Using Simulation for Strategic Blood Supply Chain Design in the Canadian Prairies

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Abstract: Since 2010, Canadian Blood Services has been modernizing its facility infrastructure. Current plans call for the amalgamation of production sites in the Prairie region by 2019. Under this plan existing production centres in Alberta and Saskatchewan will be consolidated into a single site in Calgary. Because of the potential impact to the distribution network, a simulation model of the logistics network was constructed in Visual Basic.Net, using an established simulation framework. Experiments were conducted to estimate the robustness of the network under varying assumptions for delivery interruptions and inventory reserves. Results suggest that, given reasonable assumptions on road network reliability, product demand, and inventory staging, either no, or very modest, changes to product wastage and product reliability should be expected after facility. This work demonstrates the application of a generic simulation modelling framework to resolve important policy questions.

1 INTRODUCTION

Canadian Blood Services is one of two organizations in Canada whose mission is to manage the supply of blood and blood products. In 2013/14, Canadian Blood Services distributed more than 800,000 units of red blood cells and 114,000 units of platelets. The cost of operations in 2013/14 was $1.02B (Canadian Blood Services, 2014).

Since 2010, Canadian Blood Services has been modernizing its facility infrastructure. It has replaced, or will replace, 14 local production and testing centres with two national testing laboratories, and three regional production and distribution centres, while retaining four local sites in remote locations. Plans call for the amalgamation of production sites in the Prairie region of the country (Alberta and Saskatchewan), which will consolidate local sites in Edmonton, Calgary, and Edmonton. Once facilities are consolidated, blood will either be shipped directly to customers from Calgary or via two distribution centres and stock holding units (SHU) to be located in Regina and Edmonton. See Figure 1.

Consolidation of local facilities into regional hubs allows for economies of scale, increased process standardization, and improved productivity through enhanced equipment utilization and greater production intensity. However, facility consolidation is not without critics, particularly in provinces that lose a local centre; debate over the consolidation of services generally garners considerable attention in the popular press (CanadaEast.com, 2011) and amongst political parties of all stripes. Accordingly, to address stakeholder concerns, a simulation based study of the proposed Prairie distribution network was built. The model was constructed in Visual Basic.Net, using an established simulation framework (Blake and Hardy, 2014). The model

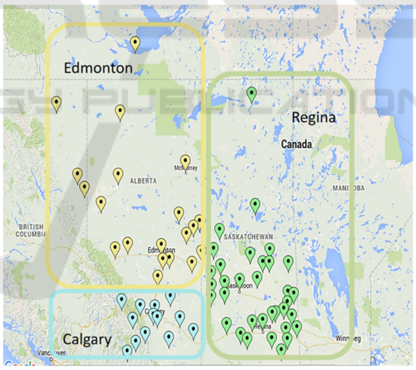

Figure 1: Map of facilities and associated customer locations. Map data © 2016 Google.

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reproduces the processes of blood supply chain management in the Prairies, including collection of raw materials, production and testing, distribution, order arrivals, order completion and dispatch. In addition, it incorporates hospital order, inventory, and transfusion practices. The framework includes routines to simulate both planned and unplanned closures of the distribution network. The model was validated against a series of benchmarks using both qualitative assessments and statistical tests. Once validated, the model was used to conduct a series of experiments in which red blood cell (RBC) outdates and availability were measured under differing assumptions regarding the level of inventory held at the SHUs and reliability of the distribution network.

2 LITERATURE REVIEW

There is an extensive operational research literature dealing with blood and blood products. Osorio, Brailsford, and Smith (2015) note that the blood supply chain has motivated researchers since the 1960's. Much of the early literature in the field focused on inventory management policies for red blood cells. The work in blood formed the basis for much of the theoretical development of perishable inventory theory. See Nahmias (1982) for a seminal review.

Over the years, the literature has expanded from pure inventory policy into the broader range of issues. Beliën and Forcé (2012) classify the literature along multiple dimensions of blood product, solution method, system hierarchy, supply chain type, and modelling structure.

Strategies for designing network topology have been extensively studied. Pierskalla (2004) presents a review of models for determining the number, size, and location of regional blood distribution nodes. Brodheim and Prastacos (1979) use a statistical analysis to create a piece-wise linear relationship between target inventory and daily demand. Prastacos (1981) compares myopic policies based on immediate data with optimal policies and shows that myopic policies cannot be "too different" from optimal.

Transhipment and rotation policies have been studied by Gregor, Forthofer, and Kapadia (1982) who show that lower outdates and greater product availability are associated with these policies when compared to traditional no-redistribution policies. Katsaliaki and Brailsford (2007) describe the use of a large scale simulation model to evaluate a blood supply chain. They show that for a single producer and single consumer system, the amount of inventory stored can be reduced if improved ordering and cross-matching policies are implemented. Lang (2010) uses simulation based optimization to set study inventory policy for a two-echelon system consisting of a single supplier and seven hospitals in which transhipment is allowed along with product substitution.

While planning for inbound and outbound logistics is frequently addressed in the literature, fewer consider the operational impact of disruptions to the delivery network. Sha and Huang (2012) describe a location-allocation model to site donor collection facilities in Beijing following an earthquake. Jabbarzadeh et al. (2014) present a robust version of the Sha and Yue model, which incorporates terms for both cost and undersupply. However, neither the Sha and Ye model, nor the Jabbarzadeh et al. models explicitly consider failure of transportation links, nor do they model period to period inventory decisions or the aging of a perishable product. Perhaps most applicable to this problem are studies by Blake and Hardy (2013) which describe a simulation methodology to evaluate inventory decisions in a regional network subject to periodic failures of the logistics network and a later paper (Blake and Hardy, 2014) which details the development of a generic simulation framework for modelling regional blood networks. Recently Blake, Hardy, and McTaggart published a simulation study of a blood supply chain subject to period delivery failures, but that study was limited to evaluation of a single stock holding unit (Blake, Hardy, and McTaggart, 2015)

We conclude that while there is an established literature on location/allocation problems in blood supply chains, there are few papers describing methods for evaluating network logistics under operational conditions. There are no papers, that we are aware of, in which a generic simulation framework has been applied to an instance of a large regional blood supply distribution network with several production and distribution hubs and hundred hospitals linked via a logistics network subject to periodic failures. We note, finally, that proof of operational implementation of blood supply chain study results is generally absent from the existing literature.

3 PROCESS DESCRIPTION

Hospital customers in Alberta and Saskatchewan, and are presently serviced from three production and distribution sites located in Calgary, Edmonton, and Regina. After consolidation, blood will continue to be collected from both fixed and mobile collection sites in regions centred on Calgary, Edmonton, and Regina. In the new network, however, whole blood will be consolidated at a regional site and then transported for processing in Calgary. Production and testing activities are expected to require between one and two days to complete and thus blood is expected to become available for release as follows:

Table 1: Expected daily distribution of units becoming available for release.

Day	Units/Year	Units/Day
Sunday	19,642	377.73
Monday	23,466	451.27
Tuesday	19,326	371.66
Wednesday	26,005	500.10
Thursday	36,676	705.31
Friday	34,167	657.06
Saturday	24,586	472.81
Total	183,868	3,535.92

The blood type profile of units collected in the Prairie region is expected to be as defined in Table 2

Table 2: Expected distribution of blood units collected in the Prairie region.

Blood Type	Units/Year	Units/Day
A-	12,569	34.53
A+	54,493	149.71
AB-	1,250	3.43
AB+	5,841	16.05
B-	3,878	10.65
B+	16,763	46.05
O-	21,456	58.95
O+	67,618	185.76
Total	183,868	505.13

After production and testing are complete, units are released for distribution. Following consolidation of production in Calgary, some customers will be serviced directly from Calgary, while others will receive blood products from their regional stock holding unit. SHUs are expected to function in two modes – on most days the SHU will operate as a local distribution hub for materials transhipped from Calgary. However, on days during which shipments cannot be completed from Calgary, the SHUs will serve as a forward store for all customers in an area. Since some large customer sites in Edmonton and Saskatoon will be supplied from Calgary, rather than their regional SHU, the anticipated volume of demand to be met at the regional SHU depends on the status of the network. For this study, it is assumed that the regional SHUs will hold sufficient inventory to meet the greater of 6 days of regular demand from hospitals in their regular catchment area or 3 days' emergency demand from all hospitals in their catchment area.

Table 3: Demand and inventory levels at supplier sites. (Reg = regular daily demand, Emer = daily demand during a delivery network failure, and Inv = target inventory).

Type	Calgary			Edmonton			Regina		
	Reg	Emer	Inv	Reg	Emer	Inv	Reg	Emer	Inv
A-	17.7	7.3	142	4.8	13.2	44	3.4	5.5	17
A+	82.8	36.9	662	22.6	59.5	203	20.2	29.2	88
AB-	1.3	0.5	11	0.3	0.9	3	0.3	0.6	2
AB+	7.4	2.3	60	1.1	5.3	16	2.2	3.2	10
B-	4.5	1.6	36	0.6	3.0	9	1.0	1.5	5
B+	26.4	11.6	211	5.0	16.8	51	4.0	7.0	21
O-	30.4	16.8	243	11.5	22.5	103	6.3	8.8	27
O+	107.5	45.8	860	28.3	78.3	255	21.6	33.3	100

3.1 Simulation Framework

The blood distribution network in the Prairie provinces is represented by a simulation model derived from a generic framework developed by Blake and Hardy (2014) Within the framework a fixed sequence of events is assumed to occur daily. The production and distribution site (supplier), the SHUs (SHU), and hospitals (consumers) are modelled as separate software classes. Each class has a series of properties that define the state of the object and a set of methods that can be called to change or update the object's state. The objects are linked together through a simulation control algorithm. This algorithm implements a special case of the next-event, time-advance inventory model outlined in Law (2006) in which a set of events are executed sequentially and a single, daily update is made to the simulation clock.

This implementation of the generic framework assumes that one or more distribution centres and several SHUs exist within a network of consumer objects. The supplier object contains methods that simulate the process of collecting, producing, inventorying, aging and distributing blood to SHUs and customers. SHU objects are implemented as a sub-class of supply objects; they inherit supplier methods that allow for inventory ordering, product receipt, product aging, and distribution of products to consumers. Unlike the supplier object, SHU objects do not collect their own products. Rather they are "connected" to a supplier object at which they place orders. Operationally, SHUs are assumed to function like distribution centres: They hold stock and fill requests for products from hospitals in their catchment area. According to operational plans in the Prairie region, some hospital consumers will be supplied directly from the Calgary DC during regular day-to-day operations. However, in the event of an interruption to the logistics network, all consumer sites within a region will order and receive product from their local SHU.

Hospitals, in the framework, are modelled as a consumer object that encapsulates methods for ordering, receiving, inventorying, and aging blood, in addition to methods for simulating patient demand.

3.2 Process Description

At the beginning of each run, the system is initialized. All objects are instantiated and their properties are set according to data read in from a transaction database. Initialization is completed by assigning a starting inventory, by blood group and type, to each supplier object, based on the anticipated demand for products from consumers and any associated SHUs.

Once initialized, the model is run for some replications of a specified number of days. On each simulated day, the model steps through a fixed sequence of events. The day begins with a call to advance suppliers' inventory. This ages the stock on hand at each supplier by one day and causes any stock with -1 days of shelf-life remaining to be outdated; a similar call is then made to advance inventory at all SHU objects.

After advancing the inventory age, both the supplier object and SHU objects make a call to have inventory arrive. The supplier object samples from a day-of-week specific distribution to determine the number of units to arrive from testing. Each unit is assigned a blood group and type and a shelf-life drawn from empirical distributions. Reductions in the rated shelf-life of arriving units are primarily intended to represent delays in the testing process, but are also used to represent mandated reductions in shelf-life when units are irradiated.

SHUs are assumed to evaluate their inventory each morning against a two-level (s,S) inventory policy and place an order for product, rather than observing a randomly distributed product collection. Thus, each morning, every SHU object evaluates its inventory. If the inventory level for a particular blood type is less than s, an order is placed with the supplier to have exactly enough stock ($S-s$, where $S \geq s$) arrive to return the inventory level to S. The supplier is assumed to fill requests for product using a FIFO inventory policy in most instances. Inventory is assumed to be delivered instantaneously from the supplier to the SHU.

Once all incoming inventory is in place at suppliers and SHUs, the simulation loops through each of the consumer objects and makes a call to advance the inventory. This causes the stock on hand to age by one day. Any units with -1 days of shelf-life remaining are counted as outdated and exit the system. Each consumer object then determines if an order is required, in a manner similar to that of the SHU. Consumers are assumed to order from either from their regional SHU or directly from the Calgary DC. In instances where a consumer object is associated with a SHU, but regularly receives products from the DC, orders are usually placed with the DC. However, when an emergency order is issued, or if the logistics network has been disrupted, all consumers are assumed to place an order with their local SHU.

Once orders are received and entered into inventory, customer sites experience demand for blood products from patients. Each day the model issues a call to each consumer object. The call generates requests for blood, using a zero-inflated Poisson distribution with a day-of-week specific mean value. Once the number of units required is known, blood group and type are assigned to the demand items via empirical distributions. Demand is filled at the consumer FIFO from available units. If no unit is available, the consumer site issues a demand for additional units, on an emergency basis, from its supplier (either the SHU or the DC). If available, emergency units are transferred to the consumer object, using the same logic as regular demand. If no unit is available, the demand is considered to be lost and counted as a shortage. The day ends, the simulation clock is then advanced by one day and the cycle repeats.

4 DATA

Data for the simulation was derived from Canadian Blood Services' operational database which provided transaction level data for all units of packed red cells collected in, distributed in, or disposed from any CBS facility in Alberta and Saskatchewan during fiscal 2013/2014. A total of 277,000 records were retrieved.

The transaction level data was processed using a set of custom routines to format the data and to prepare a set of pre-defined input data lists and distributions for the regional simulation framework (Blake and Hardy, 2014). Automatically derived from the data are simulation inputs such as lists of CBS facilities and hospitals as well as distributions describing hospital demand, whole blood collection, and product testing parameters, amongst other elements.

5 VALIDATION

Extensive verification activities were undertaken to ensure the model functions as intended. Once inputs were verified, the model was validated by comparing simulated output against historical data.

5.1 Verification

At a macro level, the distribution network is similar to a queuing network with random arrivals (collections) and random services (demand). Drawing upon that analogue, the key elements dictating system performance are inputs (collections) and outputs (filled demand or outdates)

5.1.1 Verifying Inflows

Inflows of materials within the simulation model are comprised primarily of collections. Table 4 provides a summary of model results for collections against the historical value. This table provides a 95% prediction interval, based on 10 replications of the simulation model for a 10-year period, following a 364-day warm up. The results suggest that there is no evidence that historical data is inconsistent with the simulation framework.

Table 4: Comparison of daily collections by blood group within the Prairie region.

Blood Group	Daily Collections		Prediction Interval		Historic Value
	Average	Variance	Lower Limit	Upper Limit	
A-	34.557	0.010	30.547	38.566	34.530
A+	149.66	0.035	141.316	158.004	149.706
AB-	3.525	0.000	2.244	4.805	3.434
AB+	16.042	0.003	13.31	18.774	16.047
B-	10.681	0.001	8.452	12.91	10.654
B+	46.076	0.022	41.446	50.705	46.052
O-	58.915	0.014	53.679	64.15	58.945
O+	185.774	0.120	176.478	195.07	185.764

5.1.2 Verifying Outflows

Outflows of materials in the simulation model consist of items provided to patients. Table 5 provides a summary of model results for demand, as observed in the simulation model, against the historical value for fiscal 2013/2014. This table provides a 95% prediction interval, again based on 10 replications of the simulation model for a ten-year period, following a 364-day warm up period. The results show that there is no evidence to suggest that historical demand data is not consistent with the results of the simulation model.

Table 5: Comparison of daily demand by blood group within the Prairie region.

Blood Group	Daily Demand		Prediction Interval		Historic Value
	Average	Variance	Lower Limit	Upper Limit	
A-	26.025	4.6E-03	22.546	29.505	26.066
A+	125.884	6.5E-02	118.231	133.536	125.824
AB-	2.0992	8.6E-04	1.111	3.088	1.901
AB+	10.994	2.4E-03	8.732	13.255	10.739
B-	6.042	1.5E-03	4.365	7.719	6.104
B+	35.254	6.6E-03	31.204	39.304	35.404
O-	48.020	1.0E-02	43.294	52.747	48.228
O+	157.869	5.7E-02	149.299	166.439	157.885

5.2 Validation

To confirm that the model represents reality, output values for outdates were compared against historical values. Since outdates are not an input to the simulation, but rather a result of the differences between simulated inflows and outflows, a basic test of validity is to ensure that the number of outdating units matches the historical record. The simulation model was run for ten replications of 10-year's duration, using a 364-day warm-up period under the method of batch means. The average number of outdates for RBC was recorded and a 95% prediction interval was constructed. A comparison, shown in Table 6, indicates there is no reason to suggest that outdates recorded by the simulation model are not consistent with those observed in the 2013/14 historical data.

Table 6: Comparison of model outdates within the Prairie region as recorded in the simulation against historical data.

Blood Group	Daily Outdates		Prediction Interval		Historic Value
	Average	Variance	Lower Limit	Upper Limit	
A-	0.293	0.004	0.000	0.098	0.063
A+	1.898	0.100	2.865	5.685	4.578
AB-	0.015	0.000	0.000	0.259	0.058
AB+	4.275	0.008	3.148	6.078	4.841
B-	0.074	0.001	0.242	1.524	0.258
B+	4.613	0.049	1.074	3.027	1.211
O-	0.883	0.002	0.000	0.098	0.063
O+	2.050	0.002	2.865	5.685	4.578

6 EXPERIMENTS AND RESULTS

The simulation framework assumes the distribution system will function as a network of stock holding units, each linked to the Calgary DC. The SHUs in Edmonton and Regina will provide regular shipments to some facilities and emergency shipments to all customers in their catchment area. Accordingly, the function of the SHUs is to provide regular deliveries and to serve as a buffer against network interruptions. A basic test of technical feasibility therefore involves evaluation of network operations as delivery interruptions are introduced into the system.

6.1 Delivery Interruptions

Road network reliability data was obtained from the Alberta Department of Transportation. The data covers the period between 03 Mar 13 and 04 Jan 16 and describes closures to the Trans-Canada Highway. In total, the data shows 23 road closures over 34 months. Road closures were observed to occur approximately once every 54 days. However, of the 23 closures recorded in the dataset, 20 involved a closure of less than 7 hours' duration, while the remaining three resulted in an average closure duration of 9.46 hours. Thus, in the simulation framework it is assumed that the time between road failures is exponentially distributed with a mean of 54 days and that 87% (20/23) of all road failures result in a delay that is too short to disrupt deliveries.

6.2 Experimental Framework

All scenarios for the simulation model of the Prairie region assume the existence of the Calgary distribution centre and stock holding units located in Edmonton and Regina. Deliveries to SHUs are assumed to take place six days per week (Tuesdays through Sundays).

Inventory policies at all ordering nodes in the model (SHUs, and customer sites) are assumed to follow an (s, S) type inventory policy. In all runs of the model it is assumed that facilities review their inventory daily, placing an order for stock on any day of the week that deliveries are feasible. Inventory targets for the three SHUs are as defined in Table 3 and, for hospital customers, it is assumed that *S* is equal to 6 days' of average patient demand.

It is assumed that every hospital is connected to a local SHU. Some larger facilities in Edmonton and Regina may bypass their regular SHU and instead order directly from Calgary for their day-to-day needs. Nevertheless, in the event of a disruption to the delivery network, all hospitals are assumed to draw from their local SHU.

Finally, it is assumed that the mean time between network road failures is 54 days, exponentially distributed, but that only 13% of the failures result in a significant delay to deliveries.

Two parameters were varied in the experimental framework:

1) The mean time to repair the delivery link between Calgary and the SHUs. Repair time was tested at 9.46, 15.46, and 21.46 hours to repair, with all times to repair assumed to be exponentially distributed.
2) The amount of inventory held at the SHUs. In the base case, it is assumed that the amount of inventory held at the SHUs is as defined in Table 3. In experiments, the amount of inventory held is adjusted by -1, 0, +1, or +2 days' demand to determine the impact of safety stock at the SHUs to buffer out disruptions to the logistics network.

7 RESULTS

Table 7 shows the results of the experiments in terms of units outdated per day. Results are shown as the mean time to recover from a network failure ranges from 9.46 hours to 21.46 hours and as SHU inventories are varied from -1 days' demand on hand to +2 days' demand on hand from the base case.

Table 7: Average daily number of RBC units outdated vs. mean time to road failure and changes to SHU inventory.

	Change in SHU Inventory			
MTTR	-1	0	1	2
0.394	14.392	14.720	15.637	25.158
0.644	14.643	14.389	15.598	25.155
0.894	14.756	14.535	15.905	25.105

The results in Table 7 indicate outdates are not affected by the mean time to recover the network after a road failure. However, the results suggest that increases to the inventory held at the SHU increases the amount of outdating in the system. This conclusion is supported by an analysis of variance (ANOVA) as shown in Table 8.

Table 8: ANOVA for units wasted per day against time to recover from a network failure (MTTR) and changes in the SHU inventory.

```
Analysis of Variance for Daily Wastage

Source          DF      SS       MS          F          P

MTTR             2     0.04     0.02       0.75       0.51
Change in        3   236.08     78.7    3246.35       0.00
SHU
Inventory
Error            6     0.15     0.02
Total           11   236.26
```

Table 9: Average daily number of units short vs. mean time to road failure and change to SHU inventory.

	Change in SHU Inventory			
MTTR	-1	0	1	2
0.394	5.96E-03	4.67E-03	2.18E-02	1.98E-02
0.644	4.95E-03	5.66E-03	2.02E-02	2.16E-02
0.894	7.45E-03	6.04E-03	2.22E-02	2.14E-02

Table 9 shows that product shortages increase as the mean time to recover from a network failure increases. In all cases, however, shortages were observed to be rare events, with instances occurring less than once per 45 days to once per every 168 days, depending on the scenario. Reductions in the SHU inventory below baseline values, did not significantly change shortage rates. However, when SHU inventory was increased, a significant increase in shortage was observed. In the simulation, product substitutions are explicitly disallowed. Thus, if demand appears for a particular blood type and none is available at the customer hospital, its associated SHU, or at the supplier site in Calgary, the demand is lost. The majority of shortages recorded in the simulation are due to requests for rarer AB- and B- blood. Shortages of these blood types occur when additional inventory is held at the SHUs since this policy sequesters more of these rare types to the SHUs and away from the DC in Calgary. Table 10 shows an ANOVA which indicates that road recovery time does not significantly influence shortages, but that changes in the SHU inventory level does.

Table 10: Average daily number of RBC units short vs. mean time to road failure and change to SHU inventory.

```
Analysis of Variance for Daily Shortage x 100

Source                    DF       SS       MS        F       P
MTTR                       2   0.0388   0.0194     2.56   0.157
Change in SHU Inventory    3   7.1018   2.3673   313.16   0.000
Error                      6   0.0454   0.0076
Total                     11   7.1859
```

8 CONCLUSIONS

Based on the results of the experiments, it may be concluded that consolidation of production and distribution facilities in the Prairie region will result in either no, or very modest, change to product wastage and shortage, given the assumptions on road network reliability, product demand, and inventory staging made in this study.

If one assumes the same types of operational structures as in the simulation experiments, it would be expected that 14.92 +/- 1.08 units per day of RBC would be wasted, while product shortages would be in the range of 0.01 +/- 0.008 units per day prior to consolidation; after consolidation, and assuming the most likely scenario for road closures, it is expected that 14.72 +/- 0.43 units per day of RBC will be wasted, while there will be 0.004 +/- 0.002 instances of shortage per day. Since these results are not statistically different from the base case, it may be concluded that, under the most likely scenario for network reliability, there should be no discernible changes in product availability or system wastage after consolidation.

Experimental results to test the effect of decreased network reliability and changes in inventory staging suggest that the network performance is reasonably robust. Wastage rates were observed to increase from 14.4 units per day to 25.2 units per day as inventory at the SHUs in Edmonton and Regina were varied from their baseline amounts by -1 to +2 days of demand, but were unaffected by changes in the road network reliability. In all runs tested, shortages ranged from $4.7\text{x}10^{-3}$ units per day to $2.2\text{x}10^{-2}$ units per day, or roughly 1.7 to 7.8 units per year. Shortages were observed to increase modestly as the road network reliability decreased. However, shortages were also observed to increase as more inventory is held at the SHUs and less is held at Calgary.

Overall, the results of the simulation experiments suggest that, within the range of likely network failures, the impact on customer service resulting from facility consolidation in the Prairie region is likely to be negligible.

9 DISCUSSION

The value of modelling changes in the blood distribution network in the Prairie provinces extends beyond a proof of technical feasibility. In Canada, the provision of health care is a provincial responsibility; provinces are responsible for the regulation, function, and funding of health care. Blood, because it is a biologic product, is federally regulated. Thus, while provinces pay for the provision of blood services, they are disallowed from directing the operations of blood agencies. Issues can arise when changes are suggested to blood distribution networks, particularly when such change involves the loss of facilities within a province. Concerns over the loss of facilities sometimes leads stakeholders to question whether the revised network will provide a similar level of service to that of the existing network (Blake and Hardy, 2013).

To address stakeholder concerns and, as due diligence for patient safety, Canadian Blood Services has found it useful to develop detailed simulation models of its regional networks. The models have been instrumental in establishing proof of concept and forecasting operational robustness. In this paper we have reported on the development of a specific instance of a simulation model created from a generic framework to represent changes in the distribution network in the Prairie provinces of Canada. This model, and its derivatives, have been used to address a specific series of policy questions and has served as a vehicle for fostering discussions between the blood agency and stakeholder groups in the Canadian Prairie Provinces.

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