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THE PROCESS OF ADOPTION

Roger Jenkins

Faculty of Business
University of Technology, Sydney
AUSTRALIA

Ross Chapman

Faculty of Business & Technology
University of Western Sydney, Macarthur
AUSTRALIA

ABSTRACT

A model is proposed which identifies factors associated with the adoption of discrete event simulation and places them within an explanatory framework. The model proposes four main states in the adoption process; separate, linked, activated and adopted. The model develops a coherent view of the interaction between the states and linking mechanisms, implementation mechanisms and the adoption advantage, and this is illustrated through the use of material from four organizations.

1 INTRODUCTION

MS/OR literature has reported results on many surveys of practitioners and managers on the factors which influence the adoption of MS/OR techniques, including discrete event simulation (DES). Much of this work has reported on the barriers affecting adoption, but has not placed these factors in a conceptual or explanatory framework. One of the most influential models in the area of Diffusion of Innovation (DOI) was published by Rogers (1995) who identified a number of factors which influenced the likelihood of adoption, with the most important being the perceived attributes of innovation. He also included factors relating to the nature of the innovation decision, communications channels, nature of the social system and the extent of change agents promotion efforts. Newell, Swan and Clark (1993) propose a Decision Episode Framework which places the innovation, suppliers and the users in a particular influence/relationship structure. The model proposed relationships between multiple factors influencing adoption and also provided some explanatory power to the process.

This paper proposes a model which can be used to explain the process of adoption of DES by managers in the operations management function. The model is grounded in the existing work on DOI, but also, in a manner similar to Padmanabhan and Sounder's (1994) work on diffusion of innovation, is strongly influenced by approaches which have had powerful explanatory power in the area of the physical sciences.

This paper, furthermore suggests that there is a need for more effective theories in the area of diffusion of innovation with particular emphasis on DES. The rate of adoption of DES by the manufacturing community is still surprisingly low. Hollocks (1992) reports an awareness, among a group of UK manufacturers, of about 55% for simulation which fell to about 10% when the interviewee was asked to name a package. In the same report Hollocks also reported that there were potential benefits of £300M per annum which could be realized in the United Kingdom. Similar data does not exist for Australia, but sufficient work has been done to establish that manufacturing in Australia is under constant pressure and should achieve proportionate benefits from tools which could facilitate better decisions. The low levels of awareness, the low levels of adoption, combined with potential adopters who are constantly under pressure to improve performance suggests that it is important to understand why rates of adoption are so low and to improve the methods available to facilitate adoption where appropriate. Existing approaches evidently have not enabled this outcome to be achieved.

2 DISCUSSION OF THE MODEL

The model postulates two agents, the innovation and a potential adopter. In the process described here the innovation and the potential adopter can exist in one of four states, separated, linked, activated or adopted. This can be presented as shown in Figure 1: Process of Adoption.

The model enables many factors identified in the literature to be organized within these four states and to be categorized as transition factors which influence the process as the system makes the transition from one state to the next.

2.1 States

The model proposes that the system will exist in one of four states. It is likely that there will be some iteration between the final two states if the technology is expanding within the function, requiring the development of acceptance within client groups not part of the initial adopting group.

2.1.1 Separate

In the separate state the innovation and potential adopters are cognitively isolated. Neither agent is aware of the presence of the other agent.

2.1.2 Linked

The potential adopter is aware of the presence and status of the innovation. The transition from separate state to linked state requires the intervention of linking mechanisms. The potential adopter may not be aware of the full potential of the innovation in the environment of the potential adopters organization.

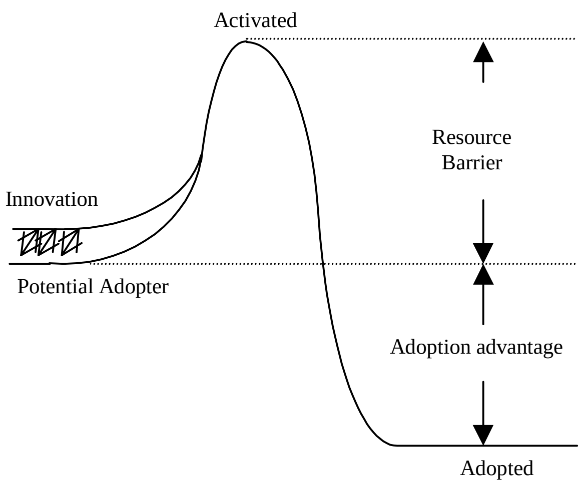

Figure 1: Process of Adoption

2.1.3 Activated

In this state the innovation is actively applied to some internal process of the potential adopter. The effective application of the innovation in this state will require the application of unusually high levels of resources. From this state the innovation is likely to be adopted if the adoption advantage is sufficient. If the adoption advantage is not sufficient then the two agents may revert to a linked but not adopted state.

2.1.4 Adopted

If conditions are appropriate the outcome of the process is a state where the innovation is adopted by the potential adopter. The adopted state will be characterized by two variables, belief and behavior. The managers in the unit will have declared in some form that they believe that DES is an appropriate technology for some situations. This belief will need to be combined with behavior which demonstrates acceptance of the technology. This behavior will be a financial commitment to the technology in the form of either the purchase of a software package, or the payment of a consulting fee for the preparation of a model which has been used to inform a decision in the function.

In the adopted state the technology will have been accepted in the decision making process for at least one area of strategic decision making in the operations management area. The technique should have been used at least once and there should be ready acceptance for the proposition that it should be used again for decisions in the same decision area. This could for example be in the area of production planning and control, evaluation of capital decisions or in the area of workforce planning. The technique is of course applicable across many areas of decision making (Robinson 1993, Pierreval & Caux 1996) and acceptance in one area may lead to acceptance across other decision areas, but for the purpose of these cases acceptance in one decision area will be deemed to constitute adoption for that unit of analysis.

2.2 Transition Mechanisms

These mechanisms facilitate or enable the transition from one state to another. This model identifies linking mechanisms and implementation mechanisms as important factors in the process of adoption.

2.2.1 Linking mechanisms

These factors enable the system to make a transition from the separate state to the linked state. Two perspectives influence this stage of the process, internal factors and external or environmental factors. The traditional perspective is that of the potential adopter. Much work on the identification of applications of MS/OR techniques and DES have noted that the adoption diffusion process is influenced by the simple lack of awareness of the innovation by the potential adopter. Factors which can influence this state include the impact of new people joining the organization with knowledge of the innovation (Utterback, 1994) depth of knowledge resources in the company (Dewar and Dutton, 1986) or the presence within the company of a boundary spanning individual (Tushman and Scanlon 1981, Robertson et al 1996).

Elapsed time since development of the innovation has also been identified as a factor which can influence the state of awareness of an innovation (Holek, 1988). DES is now a technique which has been in existence for 40 years. The simple passage of time is not going to explain an increase in the level of awareness by operations managers of this technique, any impact in this area is now going to be explained by specific events such as new promotion channels or improved penetration at the educational level.

Awareness of the innovation is generally presumed to be a positive influence on adoption. Geoffrion (1992), however, proposed that managers should not be focused on technique, they should be more concerned with process outcomes rather than the means used to achieve them. While top management support is generally accepted as being critical to adoption it is not clear whether this relates solely to their sponsorship function or to sponsorship and linking (see section on Implementation Mechanisms). The role of the boundary spanning individual is important if top managers are seen as sponsors with a bias to outcomes rather than to technique. The boundary spanning individual will be expected to have a technology bias, with sound process knowledge and to have the respect of individuals in the function across a range of roles. Actions of external agents will also influence the process.

The literature has recognized at least four important environmental factors which influence linking: external organisations, consultants, external sponsors and other visible adopters. The role of external organisations is important. Swan and Newell (1995) found that the APICS and CAPICS Societies (production and inventory control societies in the United Kingdom and Canada) played important roles in the diffusion of MRP technologies in the manufacturing planning and control strategies of organizations in those countries.

Consultants also provide an important mechanism which can establish links between innovations and potential adopters. This individual performs a similar role to the boundary spanning individual, but is external to the organisation. There are however, some important restrictions associated with the role of consultants in diffusion of innovation. Limitations related to competence of the consultants, a bias to a limited set of technologies and a user pays relationship can lead to inappropriate or poorly supported linkages which may conclude unsatisfactorily (Bessant and Rush, 1994).

The presence in Australia of external sponsors which are government supported should also be an important factor. Groups such as the CSIRO or AusIndustry can provide links between technology and potential adopters and this is observed in the recent support and dissemination of the business networks technology which has been promoted as an industrial strategy in Australia in recent years.

The fourth external linking mechanism is the presence of visible adopters. The importance of visible adopters is widely recognized as an important factor in the diffusion of innovation (Rogers 1995, Sanchez 1991, Holek 1998). Visible adopters will at least facilitate an awareness of the innovation and as this is one of the most commonly cited barriers to adoption it is clearly an important factor

2.2.2 Implementation Mechanisms

These factors influence the transition from the linked state to the activated state. This paper identifies the factors of sponsorship, perceived complexity, risk and adoption advantage as influencing the implementation transition.

The presence of sponsorship is reported as having significant impact on the diffusion of innovation. Sponsorship can be from senior management within the organization, or it can be from professional external organizations or it may be supplied by vendor organizations. The support of top management is noted by Wisniewski et al (1994) who reported that 78% of the respondents to their survey cited support of senior managers as the key factor in the adoption of quantitative techniques within the firm. The presence of support by senior management will be a critical factor in making the transition from linked to activated, but the grounds for the support may be complex and dependant on a range of factors beyond the view of the researcher or proponent or the technology. Sponsorship by professional organisations is able to have a significant impact on the height of the adoption barrier. The active role played by groups such as APICS and CAPICS in the promotion of MRP enabled isolated practitioners to observe adoption processes in other organisations, to be placed in contact with suppliers and to be given ‘moral’ support for a particular innovation. These groups can also provide supporting infrastructure in the areas of training and benchmarking for the innovation. Support by vendor organizations can take the form of the provision of training such as offered by Witness and ProModel in the use of the technology, but the cost of this type of support may not lead to a net reduction in the overall level of the barrier.

Perceived complexity has been noted as an influence on the adoption process by Rogers (1993). Surveys have also noted barriers to adoption related to the inability of experts to communicate in language which managers could evaluate (Kathawala, 1988). This behavior will lead to a perception of complexity on the part of managers if the promoters of the technology do not explain the technology in the language of the managers. Gaither (1975) noted that the skills of users and modelers was often cited as being inadequate, and this will also lead to a perception of complexity by the potential adopters.

The presence within the organization of engineers or specialists has also been identified as an important factor in the successful adoption of innovation and also for the propensity to innovate (Dewar and Dutton 1986, Sanchez 1991). Frankel (1990) refers to a similar property of the organization when proposing that the absorption capacity for the innovation and resources available to transfer the technology were important factors in the diffusion and adoption of technology.

The nature of the problem will also have an impact on perceived complexity. A contained engineering problem, dealing with inanimate engineering systems is likely to display lower levels of perceived complexity than a highly interactive scheduling process which requires support of people at numerous points in the process, such as the emergency ward of a hospital (Jenkins, Deshpande, and Davison 1998). For DES, a simple problem may require a simple model, a complex problem may well require a complex model.

The scope of DES software is wide and is increasing. Issues of complexity are based on the package selected. Even for the case of four simulators used by Banks et al. (1991), there were variations in feature complexity and this was for only a very small subset of the complete field. The authors of this study did suggest however that the ability to drive these packages could be gained in a relatively short time. Complexity of the technology is very much a selectable aspect. For DES, complexity is very dependent on the number of features available within the programming medium. The impact of perceived complexity then for DES is likely to be primarily a function of the nature of the problem and the absorption capacity of the organization rather than the nature of the technology. The most significant impact on perceived complexity will be the presence of engineers and specialists within the organisation with the training and time to master the technology.

The adoption of the innovation will usually require some expenditure on purchase and installation charges. Costs and costs/benefits have been reported as barriers to adoption of quantitative techniques by Gaither (1975), Hollocks (1992), and Sanchez (1991). The acceptance of these costs will be facilitated if the benefits of adoption are observable in other adopting organisations. Rogers (1995) has identified the observability of an innovation (when adopted) as having a significant impact on the diffusion of the innovation. If the innovation is able to be observed, then the level of perceived risk will be reduced for the manager making the adoption decision. Finally the capability to trial the innovation inside the organisation is also an effective means of reducing risk (Rogers 1995). The final state of the process outlined here is influenced by a number of factors, but adoption advantage must be perceived if the adopted state is to be robust.

2.2.3 Adoption Advantage

If the adoption of an innovation does not provide a perceived advantage for some part of the organization, then it is unlikely to be robust. The innovation must provide and communicate a benefit to the organisation and its managers, in the value system of the managers.

In the area of MS/OR techniques, including DES, the importance of adoption advantage has been identified in numerous studies. Achieving this advantage will be more probable if the organisation has sufficient size to provide the magnitude of factor prices to support the overall cost of the innovation (Frankel 1990, Dewar and Dutton, 1988. Robertson, Swan and Newell, 1996). And it is not sufficient for the model to solve a problem which is important to the modeler. A frequent problem cited for MS/OR techniques is the unwillingness, or inability, of the expert to speak in the language of the manager, or to model problems which have sufficient complexity to reflect the real world which contains the problem of interest. (Cocciari, 1989, Gaither, 1975, Kathawala, 1988, Geoffrion, 1992). The model must meet the needs of the manager who has the responsibility for the process which is being modeled, and the modeler must accept the criteria which the manager will use to judge the value of the model to the organization.

A further problem noted with MS/OR techniques, and this would certainly apply DES, is that the model takes too long to develop. (Gaither 1975, Hollocks 1992). In material used to support the Witness package the company cites a range of models developed in the Rover organization which took a matter of days (at most) to develop, but in a wider survey of practitioners it was found that most models take one to three months to complete and normally require more than one person week (but less than three person months) of work (Cochran, Mackulak and Savory 1995).

3 CASE DESCRIPTIONS

The following sections describe aspects of the application of DES in a range of Australian organizations. The cases are located in the frozen food industry, the fabricated metals industry, engineering process design, health care and one vendor organization. The cases are briefly described using a format related to the model proposed in this paper. A summary of the key attributes of each case is presented in Table 1: Summary of Case Material.

3.1 The vendor organization

This organisation has offices in a number of Australian cities and is an agent for a widely used simulation package. The organisation has chosen to market the product mainly through the inclusion in trade journals, in the manufacturing sector of brief case studies and notices of in house seminars on simulation. The response to these marketing tools has been quite significant. It has done some minor marketing through professional bodies such as the Institute of Engineers, however it feels that there may be a level of reluctance on the part of these bodies to become too closely associated with vendor organisations. It also is active in a number of exhibitions held in the region. In identifying potential adopters, it regards size as critical. If a company is less than $A100M turnover it is unlikely to be an adopter.

Generally the vendor is able to make its first contact with the potential adopter through individual engineers or technically orientated people. It then prefers to reach senior managers with financial approval authority through these engineers and considers this to be a key part of the process. When asked if they considered the number of engineers as a critical factor in whether the company was likely to be a potential adopter, they responded that it was more likely to be the number of engineers in managerial positions, which would control the probability of adoption.

The company considered the use of small case studies, and success stories to be an important part of the process of activation. Key issues brought out in the cases are the order of return which can be made on some projects, and importantly, the cases described are based on models which were prepared in very short periods of time, compared to the benefits achieved. For the examples based in Rover, models which took eight hours or four hours were cited as having contributed to analyses which lead to savings of £10K to £20K.

3.2 Case 1: Food Processor

This company is a food manufacturing company located in a country city in Australia. The factory is part of a corporation focused on the production and distribution of frozen food. For this company the storage of frozen food is a significant cost, and the quantities of food stored depend on the quality of sales forecast and the assessment of risk of stock out. This application was to improve the assessment of risk associated with different production and inventory policy parameters settings.

The manager had not been aware of simulation technology. He had approached the UTS with the problem and wished to discuss the types of technologies which could assist the company in its response to the problem. The fact that the manager was unaware of the technology could have been partly related to the remoteness of the factory.

The University offered to assign a student for a three month period to develop a prototype model to assist in the decision process and this project was completed in the three months using a standard DES model. The model was able to provide the manager with the outcomes in terms of overall inventory cost and overall reliability of supply, given variance in the parameters of batch size, re-order and manning levels in the factory. The overall benefits which were claimed by the manager in a proposal in defense of the purchase of the package was for an inventory cost reduction of $A1.3M p.a. This was mainly related to the cost of storage required for frozen goods. The actual reduction in capital associated with this inventory was much greater, but not used in the justification. A proposal for the purchase of the simulation software is currently being considered by senior managers in the company.

The trial has enabled the company to explore the potential of this modeling environment at very low cost in either commitment to software purchase or commitment of managerial time and effort. Trialability thus for this company has been an important part of the adoption process. The advantage of adoption has been confused slightly by the manager's assertion that the only problem with the trial has been that the model has already demonstrated the benefits which can be achieved through the proposed changes, and thus the need for the simulation software, or the adoption advantage, in the minds of the senior managers has been reduced. In addition to the simple financial benefits which can be gained through the use of simulation the manager is also claiming that adoption of this technology will give the company a strategic advantage in their manufacturing capability.

3.3 Case 2: Metal Fabrication

This company manufactures sophisticated machinery which is housed in a complex fabricated metal cabinet. The company has sales which exceed $A100M p.a. and the manager, the Manufacturing Director has an engineering background. The manager first became aware of the technology through direct mailout by the vendor company. The impetus to purchase the system was mainly driven by the need within the company to make a decision on a significant piece of NC machinery. The system has been in place within the company for a period of about six months, but very little work has been done with the package. A student from UTS was asked to develop a model of part of the process during the 3 month industry placement, but insufficient experience was available in house to ensure the development of a satisfactory model given the complexity of the system and problem being modeled. One manager expressed the view that, despite the status of this package as a *simulator* rather than a simulation package, the standard vendor supplied training was insufficient to give the managers confidence to start using the system. The system is seen by operational level engineers as complex, and this may reflect the situation where the problem the package has been purchased ‘for’ will probably require a complex analysis-whether by DES or by any other technique the managers propose to use.

3.4 Case 3: Health Care

This case describes the use of DES in the emergency ward of a large metropolitan hospital in the Sydney region. The linkage between the senior manager of the hospital and the technology was again due to a direct contact between the manager and the local university. Certainly it was not surprising to find that managers in this sector are not familiar with this technology, for this particular case the manager was casually discussing means for service level management in the emergency ward with academics who were familiar with this technology. A proposal was prepared by the academics to produce a study of the work at a relatively low cost and this was accepted by the hospital. A decision on whether to adopt this technology has still not been taken by the management of the hospital.

The barriers to adoption for this organisation will lie in the area of capital cost required for the purchase of the technology. The model has taken a substantial period of time to develop, this being a reflection of the extreme levels of complexity of the emergency ward system, grounded mainly in the level of tacit rules which are required to coordinate the various teams of people in the system. A further barrier to adoption will thus also be the absence within the hospital system of people who are able to develop models quickly and reliably. The model in this case was developed by a researcher attached to the University. The perceived level of complexity of the innovation will be high to those managers who wish to look at the structure of the model. Of course, if the manager only looks at the behavior of the animated interface of the model, then the manager may not feel that there is a high level of complexity in the technology. In this case there was very little support from external organisations. The relationship between the University and the chief executive officer of the hospital is the primary factor in explaining the ability of the University to run the trial. If the hospital purchases the software, the trial will have been one of the most important factors in reducing the risk to the hospital of making an inappropriate investment. The hospital will however be challenged as it attempts to internally develop skills and expertise in model building.

4 DISCUSSION OF CASE MATERIAL

4.1 Linking mechanisms

In two of the three cases, and in the vast majority of other manufacturing companies which are linked to our university's student placement program there is no effective knowledge of DES. It is a technology which can be readily demonstrated to potential adopters and with the organizations described in this paper there was ready acceptance of the approach and technology. This ready acceptance is partly a result of course of the beguiling simplicity of the animated

Table 1 : Summary of Case Material

	Vendor	Food	Metal	Health
Linking	Trade journals Conferences Professional bodies Exhibitions	University	Mailout	University
Resource barrier				
Sponsorship		None	Manf. Dir.	CEO
Perceived complexity	Keep the model small with simple graphics	Understood, depends on external modeler	Underestimated, internal resources not adequately prepared	Not appreciated yet
Risk	Will support small trials and promotes visible adopters	Trailed using university support	Risk in capital decision allows acceptance of cost of software	Trialed using university support
Adoption advantage		Significant cost reduction. Improved strategy development capability	Better capital decision	Improved service levels leading to improved funding.
Adoption Belief	----------	Strong	Fragmented	Strong
Adoption Behaviour	----------	Considering	Purchased software	Considering

interface, a simplicity which soon fragments into complexity as the novice modeler starts to confront the tacit detail of the real world.

4.2 Implementation Mechanisms

For the three cases the activated state was maintained with the supply of student or research based support. In these cases, even for the case where the company had made the purchase of the software the activated state required external support. For the functional groups described, the technology had top management support within each of the units of analysis. The top management support was a precondition for inclusion of the technology into the workplace, but it was not enough to ensure incorporation of the technology into the decision analysis process. The resource barrier is dominated by two factors. The simpler is the cost of the technology. Top management support, possibly developed via external organizations and through the observation of visible adopters can facilitate the mounting of this barrier. In the case of the food manufacturer the cost savings which could be demonstrated after a relatively short period of time using student developed models could easily support the expenditure of the required sums on software and supporting systems. The metal fabricator was willing to adopt the technology based on its potential to improve the quality of a significant capital investment decision. The cost of the system is small compared to the cost of the NC machinery, and the system can of course be used for other projects as well. In the health case the benefits have not yet been quantified, but they too, are likely to be much greater than the simple cost of the system.

A more difficult barrier may be the allocation of people with the time and skill to develop useful models. In the cases described here the animated interface demonstrated to top managers within the unit of analysis led to the development of quite sophisticated levels of expectation from the technology. Models developed at this level take substantial amounts of time, and may still not satisfy the manager who is highly conversant with the real system. In the health case the nominated system expert (the prior emergency ward manager) is driven by a need to see the model behave exactly as the real ward behaves, and given the flexibility of the resources and locations in the system this has led to the development of a model with excessive levels of code complexity and consequent verification and validation challenges for the model development team. For the metal fabricator case where the Manf. Dir. initiated the purchase the software has not been used at the engineering level since the purchase. The arrival of one of our students initiated a program which led to the desire to develop a quite sophisticated model with the usual problems of model conceptualization and data capture. The outcome after an effective two months work period was a limited model which was only a prototype of the system which the company engineers were articulating. In both of these cases there was a strong expectation of model similarity with the real world, and consequently a major model development challenge. There is also a tendency to accept existing levels of reference system complexity, with a requirement to include it in the model which while playing to the strengths of simulation (the ability to model complex systems not susceptible to analytical models) may ultimately make the model unworkable. For the food processor the model was conceptualized with a low level of animation with most work required on data file interfacing and relatively simple cost calculations. There were no offers for sophisticated animation and this may have prevented an expectation in this area.

4.3 Adoption advantage

Metals was able to accept the purchase of the innovation based on the potential of the technology to improve a major capital decision it was about to make. Similarly the Food company will find the cost of the system small compared to the savings which will be able to be analyzed with the technique. The Health case may find the decision more complex, and may well use the results of the preliminary model to make changes and then move on to other issues. The first two cases have clear cut financial benefits which can be used to offset purchase costs and the costs of developing and using models. It is unlikely that companies with small size or with few technical staff will be willing to bear the associated costs of maintaining this technology. Size brings the potential of repeated use and costly problems with values which can produce savings which will compensate for the technology. The view of the vendor that a company needs to have $100M in sales before it will be considered a probable adopter would appear to be well grounded. In the food company it should however be noted that the sponsoring manager stood to gain a personal advantage in internal standing and prestige by the mastery of new technology which had the potential to have impact on the company's logistics performance.

5 CONCLUDING REMARKS

Discrete event simulation is a powerful technology and its low levels of adoption by operations managers is a perplexing issue for the proponents of the technology. This model allows a number of the factors which influence the adoption process to be brought together in a coherent manner which will facilitate the development of an improved understanding of the relationship between the factors. The model, as presented here, is at an early stage of development and continuing work with the three companies noted above and others is required to add detail to the interplay of the factors in the process of the adoption of discrete event simulation by organizations.

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AUTHOR BIOGRAPHIES

ROGER JENKINS is a lecturer in the Manufacturing Management Program at the University of Technology.
Major research area is in the role of animated, discrete event simulation in the operations management area. Currently involved in modeling research in organizations in a range of industries including food processing, fabricated metals, specialized engineering, postal services and healthcare. Recent work has focussed in the areas of service delivery in health care organisations and supply chain management.

ROSS CHAPMAN is an Associate Professor and Director of Enterprise Programs for the Faculty of Business & Technology, University of Western Sydney, Macarthur. He holds a BA (Hons), Dip Ed and PhD. from Macquarie University. (Macq.), AFAIM, MRACI, MQSA. His research interests include Quality Management; Continuous Improvement; Innovation and Organisational Change. He is the author or co-author of 1 book and over 30 journal and conference papers in the above areas. He is the Asia-Pacific Regional Editor for Vikalpa - The Journal for Decision Makers, published by IIM, Ahmedabad, India. Editorial Board Member for The TQM Magazine, published by MCB Press, UK