Understanding the dynamics of the blood supply chain. Is demand prediction possible?

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NHS

Background

The problem

Blood is taken from the donor and PUSHED into the national stock. Hospitals then PULL blood from the national stock into the local stock. The clinician then PULLS blood from the local stock to be used for a patient. So that planners are able to balance supply and demand, these two competing forces must be synchronised.

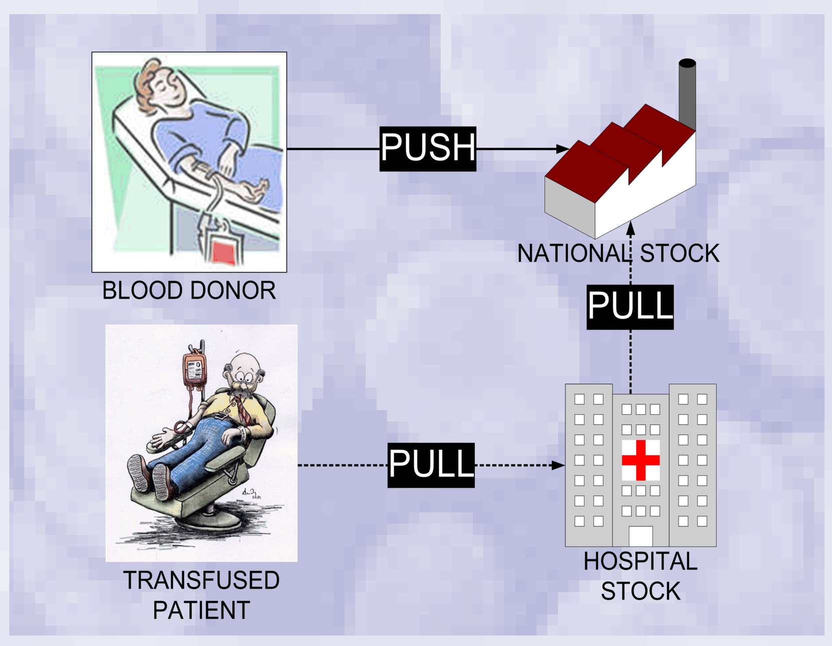


Fig 1. The Blood Supply Chain

In order to achieve this, effective forecasts of demand are required so that plans for an appropriate supply can be made. This leads to stable stock levels, reduced wastage, and guaranteed supply.

However, despite years of analysis, accurate and timely demand forecasts still elude planners.

Can demand be forecast using traditional methods?

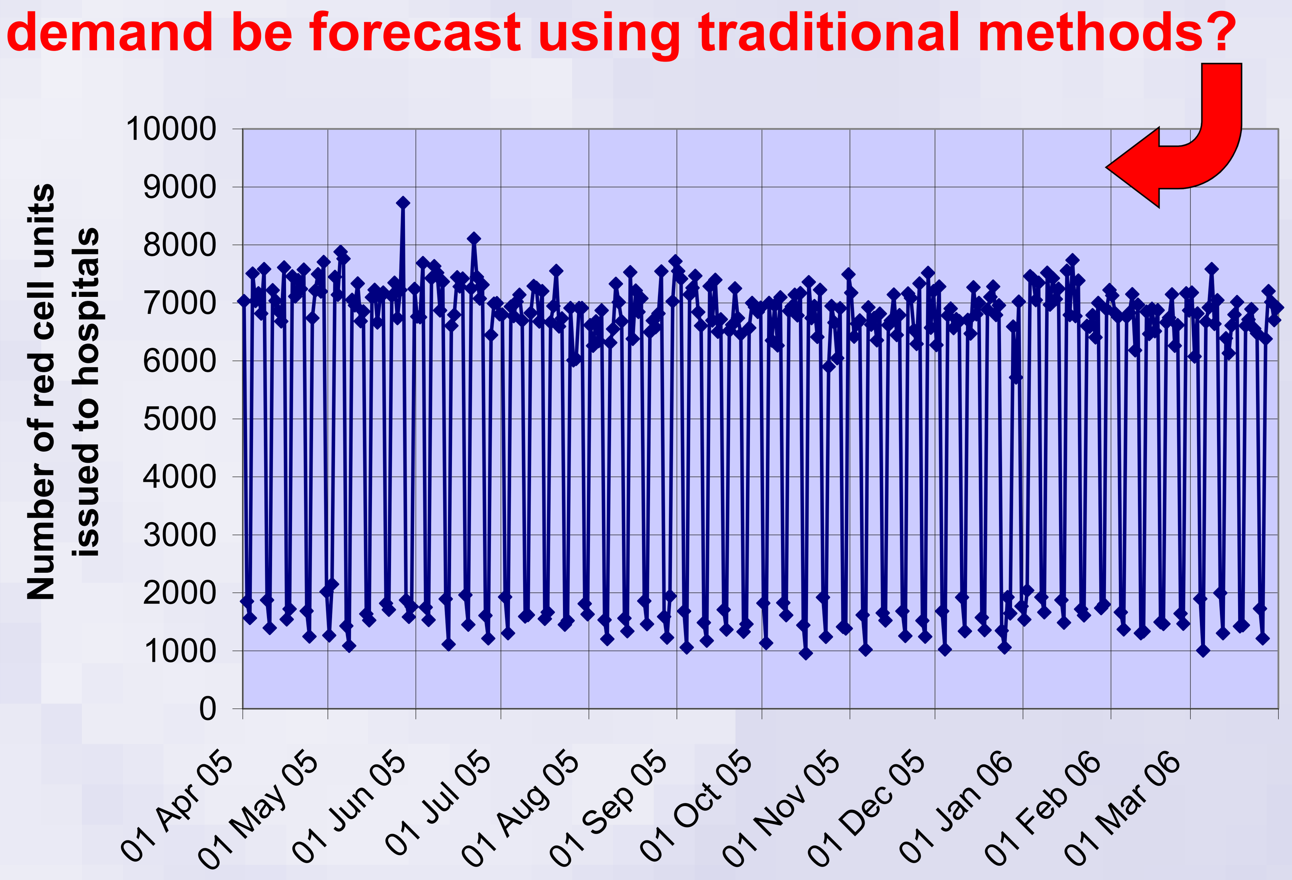
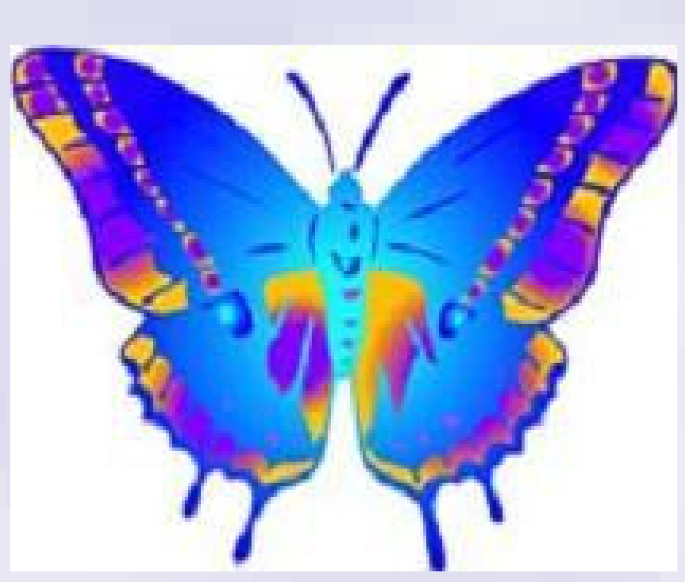


Fig 2. Daily demand data for 01-Apr-05 to 31-Mar-05

What is chaos?

"Random behaviour governed entirely by laws!"

Chaos is deterministic, generated by fixed rules that in themselves involve no element of chance. In theory, therefore, the system is predictable, but in practice the non-linear effects of many variables make the system less predictable.



The system is also extremely sensitive to initial conditions, so a small change to a system variable's initial condition may result in a completely different response. This characteristic was made famous by the "Butterfly Effect" whereby flapping of a single butterfly's wings generates a tiny change in the atmosphere which overtime becomes amplified into a major weather event in another part of the world

Chaos is defined as aperiodic, bounded dynamics in a deterministic system with sensitivity dependence on initial conditions and has structure in phase space.

Methodology

To test for chaos in the blood supply chain, daily red cell demand from the national stock was analysed for the characteristics of a chaotic system. The data analysed consisted of 2,073 data points collected between 01 Jan 2000 and 8 Sept 2005.

To detect whether the system is chaotic, 5 characteristics must be identified:

A: **Aperiodic**; the same state is never repeated twice. Investigated using the Lyapunov exponent.

B: **Bounded**; on successive iterations the state stays in a finite range and does not approach ± infinity. Investigated using partitioned data.

C: **Deterministic**; there is a definite rule with no random terms governing the dynamics. Investigated using surrogate data.

D: **Sensitive to initial conditions**; two points that are initially close will drift apart as time proceeds. Investigated using the Lyapunov exponent.

E: **Structure in phase space**; chaotic systems display discernible patterns when viewed in multiple dimensions (Fig 3). Investigated using visualisation of the attractor.

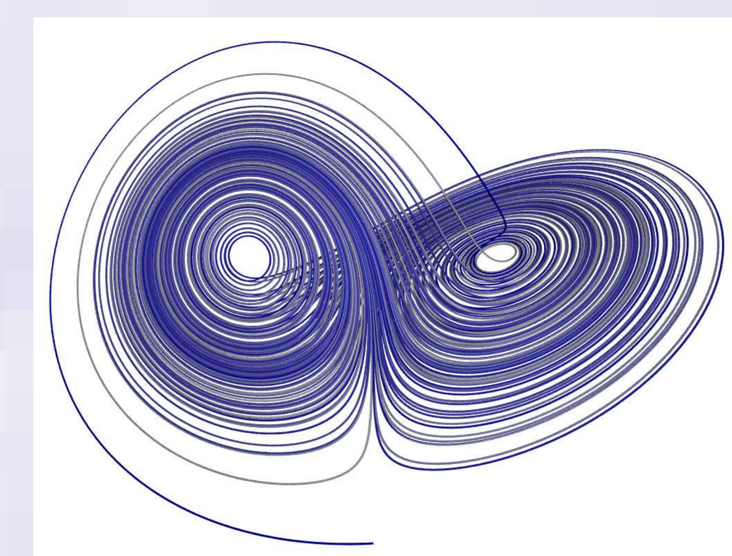


Fig 3. An attractor exhibiting structure in phase space

The Lyapunov Exponent gives the rate of exponential divergence from perturbed initial conditions; positive exponents indicate a chaotic system.

The magnitude of the exponent can also approximate the average prediction horizon (APH) of a system. After this APH has been reached, the future dynamics of the system cannot be forecast with any accuracy.

Results

The demand data obeys all 5 characteristics necessary for the system to be classified as chaotic.

- The data had a positive Lyapunov exponent of 0.282, which confirms characteristics A and D. Analysis also revealed a base unit APH of 35 days.
- All partitions of the data were equivalent. This confirms characteristic B.
- The data was not random, indicating that there was a degree of correlation between successive days demand. This confirms characteristic C.
- The attractor displayed visible structure, confirming characteristic E. This indicates there was no significant mean level shift over time.

Practical implications for the blood supply

- Is demand prediction possible? Only for short-term predictions made within the prediction horizon. It is better to allocate resource to the development of an effective short-term decision-making process rather than long-term.
- Dramatic change can occur unexpectedly: spikes in demand can occur, which are generated by the system and are not the result of external events.
- Long-term planning is very difficult; if long-term plans are made they will need to reviewed regularly.
- The blood supply chain will not reach stable equilibrium. Managers need to recognise the impact of local decisions on the wider supply chain.
- Treat the supply chain as a complete system; small changes made to optimise one part of the chain can result in massive changes in other parts.
- Driving down inventory and lead-times may not always improve performance; it could result in the system slipping into chaos.

For more on chaos and the blood supply, visit www.bloodstocks.co.uk/publications/posters/

Professor Richard Wilding, BSc, PhD, CEng, Eur Ing, FIET, FCILT.

As Chair (Full Professor) in Supply Chain Risk Management at the Centre for Logistics and Supply Chain Management, Cranfield School of Management U.K. Richard works with European and International companies on logistics and supply chain projects in all sectors including pharmaceutical, retail, automotive, high technology, food drink and professional services to name a few. He is a highly acclaimed presenter and regularly speaks at Industrial Conferences and has undertaken lecture tours of Europe and Asia at the invitation of local Universities & Confederations of Industry. He has published widely in the area of supply chain management and is Editorial Advisor to a number of top journals in the area.

His Doctoral research, undertaken while employed at the University of Warwick, applied chaos and complexity science to logistics and supply chain management. This innovative research received international media coverage including features on the BBC World Service and articles in the Times, Financial Times and New Scientist.

Richard is both a European and Chartered Engineer, he is a chartered fellow of both the Institute of Engineering & Technology (Manufacturing Division) & the Chartered Institute of Logistics & Transport. Richard is also a member of The Higher Education Academy in recognition of his innovative approaches to teaching and course design.

Richard's special areas of interest include the creation of collaborative business environments, reducing supply chain vulnerability & risk, time compression and techniques for aligning supply chains to maximise customer value and reduce cost.

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You can also subscribe to "The Supply Chain Podcast by Professor Richard Wilding"
www.supplychainpodcast.info or www.supplychainpodcast.co.uk

Further Information on Chaos in the Supply Chain.

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Other Papers which support this research

"Chaos Theory; Implications for Supply Chain Management", *International Journal of Logistics Management*, Vol 9, No 1, pp 43-56, 1998

"The Supply Chain Complexity Triangle: Uncertainty Generation in the Supply Chain", *International Journal of Physical Distribution and Logistics Management*, MCB University Press, Vol 28, No.8, pp 599-616, 1998