Mergers and Acquisitions in Blood Banking Systems: A Supply Chain Network Approach

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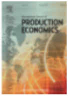

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Research Scope

The purpose of this research is:

- to study the **recent demand trends** in the area of blood supply chains,
- to model the **merger or acquisition** between two or more blood banks from a supply chain perspective, and
- to analyze the **effectiveness** of such alliances in normal times vs. demand surge scenarios.

Outlook

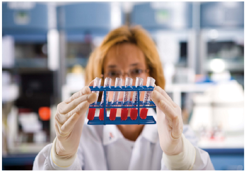
1. Background and Motivation
2. New Trend in Demand for Blood Products
3. The Supply Chain Network Model of a Blood Bank Merger or Acquisition
4. Case Study: A Merger Between Two Blood Banks
5. Summary & Conclusions

Background and Motivation

Blood service operations are a key component of the healthcare system all over the world.

38,000 donations are needed every day in the US. Every 2 seconds someone needs blood in this country.

Large, medium and small hospitals request an average of **495, 300**, and **110** units of blood per week, respectively.



Background and Motivation

A blood donation occurs when a person **voluntarily** has blood drawn and used for transfusions.

In the developed world, most blood donors are unpaid volunteers who give blood for an **established community supply** (allogeneic donation). In poorer countries, donors usually give blood when family or friends need a transfusion (directed donation).

Life Cycles of Blood Products

The collected blood is usually stored as separate components.

- Platelets: the longest shelf life is **7 days**.
- Red Blood Cells: a shelf life of **35-42 days** at refrigerated temperatures
- Plasma: can be stored frozen for up to **one year**.

It is rather difficult to have a **stockpile of blood to prepare for a disaster.**

New Trend in Demand for Blood Products

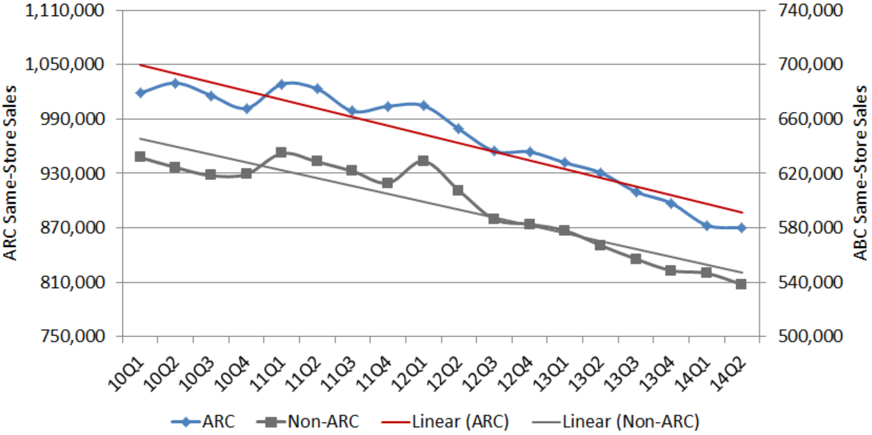
The dynamics for blood suppliers around the country has drastically changed over the past few years. **Demand for blood has declined since 2008** (American Red Cross).

Prior to 2008 there were many cases of blood **shortages** in the U.S. but the scenario has changed. Now there is an **excess**.

In 2011, the number of units of whole blood and red blood cells collected and transfused, decreased by **9.1% and 8.2%** from 2008, respectively (Whitaker (2011)). This downward trend continued over the 2011 to 2013 period with both numbers suffering **4.4% and 9.4%** (Chung et al. (2016)).

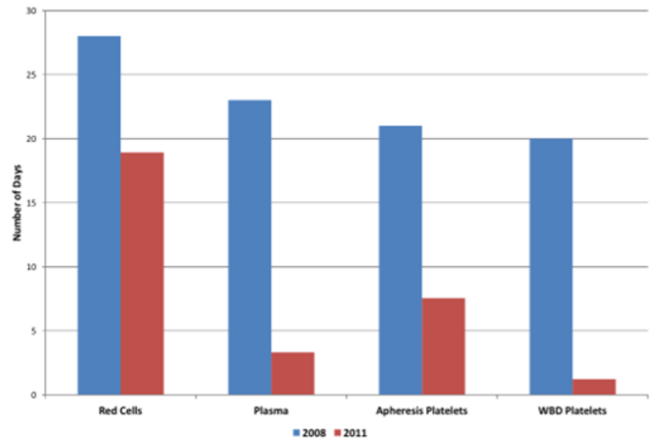
Demand for blood continues to drop despite population growth and a soaring number of people over 65.

Nationwide Distribution Trend of RBC



Americas Blood Centers; January 2010-June 2014 DW Sales/Pricing Universe

Blood Shortage in 2008 Vs 2011



Average number of days a hospital order was incomplete.

The 2011 National Blood Collection and Utilization Survey Report

Root Causes of the New Trend

Post-Recession **Economic Influences**

- Fewer elective surgeries.
- Reduced hospital census and historically low occupancy rates.

Medical/Technological Advancements

- Changes in **cancer therapy**, **coronary bypass surgery**, **hip replacement**, and **anemia**: *More transfusions do not yield better outcomes according to recent studies.*
- Implementation of Patient Blood Management (PBM) initiatives.

Impacts of the Recent Situation on Blood Operations

- **Reduced prices:** Hospitals, seeing strong supply and weak demand, are asking for a lower price per unit (Wall (2014)).
- **Reduced revenues:** From a high of $5 billion in 2008 to $1.5 billion (expected soon) (Wald (2014)).
- **Lost jobs:** Expected to reach 12,000 within the next 3-5 years, roughly a quarter of the total in the industry (Red Cross, 2014).
- **Impaired research:** Less investment in quality improvement and slower progress in testing. System's ability to invest in new products or research is reduced (Red Cross VP, 2013).

Impacts of the Recent Situation on Blood Operations

The American Red Cross Blood Services:

- **Closed** 3 of its 5 testing centers.
- **Consolidated** divisions and regional leadership teams to oversee the operations.
- Operated **bigger blood collection sites** to increase efficiency.

Average Cost of a Blood Unit

The hospital cost of a unit of red blood cells in the US:

- **increased by 6.4%** from 2005 to 2007,
- almost **stayed the same** from 2008 to 2011.
- **decreased by almost 10%** from 2011 to 2014.

Mean hospital cost per unit of Red Blood Cells in 2014: **$225.**

Patients can be billed up to **$1,000** for this unit of blood.

Mergers & Acquisitions in the Blood Services

The industry is going through **a wave of mergers and acquisitions** (Wald (2014)).

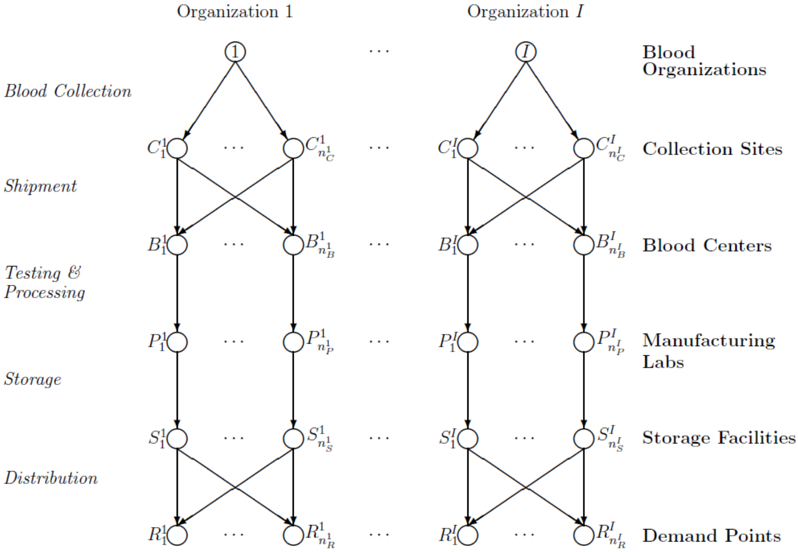
Americas Blood Centers, an association of independent blood banks, said its membership had fallen to **68** from **87** five years ago.

Most **collection agencies would survive** as independent entities. Rather, **behind-the-scene activities** like storage, testing, and distribution of blood banks will merge.

Instances of M&A in Blood Banking Industry

- In April 2010, Blood Center of **Iowa** and Siouxland Community Blood Bank merged operations.
- In August 2013, the American Red Cross acquired Delta Blood Bank, a nonprofit community blood bank serving **California**.
- In September 2013, **five nationally recognized blood centers across the US** announced the formation of a new alliance known as the HemeXcel Purchasing Alliance LLC.
- In July 2014, OneBlood, Inc. of Orlando, **Florida** and The Institute for Transfusion Medicine, Inc. (ITxM) announced that they have reached an agreement to pursue a merger.
- In December 2015, San Francisco's Blood Centers of the Pacific (BCP) and Sacramento's BloodSource announced their merger plan which would form the largest blood supplier in Northern and Central **California**.

Network Topology for I Blood Organizations in the **Pre-Merger Problem**



Pre-Merger Model: Formulation

$G_i = [N_i, L_i]$: The graph consisting of nodes and the set of directed links representing **each Organization** i; $i = 1, \ldots, I$.

$G^0 = [N^0, L^0]$: The graph consisting of the set of nodes and the set of links in the topology for the **pre-merger problem**.

$$G^0 = [N^0, L^0] = \cup_{i=1,\ldots,I}[N_i, L_i].$$

Pre-Merger Model: Formulation

Constraints

- Relationship between link flows and path flows:

$$f_a = \sum_{p \in \mathcal{P}^0} x_p \alpha_{ap}, \qquad \forall a \in L^0. \tag{1}$$

- Relationship between path flows and projected demand:

$$v_{ik} = \sum_{p \in \mathcal{P}^0_{R^i_k}} x_p \mu_p, \qquad i = 1, \ldots, I; \; k = 1, \ldots, n_R. \tag{2}$$

- Nonnegativity of path flows:

$$x_p \geq 0, \qquad \forall p \in \mathcal{P}^0. \tag{3}$$

- Capacity on links, and frequency of the activities:

$$f_a \leq \bar{u}_a \gamma_a, \qquad \forall a \in L^0. \tag{4}$$

Pre-Merger Model: Formulation

Objective Function

$$\text{Minimize} \quad \sum_{i=1}^{I}\sum_{a\in L_i}\hat{c}_a(f_a,\gamma_a)+\sum_{i=1}^{I}\sum_{a\in L_i}\hat{z}_a(f_a)+\sum_{i=1}^{I}\sum_{k=1}^{n_R^i}\left(\lambda_{ik}^{-}E(\Delta_{ik}^{-})+\lambda_{ik}^{+}E(\Delta_{ik}^{+})\right), \tag{5}$$

subject to: constraints (1)–(4).

Let $K \equiv \{(x,\gamma,\eta)|x\in R_+^{n_{\mathcal{P}^0}},\gamma\in R_+^{n_{L^0}},\eta\in R_+^{n_{L^0}}\}$ and for each path p; $p\in\mathcal{P}_{R_k^i}^0$; $i=1,\ldots,I$; $k=1,\ldots,n_R^i$.

Equivalent Variational Inequality Formulation

Determine the vectors of **optimal path flows**, of **optimal activity frequencies**, and of **Lagrange multipliers**, $(x^*, \gamma^*, \eta^*) \in K$:

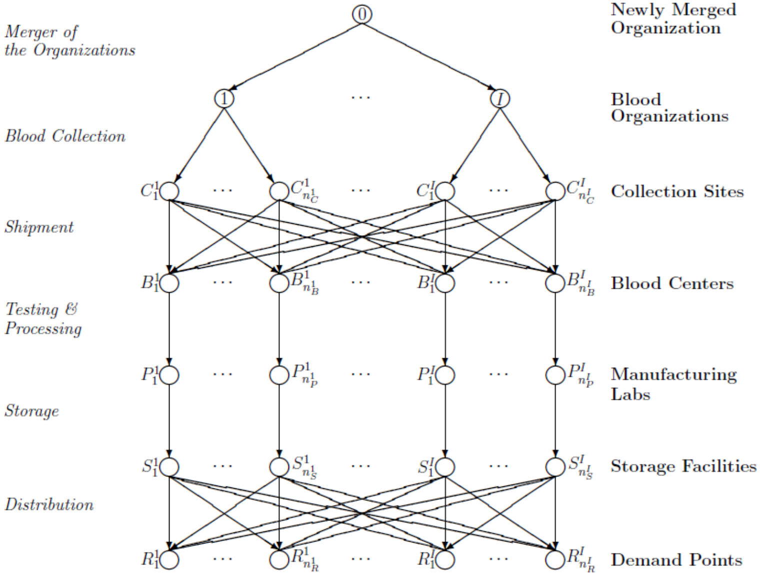
$$\sum_{i=1}^{I} \sum_{k=1}^{n_R^i} \sum_{p \in \mathcal{P}^0_{R_k^i}} \left[\frac{\partial \hat{C}_p(x^*, \gamma^*)}{\partial x_p} + \frac{\partial \hat{Z}_p(x^*)}{\partial x_p} + \lambda^+_{ik} \mu_p P_{ik} \left(\sum_{q \in \mathcal{P}^0_{R_k^i}} x_q^* \mu_q \right) \right.$$

$$\left. -\lambda^-_{ik} \mu_p \left(1 - P_{ik} \left(\sum_{q \in \mathcal{P}^0_{R_k^i}} x_q^* \mu_q \right) \right) + \sum_{a \in L_i} \eta_a^* \alpha_{ap} \right] \times [x_p - x_p^*]$$

$$+ \sum_{i=1}^{I} \sum_{a \in L_i} \left[\frac{\partial \hat{C}_p(x^*, \gamma^*)}{\partial \gamma_a} - \bar{u}_a \eta_a^* \right] \times [\gamma_a - \gamma_a^*]$$

$$+ \sum_{i=1}^{I} \sum_{a \in L_i} \left[\bar{u}_a \gamma_a^* - \sum_{q \in \mathcal{P}^0} x_q^* \alpha_{aq} \right] \times [\eta_a - \eta_a^*] \geq 0, \quad \forall (x, \gamma, \eta) \in K, \qquad (6)$$

Network Topology for the Merged Organizations (**Post-Merger Problem**)



Post-Merger Model: Formulation

Objective Function

For the merged blood organization, the total cost minimization problem can be expressed as:

$$\text{Minimize} \quad \sum_{a \in L^1} \hat{c}_a(f_a, \gamma_a) + \sum_{a \in L^1} \hat{z}_a(f_a) + \sum_{i=1}^{I} \sum_{k=1}^{n_R^i} (\lambda_{ik}^- E(\Delta_{ik}^-) + \lambda_{ik}^+ E(\Delta_{ik}^+)), \tag{7}$$

Constraints (1)–(4) are updated accordingly for the post-merger problem.

Efficiency Measures Associated with the Merger

- **Total Cost Efficiency**:

$$\mathcal{E}^{\mathcal{TC}} \equiv \left[\frac{TC^0 - TC^1}{TC^0} \right] \times 100\%, \tag{8}$$

where TC^0 and TC^1 represent the optimal objective values of the pre-merger model and the post-merger model, respectively.

Efficiency Measures Associated with the Merger (cont'd)

- **Supply Shortage Synergy Measure**:

$$\mathcal{S}^{-} = \left[\frac{S^{0-} - S^{1-}}{S^{0-}} \right] \times 100\%, \tag{9}$$

- **Supply Surplus Synergy Measure**:

$$\mathcal{S}^{+} = \left[\frac{S^{0+} - S^{1+}}{S^{0+}} \right] \times 100\%, \tag{10}$$

where S^{0-} and S^{1-} represent the expected total supply shortage costs (penalties) associated with the pre-merger model and the post-merger model.

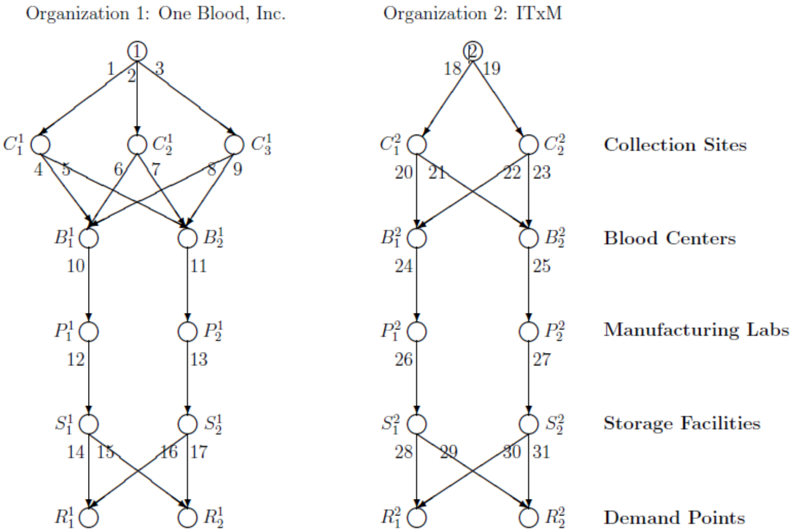
Case Study

A recent pending case of the merger between **OneBlood, Inc.,** and **The Institute for Transfusion Medicine, Inc. (ITxM)** was examined in this research.

The two blood banks announced their agreement to pursue a merger in July 2014 which would create the **largest independent not-for-profit blood center in the United States** distributing nearly 2 million units of blood annually, with combined revenues of $480 million and employing more than 3,500 people.

The merger process is said to have become **suspended in 2015**.

Case Study: Topology for the Pre-Merger Problem



Case Study: Assumptions

For Organization 1 (OneBlood,Inc.):

- Blood centers, manufacturing labs, and storage centers are co-located in two consolidated facilities, one in Fort Lauderdale, the other one in Tampa.
- Weekly demand for red blood cells in the two Floridian hospitals is assumed to follow a continuous uniform distribution on the intervals [200,400] and [150,250], respectively.

Case Study: Assumptions

For Organization 2 (ITxM):

ITxM
The Institute for Transfusion Medicine
clinical services

- Blood centers, manufacturing labs, and storage centers are co-located in two consolidated facilities, one in Chicago, the other one in Pittsburgh.
- Weekly demand for red blood cells in the two hospitals (located in Chicago and Pittsburgh) is assumed to follow a continuous uniform distribution on the intervals [220,370] and [80,110], respectively.

Case Study: Assumptions

Shortage and surplus penalty units at the hospitals

$$\lambda_1^{1^-} = 7,000, \qquad \lambda_2^{1^-} = 6,000, \qquad \lambda_1^{2^-} = 8,000, \quad \text{and } \lambda_2^{2^-} = 3,700.$$

$$\lambda_1^{1^+} = 50, \qquad \lambda_2^{1^+} = 60, \qquad \lambda_1^{2^+} = 40, \quad \text{and } \lambda_2^{2^+} = 75.$$

Throughput Multipliers, Weekly Capacities and Total Cost Functions for Blood Banks in the Pre-Merger Problem

Link a	α_a	$\bar{u}_a$	$\hat{c}_a(f_a, \gamma_a)$	$\hat{z}_a(f_a)$
1	.97	200	$.13(f_1)^2 + .2f_1 + (\gamma_1)^2$	$.8f_1$
2	.98	225	$.15(f_2)^2 + .3f_2 + 1.5(\gamma_2)^2$	$.7f_2$
3	.99	225	$.10(f_3)^2 + .25f_3 + (\gamma_3)^2$	$.7f_3$
4	1.00	35	$2f_4 + 2\gamma_4$	0
5	.99	25	$.35(f_5)^2 + .8f_5 + 9(\gamma_5)^2 + 3\gamma_5$	$.8f_5$
6	.99	40	$1.4f_6 + 4\gamma_6$	0
7	1.00	30	$.05(f_7)^2 + .1f_7 + (\gamma_7)^2$	$.7f_7$
8	.99	25	$.18(f_8)^2 + .4f_8 + 3(\gamma_8)^2 + 2\gamma_8$	$.8f_8$
9	1.00	40	$.85f_9 + 2.5\gamma_9$	0
10	.96	1,800	$.55(f_{10})^2 + 2f_{10} + 3(\gamma_{10})^2$	$.8f_{10}$
11	.94	1,600	$.45(f_{11})^2 + 2.5f_{11} + 2(\gamma_{11})^2$	$.7f_{11}$
12	.99	2,000	$.07(f_{12})^2 + .5f_{12} + 2(\gamma_{12})^2$	$.8f_{12}$
13	.99	1,600	$.06(f_{13})^2 + .4f_{13} + 1.5(\gamma_{13})^2$	$.7f_{13}$
14	1.00	36	$.9f_{14} + 3.5\gamma_{14}$	0
15	.99	40	$.25(f_{15})^2 + 2.8f_{15} + 4.5(\gamma_{15})^2 + 4.5\gamma_{15}$	$.8f_{15}$
16	.99	40	$.12(f_{16})^2 + 2.5f_{16} + 4(\gamma_{16})^2 + 5\gamma_{16}$	$.9f_{16}$
17	1.00	35	$1.1f_{17} + 2.5\gamma_{17}$	0

Link a	α_a	$\bar{u}_a$	$\hat{c}_a(f_a, \gamma_a)$	$\hat{z}_a(f_a)$
18	.98	260	$.11(f_{18})^2 + .3f_{18} + 2(\gamma_{18})^2$	$.6f_{18}$
19	.99	235	$.13(f_{19})^2 + .2f_{19} + (\gamma_{19})^2$	$.7f_{19}$
20	1.00	25	$f_{20} + .5(\gamma_{20})^2 + 4\gamma_{20}$	0
21	.99	35	$.09(f_{21})^2 + .5f_{21} + (\gamma_{21})^2 + 4\gamma_{21}$	$.8f_{21}$
22	.98	35	$.14(f_{22})^2 + .9f_{22} + 1.5(\gamma_{22})^2 + 7.5\gamma_{22}$	$.75f_{22}$
23	1.00	35	$.8f_{23} + 3\gamma_{23}$	0
24	.95	2,200	$.6(f_{24})^2 + 1.1f_{24} + 2.5(\gamma_{24})^2$	$.6f_{24}$
25	.96	2,000	$.85(f_{25})^2 + 1.5f_{25} + 3(\gamma_{25})^2$	$.7f_{25}$
26	.99	2,500	$.05(f_{26})^2 + .4f_{26} + (\gamma_{26})^2$	$.6f_{26}$
27	1.00	2,150	$.06(f_{27})^2 + .6f_{27} + 2(\gamma_{27})^2$	$.5f_{27}$
28	1.00	30	$.6f_{28} + 4\gamma_{28}$	0
29	.99	40	$.1(f_{29})^2 + .5f_{29} + 2(\gamma_{29})^2 + 5\gamma_{29}$	$.9f_{29}$
30	.99	35	$.4(f_{30})^2 + 1.3f_{30} + 2(\gamma_{30})^2 + 6\gamma_{30}$	$.7f_{30}$
31	1.00	40	$.5f_{31} + 2.5\gamma_{31}$	0

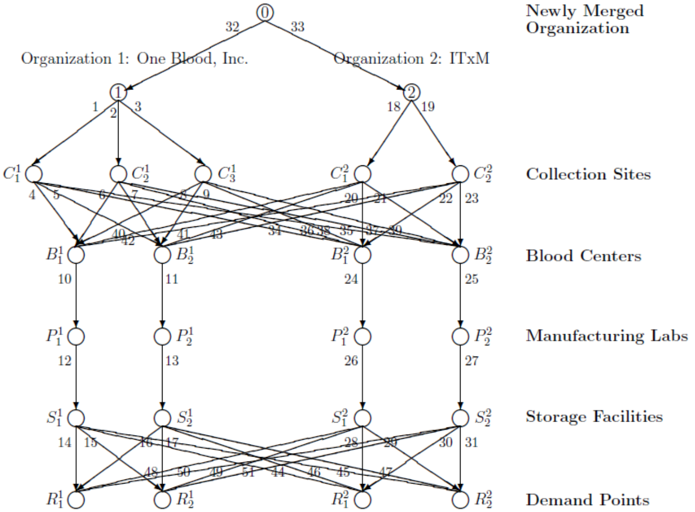
Solution Method

We implemented an algorithm based on the **Euler method** for the variational inequality formulation (6) in the pre-merger problem.

We used Matlab to calculate the optimal values of **link flows, link frequencies, Lagrange multipliers**, among other quantities of interest for **every single link belonging to each organization**.

The convergence tolerance was $\epsilon = 10^{-5}$.

Case Study: Topology for the Post-Merger Problem



Case Study: Parameters for the **New Links** in the Post-Merger Problem

Link a	α_a	$\bar{u}_a$	$\hat{c}_a(f_a, \gamma_a)$	$\hat{z}_a(f_a)$
32	1.00	n/a	0	0
33	1.00	n/a	0	0
34	.99	30	$.4(f_{34})^2 + 1f_{34} + 9(\gamma_{34})^2 + 4\gamma_{34}$	$.75f_{34}$
35	.98	30	$.15(f_{35})^2 + 1.4f_{35} + 10(\gamma_{35})^2 + 5\gamma_{35}$	$.75f_{35}$
36	.99	30	$.5(f_{36})^2 + 2f_{36} + 8(\gamma_{36})^2 + 7\gamma_{36}$	$.9f_{36}$
37	.98	30	$.25(f_{37})^2 + 1f_{37} + 12(\gamma_{37})^2 + 6.5\gamma_{37}$	$.8f_{37}$
38	.98	30	$.3(f_{38})^2 + 1.5f_{38} + 9(\gamma_{38})^2 + 4\gamma_{38}$	$.75f_{38}$
39	.99	30	$.55(f_{39})^2 + 2f_{39} + 10(\gamma_{39})^2 + 4.5\gamma_{39}$	$.8f_{39}$
40	.99	25	$.17(f_{40})^2 + 1.5f_{40} + 7(\gamma_{40})^2 + 6\gamma_{40}$	$.75f_{40}$
41	1.00	25	$.15(f_{41})^2 + 2f_{41} + 7.5(\gamma_{41})^2 + 4\gamma_{41}$	$.6f_{41}$
42	.99	25	$.2(f_{42})^2 + 2f_{42} + 6(\gamma_{42})^2 + 6\gamma_{42}$	$.55f_{42}$
43	.98	25	$.25(f_{43})^2 + 2.5f_{43} + 8(\gamma_{43})^2 + 6\gamma_{43}$	$.7f_{43}$
44	.99	35	$.15(f_{44})^2 + 3f_{44} + 4.5(\gamma_{44})^2 + 6\gamma_{44}$	$.55f_{44}$
45	1.00	35	$.17(f_{45})^2 + 3f_{45} + 7(\gamma_{45})^2 + 5\gamma_{45}$	$.6f_{45}$
46	1.00	35	$.18(f_{46})^2 + 2.5f_{46} + 5(\gamma_{46})^2 + 4.5\gamma_{46}$	$.65f_{46}$
47	.99	35	$.16(f_{47})^2 + 3.5f_{47} + 4(\gamma_{47})^2 + 7\gamma_{47}$	$.65f_{47}$
48	1.00	32	$.35(f_{48})^2 + 3f_{48} + 2.5(\gamma_{48})^2 + 5\gamma_{48}$	$.55f_{48}$
49	.99	32	$.38(f_{49})^2 + 4f_{49} + 2(\gamma_{49})^2 + 6\gamma_{49}$	$.65f_{49}$
50	.98	32	$.4(f_{50})^2 + 1.8f_{50} + 3(\gamma_{50})^2 + 5.5\gamma_{50}$	$.5f_{50}$
51	1.00	32	$.35(f_{51})^2 + 1.5f_{51} + 2.5(\gamma_{51})^2 + 7\gamma_{51}$	$.55f_{51}$

Case Study: Observations

Under Normal Demand Scenario

- The majority of links in the post-merger problem have maintained similar flows to the pre-merger problem.
- A few links (mostly of distribution type) demonstrate some notable changes in the optimal weekly amount of blood to be distributed to their respective hospitals.
- Only 3 out of the 18 newly added links play a relatively significant role in the post-merger problem.
- **Satisfaction of the hospital demand via the further blood center can not be economically justified due to a significantly higher transportation cost [At most, between 10-20% of the demand can be satisfied via the new links.]**

Impact of Disasters on Blood Supply Chains

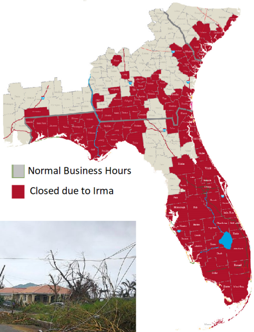
Disasters, both natural and man-made, can impact many aspects of blood organizations to a great extent.

A man-made disaster, such as a case of mass shooting or a bomb explosion, can create a huge sudden surge of demand for blood in the region.

Local people responded to a call for blood donations in the aftermath of a mass shooting in Las Vegas in October 2017.

Impact of Disasters on Blood Supply Chains

A large-scale natural disaster, such as a hurricane, can not only lead to an increase in demand for blood products, but can also disrupt the blood supply in the affected region for several days.



One Blood, Inc., had to suspend all donations for multiple days in September 2017 during Hurricane Irma while arranging with Americas Blood Centers for shipments of blood to be brought in to Florida from around the country.

Case study (Continued): A Demand Surge Scenario

We used the same merger case to compare the **resiliency** of blood banks in the pre- and post-merger problems during the response phase of a disaster, which leads to a surge in demand.

Assume a large-scale natural disaster has hit parts of Florida, resulting in an abrupt surge in the demand for red blood cells immediately after the occurrence of the disaster. We assume the demand at the two Floridian hospitals during that week experiences an **increase by a factor of 10** as compared to the base scenario.

The demand at the other two hospitals (located in Chicago and Pittsburgh) **remains unchanged**.

We then re-ran the algorithm to compare the performance of the blood banks in the pre- and post-merger problem under the new demand scenario.

Case Study: Observations

Under Raised Demand Scenario

In the pre-merger problem:

- The optimal link flows and frequencies on links corresponding to OneBlood have largely increased to be able to respond to the demand surge in the hospitals. The other organization experiences no changes, not surprisingly.

Case Study: Observations

Under Raised Demand Scenario

In the pre-merger problem:

- The optimal link flows and frequencies on links corresponding to OneBlood have largely increased to be able to respond to the demand surge in the hospitals. The other organization experiences no changes, not surprisingly.

In the post-merger problem:

- Several links across the supply chain network experience increased flows and frequencies in the optimal solution.

- The two hospitals located in Chicago and Pittsburgh (over a thousand miles away from the impacted region) have suffered drops of 8.8% and 13.7% in their projected demand values.

Case Study: Discussion on **Synergy** of the Merger

	Status Quo Scenario			Disaster Scenario		
	Pre-Merger		Post-Merger	Pre-Merger		Post-Merger
	OneBlood, Inc.	ITxM		OneBlood, Inc.	ITxM	
Total Objective Value	$161,753.22	$119,078.72	$278,957.84	$11,666,944.68	$119,079.06	$8,966,685.81
Expected Total Shortage Cost	$6,044.32	$3,570.41	$9,528.83	$2,932,952.43	$3,570.03	$1,606,741.21
Expected Total Surplus Cost	$6,796.02	$3,465.61	$10,263.21	$16,609.31	$3,465.64	$31,052.66
$\mathcal{E}^{TC}$	0.67%			23.92%		
$\mathcal{S}^-$	0.67%			45.28%		
$\mathcal{S}^+$	−0.02%			−54.68%		

When the two merging blood banks are **geographically distant**, the synergy gained from the merger is not significant under normal demand situations.

In contrast, under a demand surge scenario, the merged organization will experience a **significant synergy**, both in terms of the total operational cost as well as the expected shortage penalty.

Summary of the Research

The blood banking industry is at a crossroads in the United States facing a downward demand trend for blood products.

We developed a methodological framework that allows for the quantifiable assessment of a merger or acquisition concerning blood banks:

1. The models capture **perishability** of blood through link multipliers.

2. The models, when solved, yield the cost-minimizing blood **flows** on paths and links, along with the **frequencies** of the link activities.

3. A total cost **efficiency measure** is introduced, which quantifies the potential synergy associated with the merger or acquisition, along with measures capturing the expected supply shortage and surplus.

Conclusion from the Case Study

Two Outcomes:

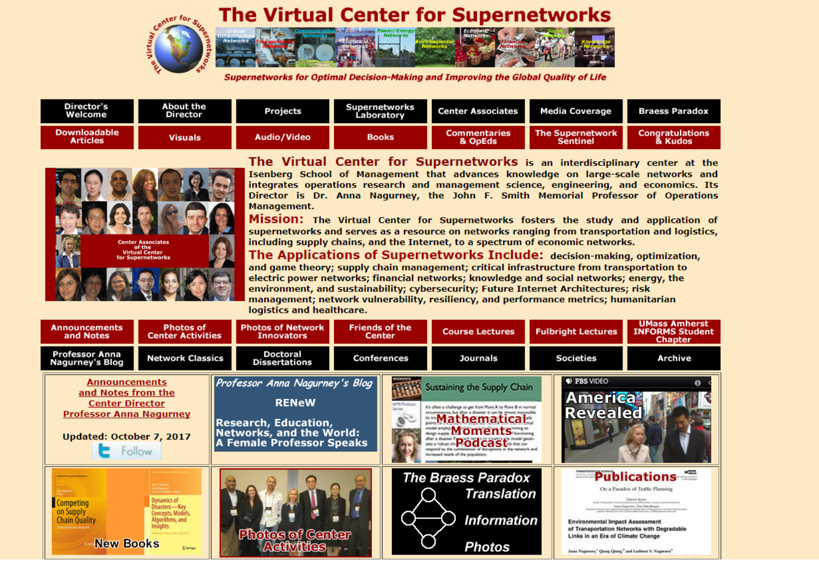
improved operational efficiency
and

enhanced stability of the blood supply

are the major motives for blood organizations to merge.

Blood banks should take into careful consideration the **intensity of irregular demand scenarios**, in addition to other **operational and organizational factors**, when facing the crucial decision of a merger, acquisition, or any other form of alliance.

Thank You!



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