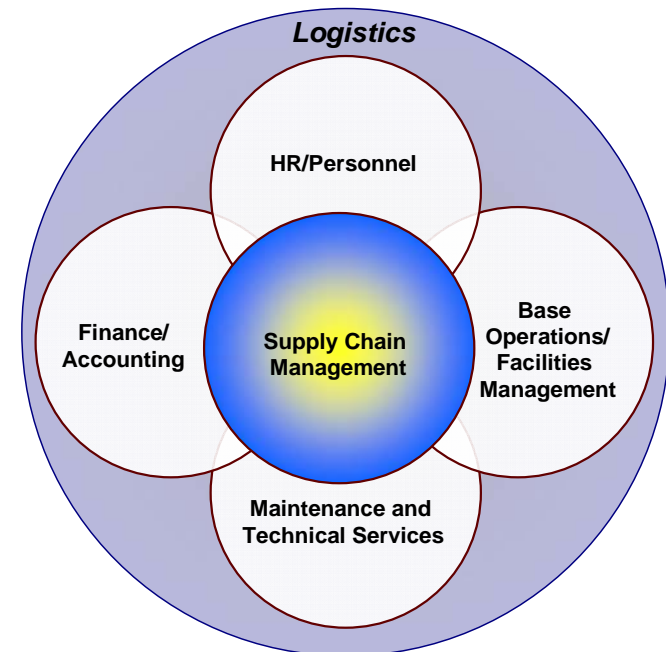
## LOGISTICS:\*

- The science of planning and carrying out the movement and maintenance of forces.... those aspects of military operations that deal with the:
  - design and development, acquisition, storage, movement, distribution, maintenance, evacuation and disposition of material;
  - movement, evacuation, and hospitalization of personnel;
  - acquisition of construction, maintenance, operation and disposition of facilities; and
  - acquisition of furnishing of services.
- **Four components:\*\***
  - Supply Chain Management
  - Finance/Accounting
  - Base Operations & Facilities Management
  - Platform Maintenance & Technical Services

## SUPPLY CHAIN

### MANAGEMENT:\*\*\*

- The discipline that integrates acquisition, supply, maintenance, and transportation functions with the physical, financial, information, and communications networks in a results-oriented approach to satisfy joint force materiel requirements.



\* DOD Joint Publication 1-02, 2001

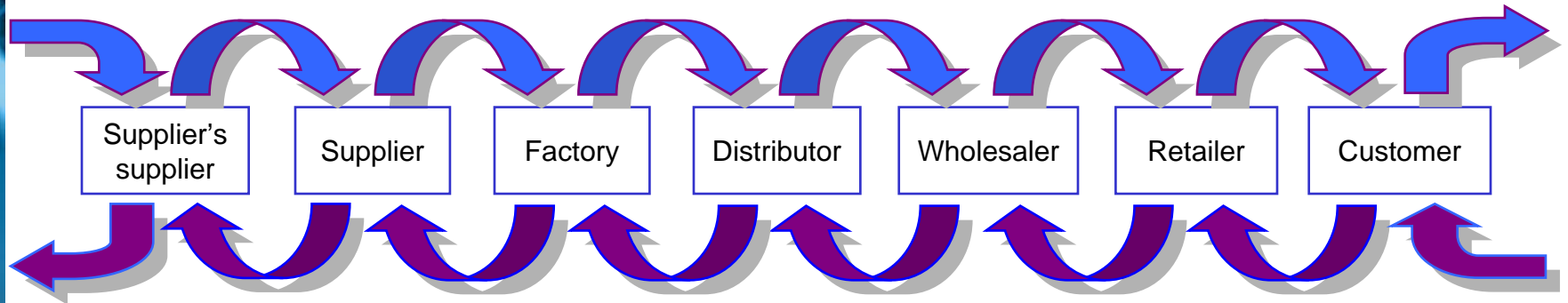
\*\* Avascent Group segmentation, 2007

\*\*\*DOD Joint Publication 4-09, 2001

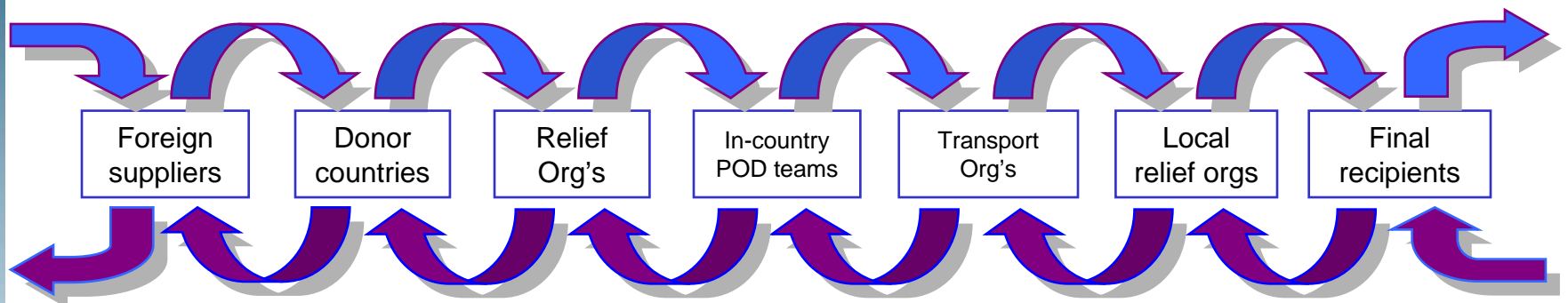


# Humanitarian Assistance – Supply Chain

**SUPPLY CHAIN:** The system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer.



- “Products” are relief supplies arriving in-country



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# Supply Chain Analytics: Typical Goals



- **Maximize inbound efficiency**
  - Teaming & sourcing strategy
  - Procurement & pricing



- **Optimize manufacturing flow**
  - JIT (Just In Time) techniques
  - Line balancing
  - Scheduling
  - Network design, floor layout, flow analysis

- **Maximize distribution efficiency**

- Location/allocation
- Vehicle routing analysis
- Dynamic programming
- Inventory analysis
- Facility planning, distribution network design



- **Maximize reverse flow efficiency**

- Network design
- Workforce planning
- Sorting, product choice



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# Supply Chain Analytics

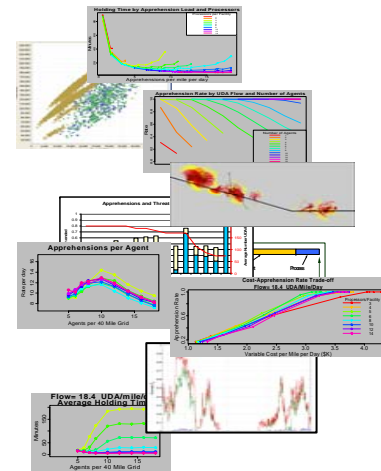
Through a strong analytical methodology, provide decision support for Supply Chain planning & operations

- Objectives
- Issues
- Constraints
- Architectures
- Functions
- Organization
- Data

## Supply Chain Analytics



## Measurable Results



## Informed Assessments & Decisions



Customized or COTS-based Analysis:

- Mathematical Modeling
- Simulation
- Statistical Analysis
- Sensitivity & “What-If” Analysis

- Performance Metrics
- Cost Estimates
- Resource Requirements
- Cost-Benefit Tradeoffs
- Dashboard Support

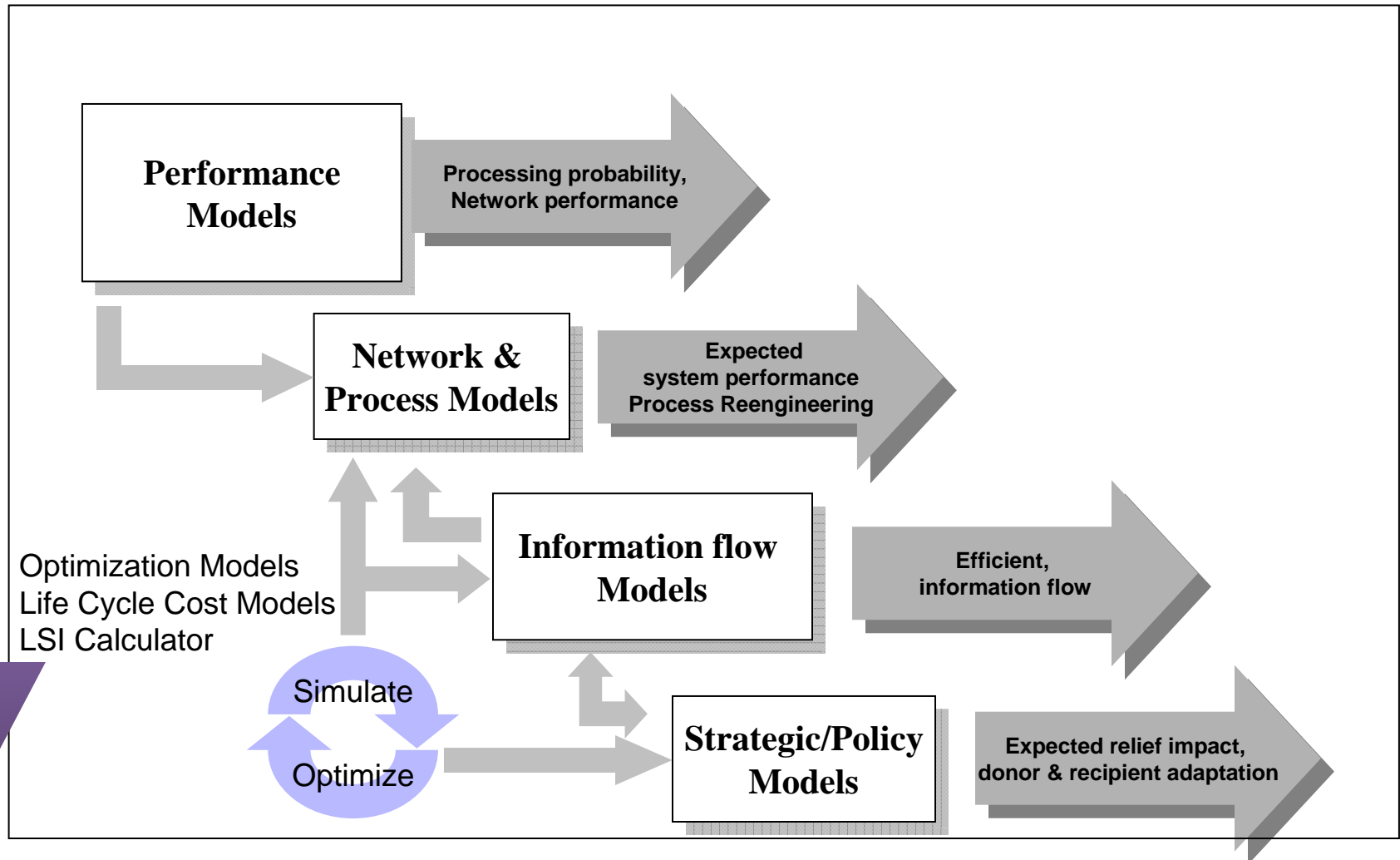
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# Types of Supply Chain Analysis

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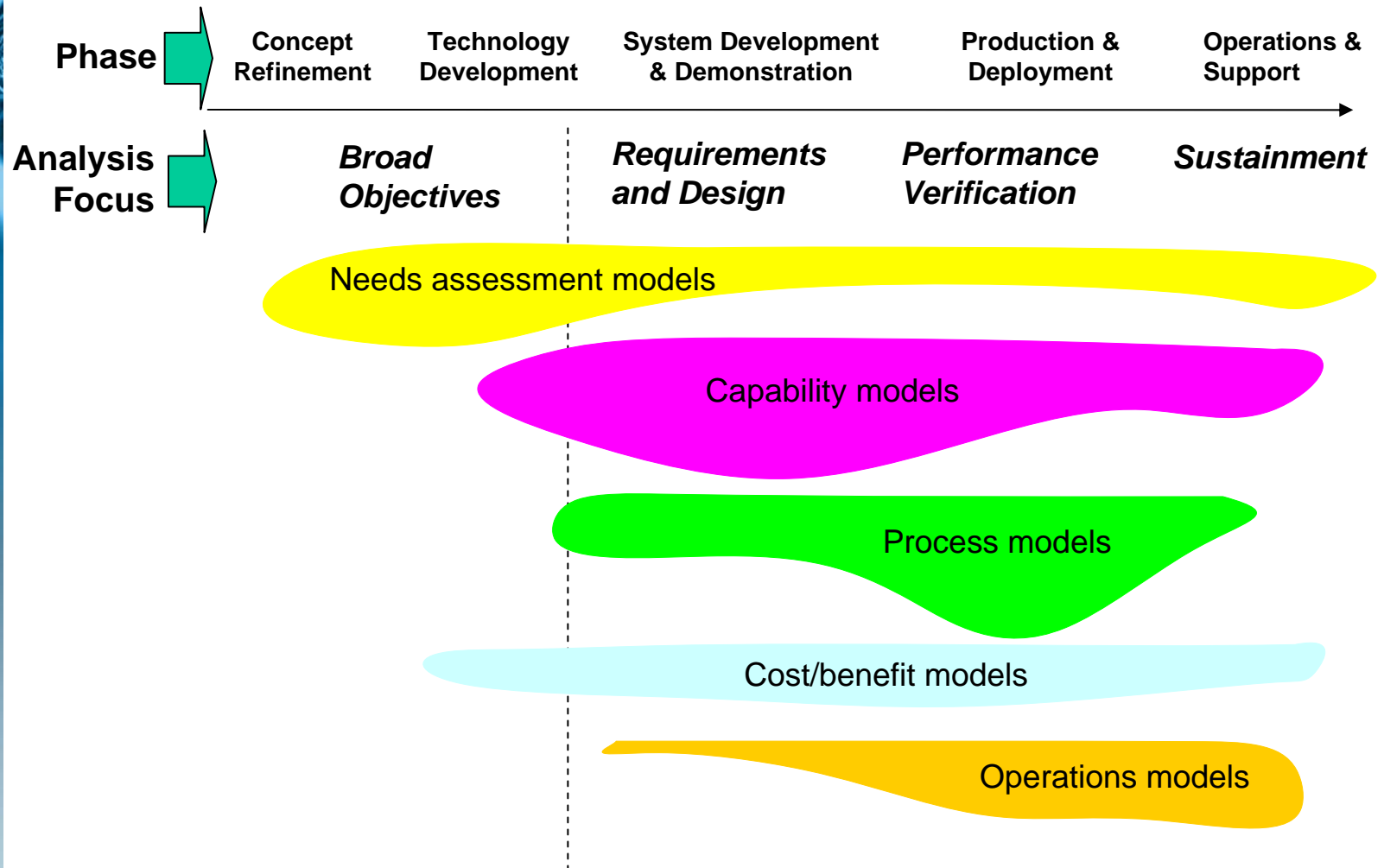
- **Strategic:**
  - Man-made
    - Development
    - Preventive
  - Natural
    - Development
    - Preparedness locally
    - International preparedness
  - Overall
    - Teaming/coordination
- **Tactical**
  - Distribution network planning
  - Source/donation planning
  - Pre-positioning, storage
- **Operational**
  - Arms and legs logistics
  - Distribution
- **Short-term (one-off) vs. ongoing (process)**

# Supply Chain Analytics – Model Hierarchy



# Apply the Right Supply Chain Analytics Tool

## SC Analytics Emphasis Shifts Across Program Phases



source: Phases: Defense Acquisition Handbook  
 Analytic focus: Simulation Based Acquisition Handbook

# SC Analysis Tools and Techniques

## Analytic Methodologies

- Optimization
  - Mathematical programming (LP, NLP, IP, MIP)
  - Stochastic optimization
  - Simulation
  - Statistical Analysis -- Correlation, Regression, Discriminant analysis, etc.
  - Forecasting
  - Data analysis
  - Data mining
  - Process, modeling
  - Decision Analysis
  - Risk Analysis
  - Six Sigma
  - Game Theory
- 
- **Methods may apply to needs assessment, capability, process, cost/benefit, operations, and other decision areas**
  - **Methods may apply at any phase of analysis**

## COTS Analysis Tools

- EXTEND
- GAMS
- Mathematica
- CPLEX
- SAS,
- SPSS,
- Statistica,
- Statgraphics,
- R
- OPNET
- ACEIT
- Crystal Ball
- Oracle
- Excel
- Access

## Supply Chain Management Tools

- Proprietary
- Special purpose



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# Effectiveness in a Relief Environment

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- **What does it mean to be effective in a relief environment?**
- **Cultural and economic differential between donor and recipient nations**
- **Individuals and organizations often act in their own self interest**
- **Suppose we decide to help “the people of country X” Who gets what? Who gets to decide?**
- **Issues of equity, need, natural outcomes, dignity**

# Performance Measures

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- **Performance measures vary with perspective. From whose perspective do we optimize?**
- **Cost measures – who pays, who donates**
- **Benefit measures – who gets credit, who receives aid**
- **Teaming aspects – is win/win possible, from whose perspective**
- **Gaming aspect**

# Performance Measures

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- **Who controls the decisions that influence the cost of transport?**
- **Whose budget is affected by these decisions?**
- **What is the effect of these decisions – is more relief actually delivered if cost is less?**
- **Who determines what gets sent where and when, by who?**
- **Performance measures follow political rationale**

# Sample Performance Measures

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- **Benefit**
  - Self-serving – organization/capability/market oriented
    - Budget used
    - Number of folks in theatre
    - Tons delivered
    - Order (early vs. late arrival on-site)
    - Publicity (e.g. media coverage / mentions / fotos)
    - New donations
    - Awards
    - Market share
  - Altruistic – mission effectiveness oriented
    - Lives saved
    - Delivered tons used (e.g. meals served, tents lived in, etc.)
    - Health care provided
- **Cost**
  - Money
  - Loss/leakage

# Example Performance Measure for Organizations – Ability to Advocate

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- **ActionAid:** Views advocacy as a useful tool with regard to emergencies- both advocating directly and supporting communities to advocate themselves- as part of their rights-based approach.
- **Christian Aid:** for immediate needs lobbies governments, donors and relief agencies, and for long-term needs advocates to recognize the causes of suffering and links to poverty, trade and debt.
- **Concern Worldwide:** advocacy to improve the effectiveness of their programs and to influence policy-makers.
- **ECHO:** Advocates for the mainstreaming of disaster preparedness and the need to make disaster preparedness integral to development policy.
- **IFRC:** Advocates for disaster preparedness, the promotion of solutions to underlying causes and better links between relief, rehabilitation and development. Promotes practical approaches to reduce vulnerability.
- **Oxfam GB:** Helps people lobby their own local and national governments for support and compensation after emergencies.

Source: A Developmental Approach to Working in Emergency Prevention, Preparedness and Response, Concern Universal, March 2006

# Accountability

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- **Accountability**
  - Fraud and waste
  - Business case approach
- **Sphere project**
  - 10 years in existence
  - purpose is to make humanitarian assistance more effective, and humanitarian agencies more accountable

Source: The Sphere Project: Humanitarian Charter and Minimum Standards in Disaster Response, The Sphere Project, Geneva, 2004

# Outline

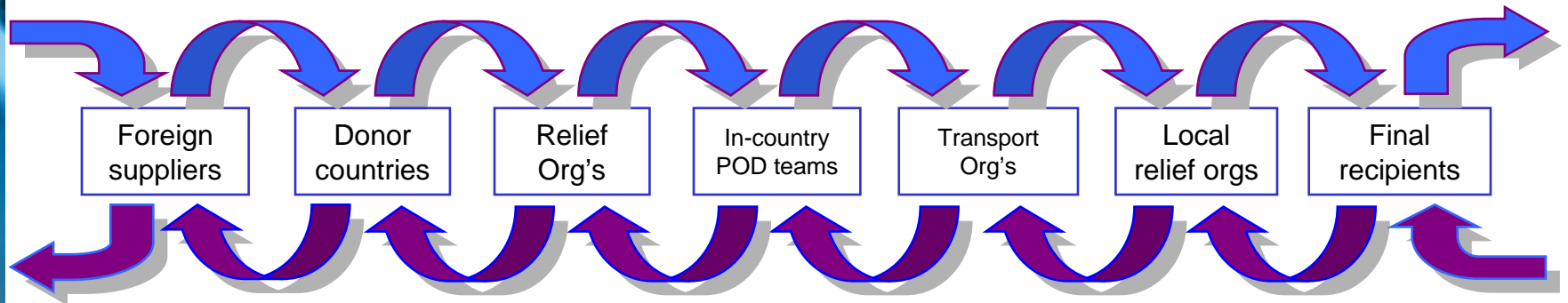
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# Humanitarian Enterprise Logistics Planning (HELP) – Example Problem

Recall that a supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer.



## Example problem

“products” are relief supplies arriving in-country

- Items are incoming at a port of debarkation (POD) in a recipient country
- The goal is multi-objective – to minimize a combination of cost and loss
- Scope is the portion of the supply chain that runs from incoming at the POD to the final recipients.

# HELP Optimization Model

## Multi-objective: minimize Cost and Loss

### Data

$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$  = given constants  
 $B$  = total annual budget

For each facility  $j$ , let

$N_{uj}$  = number of relief items per day  
 $T_{dj}$  = average disposition time  
 $N_{hj}$  = hours per day  
 $T_{tj}$  = average trip time  
 $T_{pj}$  = average processing time per relief item  
 $N_{fj}$  = number of facilities  
 $A_{fj}$  = annual cost per facility  
 $A_{bj}$  = annual cost per conveyance  
 $C_{uj}$  = cost per relief item  
 $A_{dj}$  = annual cost per POD staff  
 $A_{rj}$  = annual cost per driver  
 $A_{aj}$  = annual cost per field staff  
 $A_{pj}$  = annual cost per final staff  
 $L_{sj}$  = POD logistician saturation level  
 $C_{bj}$  = conveyance capacity  
 $M_{pj}$  = maximum relief items per final staff per day  
 $M_{aj}$  = maximum relief items per field staff per day

### Variables

For each facility  $j$ , let

$N_{aj}$  = number relief items incoming daily  
 $N_{nj}$  = number relief items lost daily  
 $T_{hj}$  = average relief item hold time  
 $N_{sj}$  = staff level  
 $C_{tj}$  = total cost  
 $P_{dj}$  = probability not lost at POD  
 $C_{pj}$  = final staff processing cost  
 $C_{dj}$  = POD staff cost  
 $C_{sj}$  = staff cost  
 $T_{bj}$  = average time waiting for conveyance  
 $T_{fj}$  = average time in facility  
 $N_{tj}$  = number of conveyance trips per day  
 $L_{bj}$  = average load per conveyance  
 $N_{bj}$  = number of conveyances  
 $N_{dj}$  = number of POD staff  
 $N_{rj}$  = number of drivers  
 $N_{aj}$  = number of field staff  
 $N_{pj}$  = number of final staff  
 $N_{mj}$  = number of POD staff per POD  
 $M_{cj}$  = maximum daily processing capacity

# HELP Non-Linear Programming Model

Maximize

$$\sum_j \alpha_1 \times N_{aj} + \alpha_2 \times N_{nj} + \alpha_3 \times T_{hj} + \alpha_4 \times N_{sj} + \alpha_5 \times C_{tj}$$

Subject to:

$$N_{aj} = N_{uj} \times P_{dj} \quad \text{if } \leq M_{cj} \quad \text{for all } j \quad \text{number processed at POD}$$

$$= M_{cj} \quad \text{otherwise}$$

$$N_{nj} = N_{uj} - N_{aj} \quad \text{for all } j \quad \text{loss at POD}$$

$$C_{tj} = C_{pj} + C_{dj} + C_{sj} \quad \text{for all } j \quad \text{total cost}$$

$$T_{hj} = T_{bj} + T_{fj} + T_{dj} \quad \text{for all } j \quad \text{hold time}$$

$$T_{bj} = (N_{hj}/N_{tj})/2 + T_{tj}/2 \quad \text{for all } j \quad \text{conveyance waiting time}$$

$$L_{bj} = N_{aj}/N_{tj} / 2 \quad \text{for all } j \quad \text{conveyance load}$$

$$T_{fj} = [1 + (L_{bj} / 2)] \times T_{pj} \quad \text{for all } j \quad \text{facility time}$$

$$C_{pj} = A_{fj} + N_{bj} \times A_{bj} + C_{uj} \times N_{aj} \quad \text{for all } j \quad \text{final processing cost}$$

$$C_{dj} = N_{dj} \times A_{dj} \quad \text{for all } j \quad \text{POD processing cost}$$

$$N_{sj} = N_{rj} + N_{aj} + N_{pj} \quad \text{for all } j \quad \text{staff level}$$

$$C_{sj} = N_{rj} \times A_{rj} + N_{aj} \times A_{aj} + N_{pj} \times A_{pj} \quad \text{for all } j \quad \text{staff cost}$$

$$P_{dj} = N_{mj}/L_{sj} \quad \text{if } N_{mj} < L_{sj} \quad \text{for all } j \quad \text{POD loss probability}$$

$$= 1 \quad \text{otherwise}$$

$$N_{tj} = \min \{ N_{bj}, N_{rj} \} \times (N_{hj}/T_{tj}) \quad \text{for all } j \quad \text{conveyance trips per day}$$

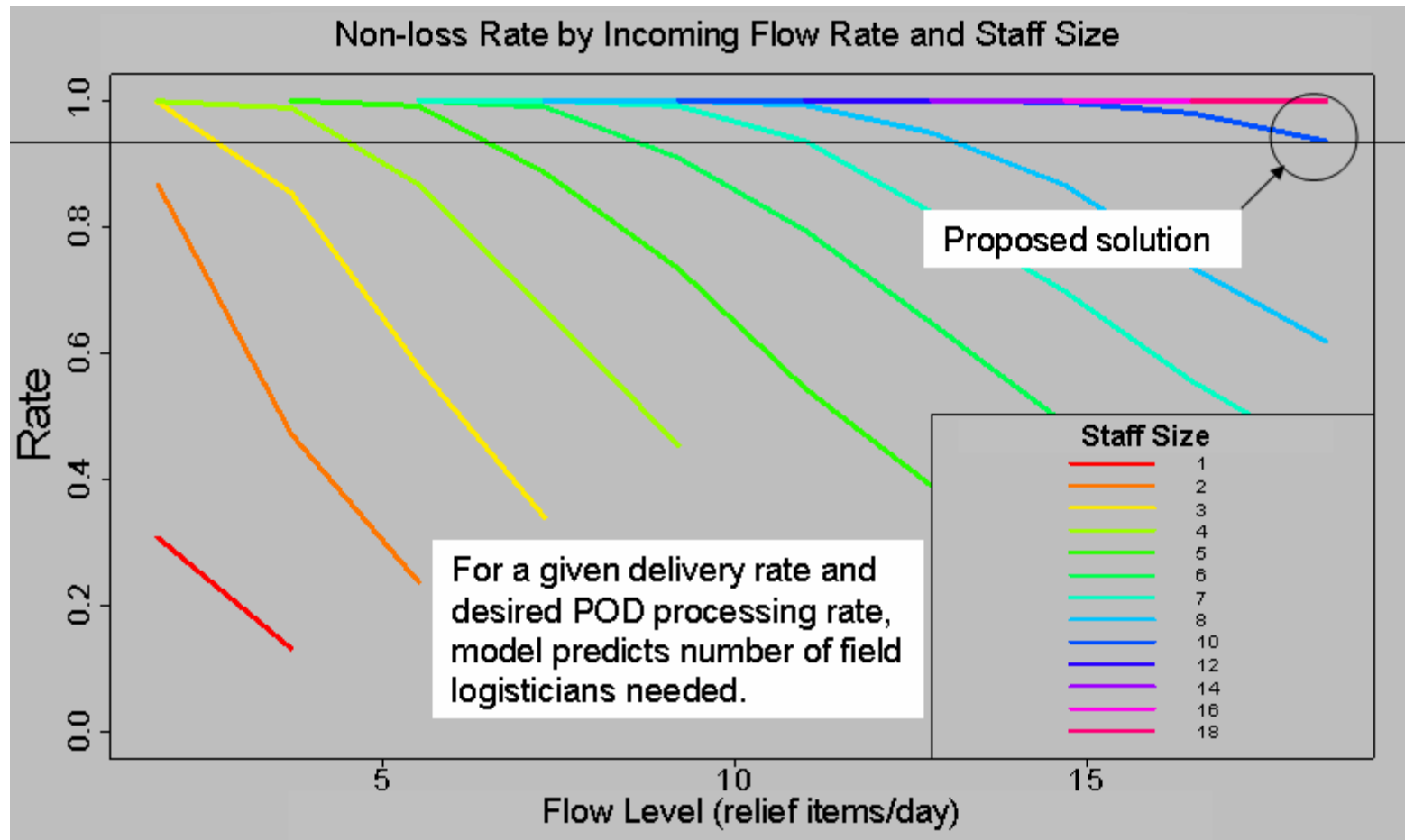
$$M_{cj} = \min \{ N_{tj} \times C_{bj}, N_{pj} \times M_{pj}, N_{aj} \times M_{aj} \} \quad \text{for all } j \quad \text{final processing capacity}$$

$$\sum_j C_{tj} \leq B \quad \text{budget}$$

$$N_{aj}, N_{nj}, T_{hj}, N_{sj}, C_{tj}, P_{dj}, C_{pj}, C_{dj}, C_{sj}, \geq 0 \quad \text{for all } j \quad \text{non-negativity}$$

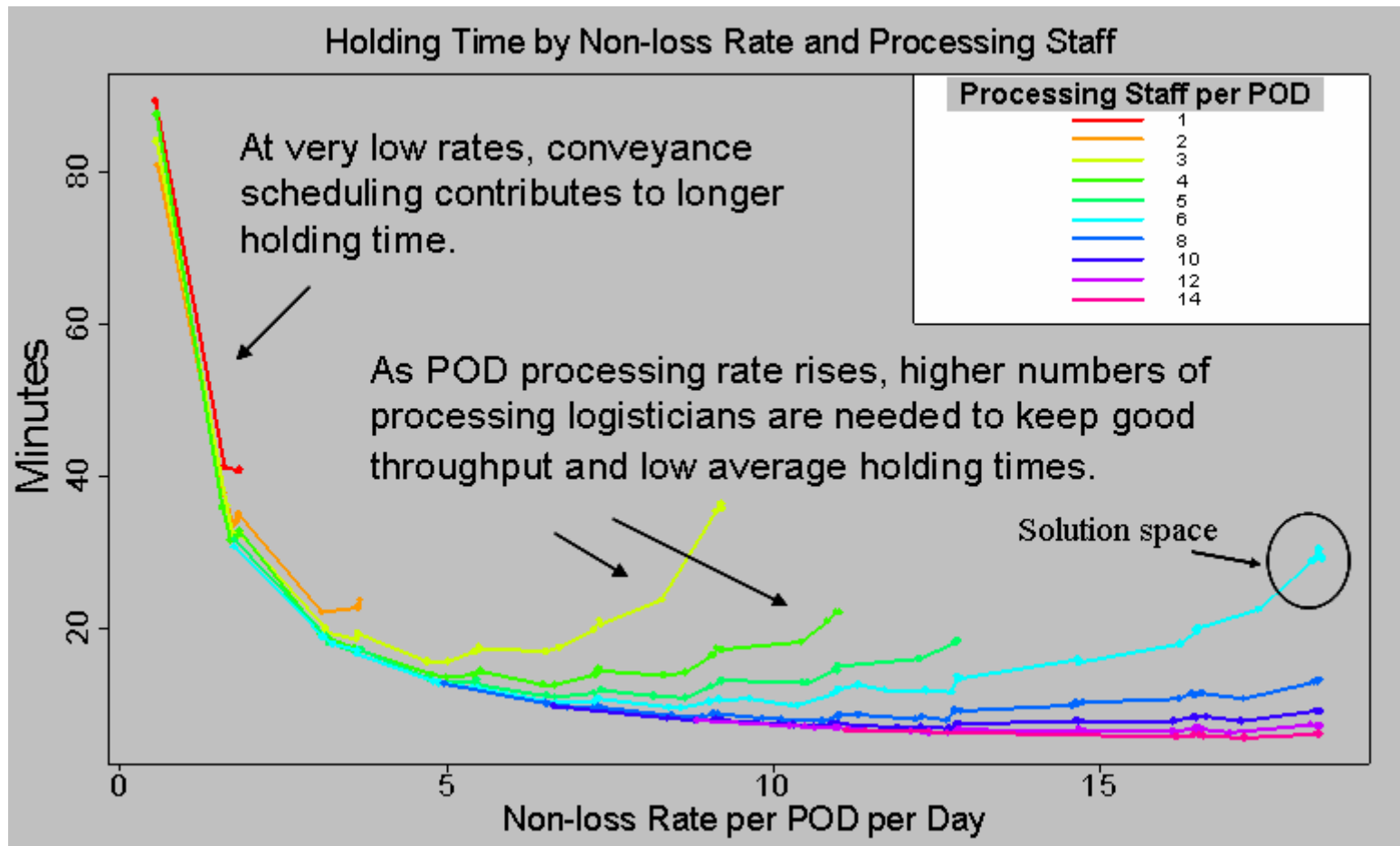
$$T_{bj}, T_{fj}, N_{tj}, L_{bj}, N_{bj}, N_{dj}, N_{rj}, N_{aj}, N_{pj}, N_{mj} \geq 0 \quad \text{for all } j$$

# HELP Sensitivity Analysis Output: Performance – Resource Level tradeoffs



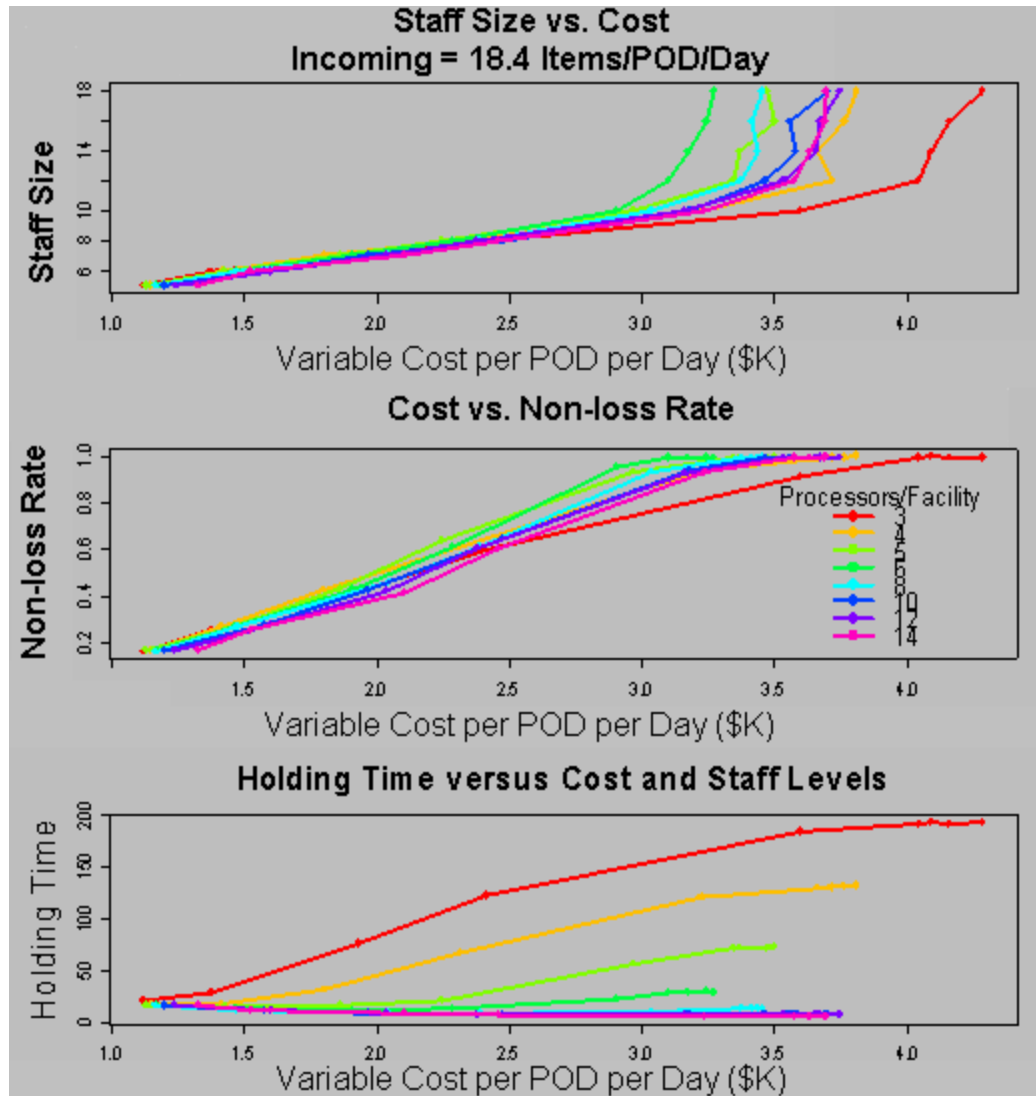
High POD processing rates can be achieved with 12 or more logisticians per POD, with 6 or more final logisticians, at given POD delivery rates.

# HELP Sensitivity Analysis Output: Performance – Resource Level tradeoffs



Proposed solution supports high POD processing rates and reasonable holding times under high POD delivery rates.

# HELPC Sensitivity Analysis Output: Cost/Capability Tradeoffs



These charts show cost/capability tradeoffs:

- Cost per POD to achieve desired loss rate for various numbers of processing staff
- Cost per POD to achieve desired average holding time for various numbers of processing staff

# Outline

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- Value Proposition
- Humanitarian Assistance
- Humanitarian Relief Organizations
- Humanitarian Logistics
- Supply Chain Analytics
- Performance Measures
- Example Application
- **Conclusion**

# Uses of Supply Chain Analytics in HA

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- **Use Supply Chain Analytics in Planning**

- Estimate benefits of pre-positioning
- Demonstrate deep understanding of problem
- Prove concept – show approach validity, demonstrate capability to deliver
- Demonstrate how to reduce total costs
- Show how to deliver more benefits to stakeholders
- Pre-plan cargo offload sequence
- Scenario analysis

- **Use Supply Chain Analytics in Delivery**

- Reduce cost and loss
- Increase aid quantity and quality delivered, reliability, responsiveness, flexibility, etc.



# Uses of Supply Chain Analytics in HA

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- **Use Supply Chain Analytics in Fund-raising**
  - Demonstrate preparedness
  - Demonstrate cost-effectiveness of plans
- **Use Supply Chain Analytics in Teaming**
  - Demonstrate value of partner arrangements
  - Structure teaming arrangements
  - Set up cost-effective sourcing network ahead of time
- **Significant cost savings**

# Conclusions

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- **Supply chain analytics can provide significant benefits in many areas of humanitarian assistance supply chains**
- **Performance is multi-faceted**
- **Much work remains**