Demand forecast and inventory management: sizing inventory of blood products in a blood bank in Brazil

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Abstract

The management of stocks of products derived from blood is a major problem for healthcare services in Brazil. This study aims to evaluate the demand for these products and establish parameters to control their stocks. This can increase the availability, as it intends to reduce blood shortages and wastages.

Keywords: Blood Center. Demand Forecasting.Stocks management.Blood products.

Introduction

Improve the blood availability is a concern of Brazilian health institutions. The services of collection and distribution are very important to guarantee an efficient care service. To save lives, it is necessary that this product be available at the right moment with right quality.

The hemocenters in Brazil are responsible for: collect, process, stock and distribute the blood derivates. The demand for these products is increasing by the blood use in the treatments. On the other hand, the number of potential blood donors is reducing (GREINACHER et al., 2007). It is important say that there is the blood's demand by natural disasters and this variable must be considered when we propose a model to estimate the demand (SCHIMIDT, 2002).

In Brazil, this situation is more critical, because it is observed that only 2% of population can be considered blood donors. The World Health Organization (WHO) states the number of 3% to 5% of blood donors. Brazil needs 5.500 blood bags every day and to supply this demand is necessary to increase the number of donors (BUSS, 2005). The rate of blood donation in Brazil was 1.9% in 2010. In some regions, this rate is smaller, like the North and Northwest Brazilian regions, where the rate is 1,4% (CADERNO DE INFORMAÇÃO SANGUE E HEMODERIVADOS, 2011). At Rio Grande do Norte state, the rate of blood donors can be observed at Table 1.

Table 1 – Rate of Blood Donation, Rio Grande do Norte, 2008 to 2010.

Population	Rate of Blood Donors		
	2008	2009	2010
Total	**1,27%**	**1,35%**	**1,42%**

Source: Caderno de Informação de Hemoderivados e Sangue. 5ED. Brasilia: 2011.

By the Table 1, we can observe that this rate are increasing but is smaller than the rate stipulated by WHO. A variable more critical is the fact that there is the high rate of rejection of blood bags, either due to failures during collects and blood process, expiry date or rejection after the quality control test. This contributes to the low availability of blood in Brazil. We can conclude that it is necessary do an inventory management of the blood products to improve the efficiency, that impacts directly to increase the potential do safe lives. If there is no a stock control, is probably that problems like shortages and wastage happens.

This paper aims discuss this question, using a Blood Bank of Rio Grande do Norte state that has faced the low availability of blood products.

Blood Bank Inventory Management

The blood must be processed to be obtained some products, called blood components and blood products. Normally, the production is focused to produce the blood components. It is possible obtain four different types (GOMES E GONÇALEZ, 2009):

- Packed red blood cells (CH);
- Platelets (CP);
- Fresh frozen plasma (FFP);
- Cryoprecipitate (CRYO);
- Concentrate granulocytes (GC).

These components have many uses, like the treatment of symptomatic anemia, coagulation disorders, thrombocytopenia, fibrinogen deficiency and severe neutropenia, among other diseases (GOMES E GONÇALEZ, 2009).

It is common the media notice that is missing blood in Brazil and this fact causes postponement or cancellation of urgent surgery, for example. When this fact happens, campaigns for attracting donors to replenish the stocks are carried out and goals to collection process are defined based on past experiences or according to medical requests. However, it is not observed a methodology to scale these goals.

It was done some research to find models to management the demand of blood in Brazil. However, it was found only a basic model for this procedure in the “Guide of Health Ministry of Brazil”, published in 2011, entitled “National Guide to Management the Inventory Blood in Emergency Situations”. At this guide, they suggest steps related to structure, to professional reunions and to the material necessary at emergency situations. Also, some indicators to help the management process is proposed. It defines one methodology to dimension the blood inventory (equation 1). This measure is done by the demand of the last six months and this number is divided by 180 and multiplied by three.

$$\mathrm{EM} = \frac{\mathrm{NB}}{180} \times 3 \quad (1)$$

EM = Minimal stock;
NB= Number of blood bags demanded in the last six months.

How this method is used at unusual situations, in normal conditions it is not applicable, because is necessary analyzes more detailed to the inferences can be aggregated to a forecast and inventory model more closely to the reality. According to this, it is observed that the studies are limited in this area.

Models applied in Blood Bank Inventory Management

In inventory management, some information is required, like the demand expected, numbers of orders and the availability of the item (KRAJEWESKI et al., 2009). The inventory has some functions (LUSTOSA et al., 2009): economies of scale made possible due to the discount generated by the acquisition of large quantities or in gains related to production processes and transport; protection in order to protect the supply chain in cases of absence of items and advance to meet anticipated demand.

In the Blood Bank case, the use of the inventory is meet the demand, because this kind of product is irreplaceable and is used in emergency cases. The Blood Bank mission is guarantee that the blood components and the blood products being available to hospitals and emergency centers. The other factors are not related in this mission because this kind of institution does not aim the profit.

To dimension an inventory management, some steps are suggested (MARTINS e LAUGENI, 2005):

- ABC inventory classification;
- Define the system parameters;
- Define the safety stocks.

According to these steps, the Pareto Diagram can be used to understand the blood product importance (LEOPRABHU, PRAKASH and DEEPAN, 2010). The same authors proposed a model to define the stock level for most important blood products. The variables used at this model are the safety stock and the lead time of the process.

The model is formed by four equations to define the safety stock, the lead time process, the minimal stock and the maximum stock. This model is the same used by Wild (2002).

To define the safety stock, it is necessary suppose a service level required (NS). In this case, was proposed the 99,99% to all blood products, due to the importance of having this product for many health treatments, where there is serious risk of life. The Equation 2 shows how the safety stock is calculated.

$$\mathrm{Eseg} = \mathrm{NS} \times \mathrm{FLT} \times \mathrm{DP} \quad (2)$$

Eseg = Safety stock;
NS = service level required;
FLT = lead time of the process;
DP = standard deviation.

The lead time is obtained based on the timing of all process, showed in Equation 3.

$$\mathrm{LT} = \text{Máx LT} \times \text{Máx Demand} \quad (3)$$

LT = lead time necessary;

Max LT = maximum process lead time;
Max Demand = maximum demand value found in the time series data.

Based on these equations, it is possible calculate the minimum and the maximum stock levels (Equations 4 and 5).

$$\text{Minimum/Month} = \text{Eseg} + \text{LT} \quad (4)$$

Minimum/Month= minimum inventory level to be maintained for months;

Eseg = safety stock;
LT = lead time necessary.

$$\text{Maximum/Month} = \text{Average} + \text{Minimum/Month} \quad (5)$$

Minimum/Month = minimum inventory level to be maintained for months;
Eseg = safety stock;
LT = lead time necessary.

It is important say that this king of inventory is composed by two sub models, called inventory assigned, when blood donations are directed to a specific receptor and unallocated inventory, that inventory in emergency appeal for unknown recipients. In emergency cases, the product must be released, even being assigned inventory, with the prospect of replacement (LEOPRABHU, PRAKASH and DEEPAN, 2010). The same authors understand that it is necessary the maintenance the database of donors to call these donors to make new collection when necessary.

The case

The Blood Bank analyzed was created in 1989 to meet the hospitals of west region of the Rio Grande do Norte state. The blood collection is realized from Monday to Saturday during all days.

It was observed that is necessary collect 900 blood bags every day (information given by the employers). In some months (July, for example) the necessity reaches 1000 bags. To each bag, it is possible to produce three types of blood products or blood components.

The system used at the Bank Blood informs that it was produced 15.804 products in 2011 and 7.730 blood bags were dropped.This means that 48,91% of all material collected was shortage.The most common motives of this is the problem at the collection process, the expiration date and the rejection after testing for quality control. In some cases, a part of the blood inside the bag is dropped, because the result of the blood subdivision process must be used in industrial scale to produce the hemocomponents. This process is done in France. However, the Blood Bank did not guarantee the quality stipulated to send this material to be processed.

So, with the low rate of donors and the big wastage, the inventory management is a challenge to guarantee the blood offer. Six types of products are produced: fresh frozen plasma, red blood cells, pediatric red blood cells, red blood cells leukocytes, platelet concentrates, platelet concentrates collected by apheresis procedure.

The period used is the data from 2010 and 2011 years registered at the blood book. This book presents information like: demand of each blood type and the type of blood product demanded. The data was separated by month, getting the total quantities of product hemotherapeutic by blood type in the respective periods. The Table 2 shows an example of the series collected, segmented by product type and blood type (fresh frozen plasma).

Table 2 – Fresh frozen plasma demand in 2010 e 2011

	Blood Type							
Period	**A+**	**B+**	**AB+**	**O+**	**A-**	**B-**	**AB-**	**O-**
Jan/10	24	32	1	19	0	1	6	5
Feb/10	54	7	3	35	0	0	0	2
Mar/10	42	26	2	23	0	4	0	2
Apr/10	13	0	0	34	1	0	0	1
May/10	39	8	5	51	0	0	0	2
Jun/10	20	8	0	36	0	0	0	1
Jul/10	15	7	0	15	0	1	0	2
Ago/10	6	3	0	5	0	0	0	4
Set/10	13	0	0	40	0	0	0	8
Oct/10	10	15	0	33	0	0	0	5
Nov/10	15	7	5	45	7	0	0	23
Dez/10	19	0	10	152	1	0	0	3
Jan/11	17	4	3	23	0	0	0	0
Feb/11	38	0	0	20	3	0	0	3
Mar/11	57	7	0	22	2	0	0	18
Apr/11	28	6	2	18	0	0	0	7
May/11	24	1	0	60	2	0	0	7
Jun/11	15	6	0	17	0	0	0	16
Jul/11	34	13	0	39	0	4	0	0
Ago/11	21	0	0	31	1	0	5	5
Set/11	120	6	0	9	0	0	0	2
Oct/11	64	10	0	41	6	0	0	11
Nov/11	14	36	0	25	5	0	0	0
Dez/11	31	9	0	9	3	0	0	2

Using the data organized, it was observed that the all blood products types followed the same pattern of demand. The Figure 1 exemplifies the pattern of the demand in 2010 and 2011 of the fresh frozen plasma product. The other blood products were organized as the same way.

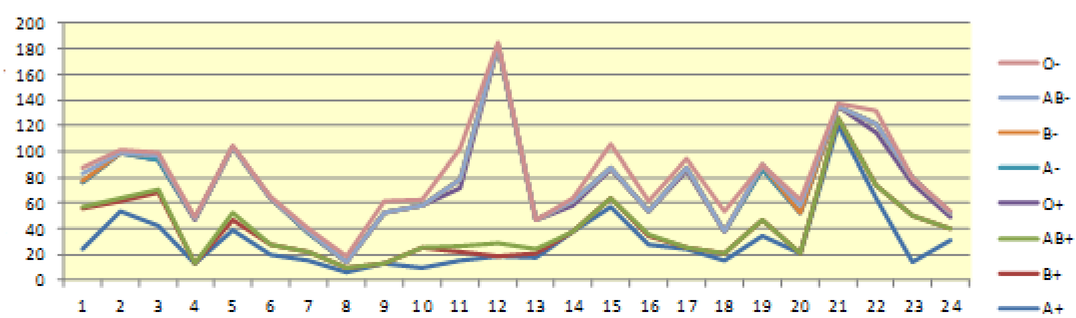

Figure 1 – Fresh frozen plasma demand by type of product in 2010 e 2011.

By the Figure 1, is possible observe that in February and March and the last months the demand are increased by the carnival and the Christmas. This happens because the number of accidents grows up and this impacts the demand of hospitals.

Also, it is possible observe that the data presents trend component. This behavior is because the number of cardiac surgeries are increasing each year and this kind of service demand much blood. Furthermore, the population growth and the Oncology Centers, for example, increases the demand. These facts do not happen only in Brazil. The research shows that the frequency of the medical procedures that the requiring extracorporeal circulation grows up (ROCHE and STEMGLE, 1973).

By the elements identified in the data (trend and seasonality components), the forecast model developed was done based on Tubinos' methodology (TUBINO, 2007). The Table 3 shows the results obtained by the methodology application. It is presented the demand projections of the two years and the Table 4 presents the results for the fresh frozen plasma detailed for 2013.

Table 3 – Demand projection for fresh frozen plasma.

2013 forecasted demand – PF				
Month	**Period**	**Tendency**	**IS**	**F.D.**
jan/13	37	68,7848	0,5024	35
fev/13	38	66,6852	0,2357	16
mar/13	39	64,5856	0,812	52
abr/13	40	62,486	0,8299	52
mai/13	41	60,3864	1,3428	81
jun/13	42	58,2868	2,4653	144
jul/13	43	56,1872	0,613	34
ago/13	44	54,0876	0,7938	43
set/13	45	51,988	1,2374	64
out/13	46	49,8884	0,6652	33
nov/13	47	47,7888	1,0036	48
dez/13	48	45,6892	0,6186	28

Table 4 – Demand projection for each type product made for fresh frozen plasma.

Forecasted demand				
Month	**PF**	**CH**	**CHPL**	**CP**
Jan/13	47	422	117	91
Fev/13	64	420	204	220
Mar/13	106	614	160	348
Abr/13	61	490	129	190
Mai/13	94	426	129	181
Jun/13	54	501	172	255
Jul/13	90	575	62	238
Ago/13	63	511	169	218
Set/13	137	473	197	182
Out/13	132	455	145	148
Nov/13	80	479	101	136
Dez/13	54	497	94	61

Based on Table 4, were applied the proportionality calculated based on actual demand and the future projections for each blood product. This strategy was used because the large volume of data.

After this procedure, it was analyzed the most important blood products for the Blood Bank. To get it, the Pareto Principle was used and it was possible observe the blood product more demanded.

The products considerate the A type are the O + red blood cells and red blood cells A +, items that together require about 40% of the total demand for blood products.

It was expected that the greatest demand was for products of -O blood, since it is considered universal donor. However, the Figure showed that blood types that were most demanded were the products made for -O + and the A +. Thus, the blood center managers should be aware about the availability of blood products, in order to maintain constant donors, especially those blood types. Among the products that have lower demand are the products of blood types B-and AB-.

This happens because in the Brazilian population the most common blood type is O and A (87% of the population). The B blood get 10% and AB blood get only 3% of the population. Is important observe that 85% of the population presents Rh positive.

To define the inventory, the first step was estimate the timing of the collect and blood process. The Table 5 presents the timing done.

Table 5 – Timing of the blood process.

Product	Lead Time (hours)
1. Freshfrozen plasma	28,929
2. Concentrates of Red blood cells	28,079
3. Concentrates of on poor Red blood cells Leukocytes	30,579
4. PlateletConcentrate	29,762

By these timing, it was possible calculate the lead time factors, information necessary to obtain the safety stock. To fresh frozen plasma, the lead time factor obtained was 0,0416. Based on the real demand series, the stock levels were defined to all blood products. The Figure 6 presents the fresh frozen plasma results.

Table 6 – Fresh frozen plasma parameters

Fresh Frozen Plasma								
Blood Type								
	A+	B+	AB+	O+	A-	B-	AB-	O-
Average	30,54	8,79	1,29	33,42	1,29	0,42	0,46	5,38
Maximum/Month	120	36	10	152	7	4	6	23
Standard deviation	24,58	9,72	2,44	28,75	2,07	1,14	1,56	6,02

It was adopted the service level of 99,99% to all blood types. This means the service factor 3,620. Based on all these information, were defined the inventory parameters for each blood product done by each blood type. The Table 7 presents the results for blood products (Fresh Frozen Plasma).

Table 7 – Stock levels for fresh frozen plasma

Fresh Frozen Plasma			
Blood Type	Safety Stock	Min/Month	Max/Month
A+	19	24	144
B+	8	9	45
AB+	2	3	13
O+	22	28	180
A-	2	2	9
B-	1	2	6
AB-	2	2	8
O-	5	6	29

The values obtained to minimum stock are different from safety stock because the safety stock is used to calculate the minimum stock. Some authors define the minimum sock as the same as Safety Stock, but the methodology considered in this research does not do this.

Based on the forecast obtained and the stock levels, it is possible analyze the models. The next figures present the results for the fresh frozen plasma. The blue line represents the demand forecast of the blood product. The other lines means the levels of maximum, minimum and the safety stock, been represented by the colors red, green and yellow.

Results

Aiming to observe possible inconsistencies in projected demand, it was drawn a graph to compare the data with the actual demand with demand estimated by the model, presented in Figure 2 (the aggregate demand of related blood products). The dotted lines indicate the onset of anticipated demand for 2012 and 2013.

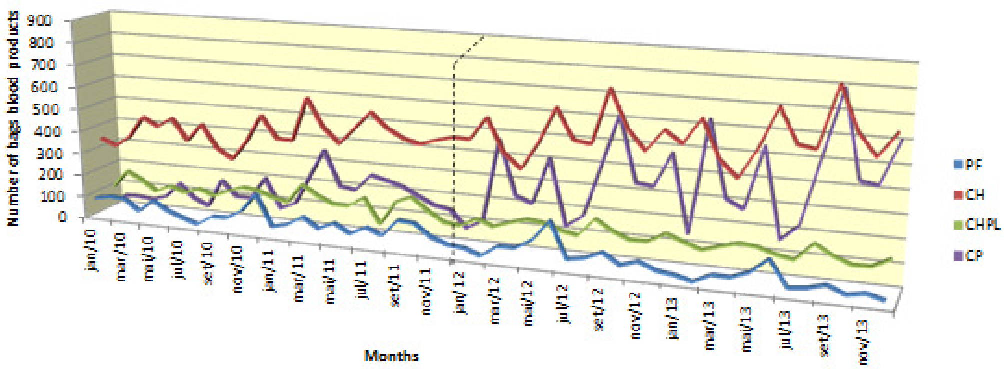

Figure 2 – Actual demand and demand estimated by the model

By the Figure 2, is possible conclude that the behavior of the demand estimated is near from the behavior of real demand. It was found four standards behavior for the blood products.

- First Standard: the demand estimated are below the maximum stock level, however these values permeate between the minimum and security, as shown in Figure 3.

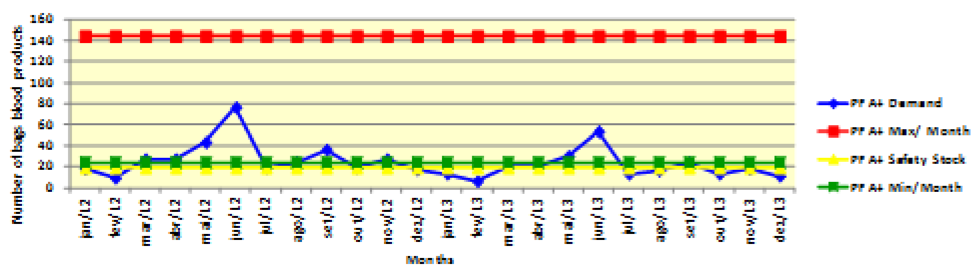

Figure 3 – Demand estimated and the stock levels for fresh frozen plasma A+.

This means that is possible work by stock level near from the minimum stock. This action can reduce the wastage. The fresh frozen plasma follows this behavior. It is possible use a service level smaller than 99,99%, because it causes extra stock and it is note necessary.

- Standard 2: The demand is concentrated between the minimum and maximum levels (Figure 4).

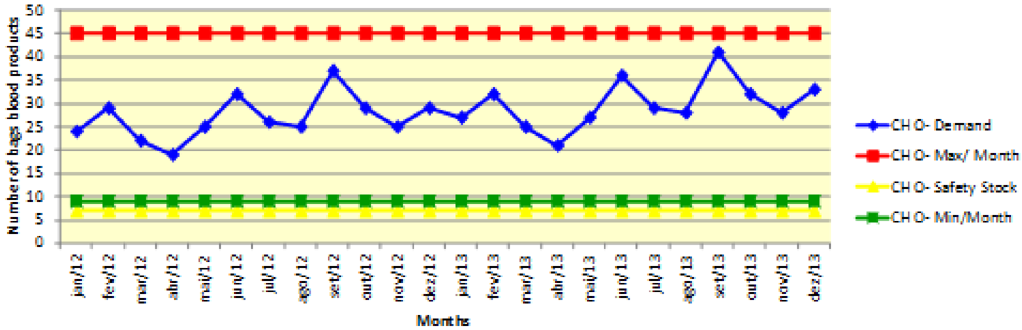

Figure 4 – Demand estimated and stock for the red blood cells O-.

In this case, the model provided by LEOPRABHU, PRAKASH and DEEPAN (2010) works well. The major blood products of red blood cells follow this behavior. In some cases, however, it is not true.

- Standard 3: the demand estimated exceeds the value assigned to the maximum stock level (Figure 5).

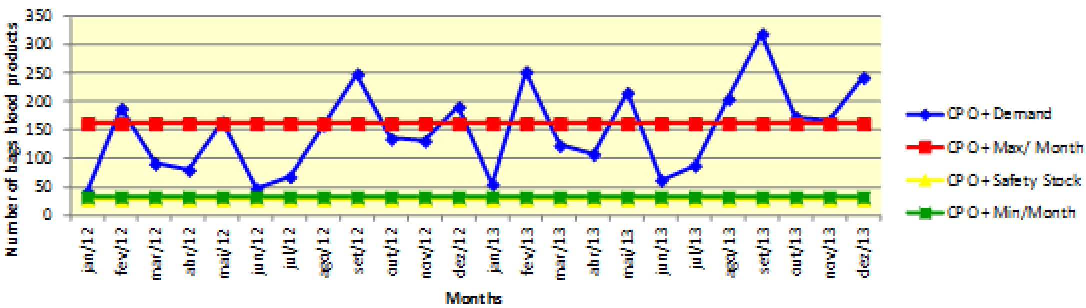

Figure 5 – Demand estimated and stock levels for platelet concentrate O-.

In this case, the inventory management model proposed by LEOPRABHU, PRAKASH and DEEPAN (2010) does not work well and, in some cases, the stock will be smaller than the demand. It is necessary use another model to this kind of blood product.

Conclusions

In the major researches related to inventory management of Blood's Bank, the demand is estimated by blood type and do not specify the blood product produced from the blood type.

By this research done, is possible conclude that it is necessary control the stock levels to minimize the wastage and the lack of product. There is no a perfect model that will works to all kind of blood products made from blood types. It is necessary use different models to each blood products.

Generally, the demand estimated was between the stock levels, but there were many cases that the demand was bigger than the maximum stock level, specially the platelet concentrate product.

In some cases, the demand estimated get near the minimum stock level. To these cases, we suggest use a smaller level of service.

It is important to say that it is necessary constantly update the data to maximize the blood products offer and reduce the wastage.

References

Balogh, M. B. and Fehrenbach, M. J. 2008. *Anatomia, histologia e embriologia dos dentes e das estruturas orofaciais*. Manole, São Paulo.

Belien, J. 2012. Supply Chain Management of blood products: a literature review. *European Journal of Operational Research*.

Buss, D. 2005. *Sangue – Fluido da Vida*. Sala de Comunicações , São Paulo.

Carmo, B. B. T.; Pontes, H. L. J; Albertin, M. R.; Barros Neto, J. F.; Dutra, N. G. S. 2009. Avaliação da demanda por biodiesel em função de um modelo de previsão de demanda por diesel. *Revista Produção Online* 9(2): 511-535.

Correa, H. L. Correa, C. A. 2008. *Administração de Produção e Operações: manufatura e serviços: uma abordagem estratégica*. Atlas, São Paulo.

Davis, M. M. et al. 2001. *Fundamentos da Administração da Produção*. Bookman, Porto Alegre.

Greinacher, A., Fendrich, K., Alpen, U. e Hoffmann, W. 2007. Impact of demographic changes on the blood supply: Mecklenburg-West Pomerania as a model region for Europe. *Transfusion* 47(3): 395–401.

Leoprabhu, E. Prakash, S. S. Vivek, I. Deepan, P. Ranganathan, R. 2010. *Inventory Management for Blood Banks. Coimbatore Institute of Tecnology* 2006-2010.

Lustosa, L. et al. 2008. *Planejamento e controle da produção*. Elsevier, Rio de Janeiro.

Roche, J. K. and Stemgle, J. 1973. M. Open-Heart Surgery and the Demand for Blood. *Journal of the American Medical Association* 225(12):1516-1521.

Schimidt, P. J. 2002. Blood and disaster – supply and demand. *New England Journal of Medicine* 346(8): 617-620.

Silva, E. L.; Menezes, E. M. 2005. *Metodologia da pesquisa e elaboração de dissertação*. UFSC, Florianópolis.

Thibobeau, G. A. Patton, K. T. 2002. *Estrutura e funções do corpo humano*. Manole, São Paulo.

Tubino, D. F. 2007. *Planejamento e Controle da Produção: Teoria e Prática*. Atlas, São Paulo.

Wild, T. 2002. Best Practice in Inventory Management. Elsevier Science, Woburn.