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Simulation down under

Matthew P. Pepper
University of Wollongong, pepper@uow.edu.au

Trevor A. Spedding
University of Wollongong, spedding@uow.edu.au

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Abstract

This paper provides a brief literature review of the current applications of simulation in Australia. The paper identi-fies areas that use simulation modeling and dynamic tools for growth and improvement, while also highlighting opportunities for future applications of simulation. The simulation applications highlighted in this paper are focused on some of the most significant issues facing Australia today.

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SIMULATION DOWN UNDER

Matthew Pepper
Trevor Spedding

School of Management and Marketing
University of Wollongong
Wollongong 2522 NSW Australia

ABSTRACT

This paper provides a brief literature review of the current applications of simulation in Australia. The paper identifies areas that use simulation modeling and dynamic tools for growth and improvement, while also highlighting opportunities for future applications of simulation. The simulation applications highlighted in this paper are focused on some of the most significant issues facing Australia today.

1 INTRODUCTION

Given an abundance of natural resources, Australia provides a rich environment for manufacturing and agriculture. The commodity market has been a dominant presence, and remains one of the most important industries in the country. From a more holistic approach, with globalisation increasing competitive pressure, simulation provides an essential strategic tool for organisations to embrace.

The constant pressures experienced by almost all industry sectors to remain competitive are well documented. The onset of globalisation and increasing oil prices means that Australian organisations must constantly review their strategic direction if they are to hold on to their market share. Given the potential of simulation modeling as a decision support tool to inform and perhaps underpin this constant strategic outlook, there is still a long way for it to go, before its potential is fully utilized..

This paper presents a brief literature review of the state of simulation in Australia, across a variety of applications (such as manufacturing, healthcare and agriculture), while loosely following the format of a typical supply chain, in order to present to the reader an overview of applications from all tiers of the chain from raw materials production through to the logistics function. Applications of the simulation models presented in the literature review represent some the most significant issues facing 21st century Australia together with some of its national obsessions. These include the environment, healthcare, ageing demographics the migrant workforce, and sport.

2 APPLICATIONS

2.1 Manufacturing

There is a long history of manufacturing in Australia. Like many countries in the late twentieth century Australia has found it difficult to compete against the quality and cost of imported products, however a vibrant manufacturing environment still remains in many areas. Whilst steel making is now declining there is still a significant steel making facility in Wollongong in New South Wales. Car manufacturers such as Ford and Holden (General Motors) make cars for the local market and the Australian Government has recently made a large investment in a manufacturing plant to make a hybrid Toyota car.

The work of Jenkins and Chapman (1998) explores the process of adoption for discrete event simulation, and provides a framework that "*can be used to explain the process of adoption of DES by managers in the operations management function*" (Jenkins and Chapman 1998) using a number of Australian organisations from a variety of industries.

This framework provides a useful tool for organisations looking to embrace simulation, especially for those industries such as mining, that were previously used to more "*ad-hoc methods for planning and operating*"(Hoare and Willis 1992) . Iron ore is a significant export commodity for Australia (Everett 1996), so simulation studies in this area make a large impact on the industry. Hoare and Willis (1992) describe how simulation software was successfully used to demonstrate increases in production and the removal of inefficient activities that generated larger profits for a large ore mine in Australia. Everett (1996) extends this study further along the supply chain, successfully using simulation models to determine the optimum "*stacking and recovery of iron ore … at the port prior to shipment*" (Everett, 1996), in an effort to reduce the disrup-

tion caused by the frequently changing percentage content of elements within the raw material.

Moving further along the supply chain, the manufacturing function has provided solid ground for the use of simulation on Australian turf. Simulation has been used by practitioners to solve a variety of manufacturing problems. Welgama and Mills (1995) use SIMAN simulation language as a design and analysis tool for Just-In-Time (JIT) systems within the chemical industry, comparing alternative cell designs and strategies to estimate utilization levels of employees and gain system stability. Letjtman et al. (2002), use simulation to validate scheduling and machine layout improvements proposed through the application of JIT and Group Technology theory, while Chan and Smith (1993) explore the modification of existing systems, successfully improving a welding assembly line in a JIT environment. Mane et al. (2002), use discrete event simulation to model the operations of an automotive supplier, optimizing production sequencing. Cave et al., (2002) investigate the use of a Simulated Annealing approach to schedule optimization, successfully proving that this approach can be used. Yuan et al., (2004) go on to consider the total set-up costs incurred for a range of production schedules within a metal casting company, identifying the optimal sequence of events to incur the largest saving. Creighton and Nahavandi (2002), developed a reinforcing learning agent for the purpose of improving scheduling and operating policies within a stochastic serial line, using this to investigate means of reducing the time required to "*create and implement an agent"* (Creighton and Nahavandi 2002) .

The use of cross-entropy has been used to investigate a number of different applications, such as model-based clustering analysis (Botev and Kroese 2004), the estimation of buffer overflows in queuing networks (de DeBoer and Kroese 2002), as well as the design of algorithms for *"Multiple Instruction Multiple Data distributed memory machines using Message Passing Interface library routines"* (Evans and Keith 2007).

Areas of application are also diverse, with studies across industries such as chemical processing (Welgama and Mills 1995), automotive (Chan and Smith 1993, Mane et al. 2002), metal casting (Yuan et al. 2004), batch manufacturing (Gunn and Nahavandi 2002), frozen food, and healthcare (Jenkins and Chapman 1998). Associations such as the Simulation Industry Association of Australia (SIAA) (www.siaa.asu.au) and the Modelling and Simulation Society of Australia and New Zealand (MSSANZ) (www.mssanz.org.au) provide forums dedicated to the advancement and dissemination of simulation use, research and development in the antipodes.

One of the most significant problems facing Australia is in the area of logistics, distribution and transportation. One historian (Blainey 1977) described the problem of developing an effective and efficient industry as the tyranny of distance. The continent is huge and sparsely populated with much of it's population distributed around the south-east coast. It is not surprising therefore that there have been several major simulation studies focusing on logistics and the supply chain. Work by Kozan (1997) for example explored the efficiency of container terminals. Taking a more holistic view to transportation networks, public transport (Currie et al. 2007) has also provided a focus, with a comprehensive funding initiative to "*develop a national repository for computer modelling and simulation tools for the Australian rail industry*" (Anonymous 2003a) being implemented.

Australian Air Services and the University of New South Wales are working jointly on a project which will result in the development of Air Traffic and Operations Management Simulator (ATOMS) (Kelly 2008).

2.2 The Environment

Expanding the scope of thinking beyond the supply chain leads the consideration of the environmental impact of any industrial endeavors. The environmental issues are a major concern in Australia. One of the first acts of the new Australian Government was to sign up to the Kyoto agreement. Lack of water, bush fires and pollution remain a very significant issues for the government, industry and community. These concerns have led to several simulation studies on the climate and it's effect on the environment.

The general impact of a doubled CO_2 content on the potential of bush fires was investigated in Williams et. al's 2001 paper. They used a climatic model based on a 43 point grid system which covered Australia's landmass to simulate the sensitivity of fire to an increase in CO_2. Another paper, typical of work in this area, by Tindall et. al (2006) explores the problem of predicting the characteristics of Australia's ongoing drought. In this study analyses patterns of various atmospheric fields are used to simulate local rainfall spatial variability.

In their 2002 paper Hensher and Ton introduce a Transportation and Environment Strategy Impact Simulator (TRESIS) a decision support system for planners to predict the strategic and environmental benefits of transport strategies. TRESIS, a static behavioural model is based on a system of spatial location travel and vehicle choice models.

Barry (2006) simulated the effects of how roadways pollute stormwater by actually pumping water onto roadways and measuring the pollutants in water samples.

Lau and Nath (2000) simulate the El-Nino Southern Oscillation (ENSO) to characterise the variability of Asia-Australian Monsoons based on an Atmospheric general circulation model (GCM) and Whetton et.al (1996) observed climatic data of the snow-cover of the Australian Alps and combined their study with a scenario analysis to predict the effects of climatic change.

The development of a model using bioeconomic simulation for improving irrigation scheduling decisions and the adoption of more efficient irrigation systems is explored by Brennan (2007).

2.3 Economics and Commerce

Another significant problem facing Australia is the management and support of its population which, is diverse in terms of culture, skills and geography. There has therefore been several economic models developed to study the problems associated with the population. These are usually in the form of econometric studies which the authors describe as simulation studies because of their dynamic nature and the potential to perform scenario analysis.

Shepard and Dixon (2002) develop a series of simulation experiments where ***national unemployment*** figures form a model which characterises the relationship between regional and national unemployment in Australia. The model is based on a regressive time series model.

Creedy et al. (2003) simulate a structural change in the ***means benefit system*** to show how Non behavioural and behavioural simulation studies were carried out using the Melbourne Institute Tax and Transfer Simulator (MITTS). By flattening the current tax structure the authors show how government expenditure would be lower for couples but higher for sole parents. A similar team of authors (Creedy et al. 2006) focus on sole parents in their 2006 study by using a microsimulation based on a pseudo distribution of income levels. They conclude that even if sole parents could move back into the labour market they would be significantly worse of than remaining under current welfare system.

Lixen et al. (2006) develop a behavioural tax microsimulation model to investigate the implications of ***population ageing*** on government expenditure and revenue. They conclude that the cost of social security will increase whilst the revenue from taxes will decrease. They suggest a reduction in the taper rate system which will be less costly in the older population. A simulation study by Guest (2005) also explores the issues of an ageing workforce.

Kalb and Lee (2007) develop a policy simulation to quantify the effect of ***childcare subsidy*** on labour supply. The paper effectively illustrates how an extended childcare subsidy proposed by the Government in 2006 can be evaluated using a micro-simulation model.

Throughout its recent history the basis of Australia's development has been it's multicultural society. Since the second world war alone 5.7 million workers have arrived in Australia with permanent ***migration*** visas. (Australia's current population is around 20 million). Chang (2004) develops a simulation model to investigate the effect of immigration on the wage differential between skilled and unskilled workers. The analysis is based on a dynamic inter-temporal general equilibrium model and concludes that there is evidence that immigration exerts a significant downward pressure on unskilled wages.

Miller and Neo (2003) also conduct an analysis of the earning of immigrants, this time in a comparative study. Simulating a number of alternative scenarios they conclude the wage differential between ***immigrants*** and natives is greater in the USA than in Australia during their first year. However in subsequent years the flexibility of the labour market in the USA allows more rapid wage growth for immigrants than in Australia, and therefore conclude that American immigrants progress faster than their Australian counterparts.

Because of its geographic isolation import, export and trade are particularly important issues in Australia. Sirawardana (2007) simulates the impact of the ***Bilateral Free Trade*** agreement between the United States of America and Australia. The simulations are conducted using the Global Trade Analysis Project (GTAP). By simulating the GTAP multi-cultural computational general equilibrium (CGE) model, the authors conclude that the removal of trade tariffs will result in more substantial changes in Australia when compared to the USA but overall, both countries would experience significant growth in a number of sectors.

Other applications of simulation in the commecial environment include the following: Brands and Gallagher (2005) simulate performance and diversification properties of ***Fund-of-Fund (FoF) portfolios*** and show that on average increasing the portfolio will increase volatility whilst the mean return remains constant.

Bendall and Stent (2005) develop a stochastic simulation based on Real Option Analysis (ROA) to determine the flexibility of strategies available in management decision making. The methodology and sensitivity analysis is applied to a venture using new technology in ***shipping: a proposed investment*** in an express liner service using high speed container ships.

Alcock and Docwra (2005) utilise a stochastic address model of broadcast oligopoly markets to analyse the Australian ***broadcast television market***. The authors investigate the effect of a single government participant in the market. The simulation analysis concludes that their presence can positively improve the outcomes for viewers and further scenario analysis shows that privatisation will reduce choice and diversity and additional private market participants would not significantly benefit viewers.

Lightbody (1997) outlines the details of *a* ***factory simulation for teaching*** the principles of Management Accounting. The activity based learning exercise exposes the students to a manufacturing environment where they are able to experience various management accounting techniques such as single costing, job costing, process costing and activity based costing etc.

2.4 Healthcare

There are some unique issues surrounding healthcare issues in Australia. The current system is a mix of private and public funded healthcare which the significant challenge of serving remote communities in much of regional Australia. Surprisingly simulation studies in this area are nowhere near as well developed as comparative studies in the United States.

Mui (1999) uses microsimulation and Monte-Carlo simulations techniques to investigate coronary heart disease history over time in specific locations in Australia. The model predicts a decline in coronary heart disease results by 2014, however once the ageing population is taken into account the results predict that the number of hospitalized coronary heart disease patients will rise significantly.

A simulation model based on a 3D animation of a human spine has been used to reduce spinal injuries by estimating safe carrying loads (Anonymous 2003b).

2.5 Sport

Perhaps the national obsession in Australia is sport. It is not surprising therefore that there has been several serious simulation studies focusing on sport. Willis and Terril (1994) used simulated annealing to schedule the Australian State ***Cricket*** Season in a project carried out in collaboration with the Austrian Sport Cricket Board.

Gray et al. (2005) use a predictive model to simulate and therefore examine the effects of the ***Australian Rules Football*** (AFL) gambling market. The strategy proposed by the probit model in the paper will result in the gambler doubling his initial bankroll every 1.2 seasons.

Madden (2006) uses a Computable General Equilibrium model (CGE) to investigate the consequences of hosting mega sporting events such as the ***Olympic Games*** or Soccer World Cup. Using the Sydney Olympic Games as an example they conclude the contrary to popular press reports there is no significant economic advantage in hosting such events.

CONCLUSIONS

This paper has demonstrated the diversity of simulation applications in Australia. Although there has been limited examples of discrete or continuous simulation in its purest forms, many applications of dynamic or stochastic models have been successfully applied to a range of topics. Significant contributions including manufacturing, the environment, healthcare, economics and commerce illustrate the practical benefits simulation studies can provide to real problems. This literature survey has underlined how simulation modeling in all its various forms is a powerful tool for analyzing some of the most critical problems facing 21st century Australia.

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AUTHOR BIOGRAPHIES

TREVOR SPEDDING is the Head of School of the School of Management and Marketing and Deputy Dean of the Faculty of Commerce at the University of Wollongong, Australia. His research interests are in simulation, operations, supply chain analysis and modelling.

MATTHEW PEPPER lectures within the School of Management and Marketing at the University of Wollongong, Australia. His research interests lie in operations and supply chain analysis and modelling.