Institution: Buckinghamshire New University

Unit of Assessment: 19 Business & Management Studies

Title of case study: Intermittent Demand Categorization and Forecasting (Bucks New University)

1. Summary of the impact

Our research team has developed new approaches to classifying demand series as 'intermittent' and 'lumpy', and devised new variants of the standard Croston's method for intermittent demand forecasting, which improve forecast accuracy and stock performance. These approaches have impacted the forecasting software of Syncron and Manugistics, through the team's consultancy advice and knowledge transfer. Subsequently, this impact has extended to Syncron International and JDA Software, which took over Manugistics. These companies' forecasting software packages have a combined client base turnover of over £200 billion per annum, and their clients benefit from substantial inventory savings from the new approaches adopted.

2. Underpinning research

This research originated in joint work by Roy Johnston (Warwick University) and John Boylan (Bucks New University). The research was undertaken in 1993 and 1994, during which time John Boylan was employed by Bucks as a full-time Lecturer. This early research, based on simulation modelling, identified conditions under which Croston's method is more accurate than Single Exponential Smoothing (1). A break-point for the average interval between demands was found, above which Croston's method is more accurate. An investigation was also conducted on the effect of other variables, such as variances and distributions. However, no break-points were identified which took these factors into account. Whilst this research did not form the basis of recommendations for Syncron or Manugistics, it did lay the groundwork for later research which was adopted by the companies.

The research was extended at Bucks New University by Aris Syntetos, supervised and mentored by John Boylan, between 1999 and 2001. During this time, Bucks employed Aris Syntetos as a full-time Lecturer and John Boylan as Head of Research. The first finding of this research was that Croston's method is biased (2); this was proven by mathematical analysis. The second finding, based on a Taylor series argument, was that a simple adaptation to Croston's method would result in approximately unbiased forecasts (3). Later, this adaptation has become known as the Syntetos-Boylan Approximation. The third finding, based on a mathematical analysis of Mean Squared Errors, was to extend the original categorization scheme (1) by including a measure of the 'lumpiness' of the demand data (4).

As part of this research, the findings were tested on real data. This confirmed the bias of Croston's method and the reduction in bias by using the Syntetos-Boylan Approximation. It also validated the categorization rules, which had been derived on theoretical grounds. Finally, it showed that these forecasting benefits translated into inventory reductions in a re-order interval context (5). However, financial evaluations of this benefit were not possible because of the absence of unit cost data.

The next phase of research was to evaluate the financial effect of the new approaches on real company data at Syncron (UK) Ltd. This research was part of a Teaching Company Scheme (TCS) by Syncron and Bucks New University. The research was undertaken by George Karakostas, supervised by John Boylan. George Karakostas was employed by the University as a TCS Associate, on a full-time basis, between 2001 and 2003, while John Boylan continued to be

employed as Head of Research.

The research empirically demonstrated the robustness of the categorization rules on real data (6). It also showed that marked reductions in inventories could be achieved from the application of the Syntetos-Boylan Approximation. This finding was consistent with independent empirical research conducted at Lancaster University (Eaves and Kingsman (2004) Forecasting for the ordering and stock-holding of spare parts. Journal of the Operational Research Society, 55, 431-437). The Bucks' research team found that savings of over 11.7% of inventory value were attainable, with a slight undershoot of the Customer Service Level.

3. References to the research

The research was disseminated in the following peer-reviewed journal articles:

1. Johnston FR, Boylan JE (1996) Forecasting for items with intermittent demand. Journal of the Operational Research Society, 47, 113-121.
2. Syntetos AA, Boylan JE (2001) On the bias of intermittent demand estimates. International Journal of Production Economics, 71, 457-466.
3. Syntetos AA, Boylan JE (2005) The accuracy of intermittent demand estimates. International Journal of Forecasting, 21, 303-314.
4. Syntetos AA, Boylan JE, Croston JD (2005) On the categorization of demand patterns. Journal of the Operational Research Society, 56, 495-503.
5. Syntetos AA, Boylan JE (2006) On the stock-control performance of intermittent demand estimates. International Journal of Production Economics, 103, 36-47.
6. Boylan JE, Syntetos AA, Karakostas GC (2008) Classification for forecasting and stock-control: a case-study. Journal of the Operational Research Society, 59, 473-481.

All of the above references are in the public domain.

Evidence of the quality of the underpinning research is summarized below:

- Articles (1), (2), (3) and (4) have all been cited more than 100 times, according to Google Scholar. They were all referenced in the widely-cited review article by Gardner (2006): Exponential smoothing: the state of the art – Part II, International Journal of Forecasting, 22, 637-666.
- Articles (1) and (3) were also cited in the major review article by De Gooijer and Hyndman (2006): 25 years of time-series forecasting research, International Journal of Forecasting, 22, 443-473.
- Article (5) has been cited 70 times (Google Scholar, 1 October 2013), including citations by researchers at the universities of Brescia, Lancaster, Lulea, Richmond, Saint-Etienne, Stanford, Takming, Texas, Thessaloniki, Tilburg, and Valencia.
- Article (6) has been cited over 50 times (Google Scholar, 1 October 2013). The article is based on research undertaken as part of a Teaching Company Scheme (TCS), now known as a Knowledge Transfer Partnership. The project received a good grade from the TCS Central Office. (Letter from EH Robson, TCS Director, 9 January 2004).

4. Details of the impact

Contribution and Impact on Syncron

In autumn 2001, Bucks New University and Syncron UK commenced a two-year Teaching Company Scheme. The aim was to enhance the capability of Syncron's demand forecasting and inventory management software.

The research team provided a review and critique of Syncron's Demand Forecasting and stock Replenishment Planning system (2). This identified the following issues, amongst others: limited capacity to store demand histories, inflexibility of hard-coded tables to categorize demand, and limited capability to forecast intermittent demand items. The team proposed and evaluated new methods for intermittent demand forecasting, based on the Syntetos-Boylan Approximation and variations of that approach (2, 3). Error evaluations showed marked reductions in Mean Squared Errors, of approximately 25%, when employing the new methods instead of the existing method (3). The research also showed that the old company categorization approach was inappropriate, and that greater forecast accuracy could be achieved with a new categorization method proposed by the University.

Syncron adopted the University's recommended approaches and these have remained in effect from the beginning of 2008 to the end of 2013 (4). On Syncron's web-page for its Demand Forecasting Software, the company highlights "Our best-in-class dynamic demand forecasting for stock with frequent, highly sporadic or intermittent demand". It then headlines "Demand Forecasting Software: Automatic Demand Classification". The enhancement to Croston's method is also cited: "Special forecasting techniques such as a refined Croston methodology are used to handle sporadic and intermittent demand" (4).

Contribution and Impact on Manugistics and JDA

In 2002, John Boylan was commissioned by Manugistics to provide consultancy advice on the development of a systematic demand classification and forecasting system. This had arisen from debate within the company about the relative merits of a formal classification system and a "pick-best" methodology, based on minimizing model-fit error. Boylan (5) recommended a formal classification system, arguing that it could offer a more accurate and sophisticated approach if appropriate categorization rules were used.

The recommendation of a formal demand classification approach was communicated by report (5) and by a video-conference between Boylan and Manugistics' board members in the US. This recommendation was accepted by the company and implemented in their software. After Manugistics had been taken over by JDA, the approach was also implemented as part of JDA's Global Inventory Management software, and has remained the basis for the JDA Demand Classification package from 2008 to the end of 2013 (6). Boylan (5) also recommended, based on his categorization research with Aris Syntetos, that the company should distinguish between 'erratic' and 'lumpy' demand series. These categories remain at the heart of the JDA Demand Classification software (6), and the JDA Demand Management package.

Financial Benefit to Syncron's and JDA's Clients

Syncron's clients for its Global Inventory Management software include the following companies (7), listed with their annual revenues: Deutsche Bahn (39.3 billion Euro, 2012), JCB (£2.75 billion, 2011), Mazda (2.3 trillion Yen, 2011), Metso Minerals (3.5 billion Euro, 2012, Mining and Construction), Renault Trucks (4.3 billion Euro, 2011) and Volvo Construction Equipment (65 billion SEK, 2011).

JDA Demand Management software clients include (8): Avon Products ($10.72 billion, 2012), Bristol-Myers Squibb ($18.8 billion, 2009), Canadian Tire ($8.98 billion, 2010), Dell ($62.1 billion, 2012), Harley Davidson ($5.31 billion, 2011), Hyundai ($84 billion, 2012), Kraft Foods ($18.34 billion, 2012), O2 (UK) (£2.97 billion, 2010), Renault (41.3 billion Euro, 2012), Swire Pacific, (HK$ 36.29 billion, 2011), Toshiba Semiconductor ($12.36 billion, 2010), and Vodafone (£46.4 billion, 2012).

The combined turnovers of these clients amount to approximately £240 billion, at current exchange rates. Application of aggregate 'Days of Inventory Outstanding', by Industrial Sector (9), gives a very approximate estimate of total inventories of £19 billion. JDA Demand Management is also used by the Defense Logistics Agency, which reported inventories of £13 billion in 2012 (10), giving approximate total inventories of £32 billion. There is no reliable data available on the proportion of the companies' inventories which are slow-moving. However, a modest assumption would be at least one-third, giving an estimate of slow-moving stock of £10 billion.

The most comprehensive analysis of the financial impact of enhanced categorization methods and of the application of the Syntetos-Boylan Approximation (SBA) was conducted by Eaves and Kingsman (2004): Forecasting for the Ordering and Stock-Holding of Spare Parts, Journal of the Operational Research Society, 55, 431-437. They concluded that enhanced categorization (using a similar but not identical approach to that recommended by Bucks) and application of the SBA method resulted in a saving of 13.6% of the total value of inventory, with slightly smaller savings if Croston's method were used instead of SBA. This is consistent with the financial saving of 11.7% identified in the TCS project with Syncron. If the clients of Syncron and JDA have been able to achieve similar savings, of at least 10% in inventory values, then this equates to a saving of £1 billion of stock. Whilst it is accepted that this number is highly approximate, it gives an indication of the financial impact of the research described in this case-study. It is difficult to estimate the environmental benefit of the associated reduction of inventory obsolescence, although this should be considerable. Excessive slow-moving stock is most prone to obsolescence and to the concomitant waste of resources in making goods that are never used.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Review and Critique of Syncron Demand Forecasting and Stock Replenishment Planning Software. GC Karakostas, 2002.
2. Enhancement of Single-Level Forecasting Software Module. GC Karakostas, 2002.
3. Boylan JE, Syntetos AA, Karakostas GC (2008) Classification for forecasting and stock-control: a case-study. Journal of the Operational Research Society, 59, 473-481.
4. Letter from Managing Director, Syncron UK Ltd, 19 November 2013.
5. Development of a theoretically consistent, scientifically based and systematic demand forecasting system (Final Report for Manugistics), John Boylan, 2002.
6. Email from Vice President, Product Management, JDA Software, 14 October 2013.
7. Syncron Supply Chain Inventory Management. Inventory Management Software. www.syncron.com/en/Solutions/global-inventory-management
8.. JDA Demand Management Brochure www.jda.com/company/display-collateral/pID/488/
9. Supply Chain News: Inventory Performance 2011 (Supply Chain Digest 22/7/11) www.scdigest.com/assets/FirstThoughts/11-07-22.php?cid=4759
10. Defense Logistics Agency, Annual Financial Report, Fiscal Year 2012 (Unaudited).