Title: What is it that the application of modelling and simulation can contribute towards understanding and managing service quality data for internet service providers (ISP) in Australia?

Author: Karthik Vilapakkam Nagarajan

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# What is it that the application of modelling and simulation can contribute towards understanding and managing service quality data for internet service providers (ISP) in Australia?

Karthik Vilapakkam Nagarajan
University of Wollongong

# What is it that the application of Modelling and Simulation can contribute towards understanding and managing Service Quality data for Internet Service Providers (ISP) in Australia?

**A thesis submitted in fulfilment of the requirements for the award of the degree**

**Master of Information and Communication Technology- Research**

**from**

**UNIVERSITY OF WOLLONGONG**

**by**

**KARTHIK VILAPAKKAM NAGARAJAN**

**B.E (ECE) UOM, M.Es With Distinction (Comp and Telecommn Engg) UOW**

**Cert IV AWT, CCNA**

**SCHOOL OF INFORMATION SYSTEMS AND TECHNOLOGY**

**2008**

# Certification

I, Karthik Vilapakkam Nagarajan declare that this thesis, submitted in fulfillment of the requirements for the award of Master of Information and Communication Technology (Research), in the School of Information Systems and Technology, University of Wollongong, is Wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualification in any other university or academic institution.

Karthik Vilapakkam Nagarajan

30th August 2007

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**Karthik V.N.**

**(Aug 2007)**

# Abstract

This thesis assesses the appropriateness and effectiveness of discrete event simulation technique to understand and manage service elements in the ISP (Internet Service Provider) context. The baseline for this research involved the secondary data published by ABS (Australian Bureau of Statistics) and TIO (Telecommunications Industry Ombudsman) involving ISP numbers, Internet issues/complaints data. As many relatively new services are being offered, ISPs are finding it difficult to cope with varying customer expectations and their future technology expectancy. Access to infrastructure, avoiding anti—competitive behaviour from large players and service differentiation has become more important than ever for their survival. A number of challenges such as lack of provision of good quality service, lack of ability to cope with increasing (or varying) customer demands and expectations and lack of flexibility in providing services need to be overcome. The service environment in networking has focused heavily on the technical side and very little attention has been given to functional variables such as complaints handling, aligning technical and functional service quality processes and effective service recovery during service failures. Relying fully on the technical side obscures the nature of service. This research identified the fact that end users' perspective of quality of services need to consider not only the inherent quality of the network, but also the service quality provided by the ISP. Users perceive poor service quality provided by their ISP if they do not get help desk support required from using the ISP services. This can turn a complaint about a problem in to a complaint about the company. The research question is answered by this thesis "*What is it that the use of discrete event simulation technique can contribute to the*

*understanding and managing service quality data for different ISP service operations?"*

The research methodology chosen was discrete event simulation methodology. The discrete event technique involves building up models based on the dynamic behavior of a network system as the time progresses. The appropriateness and effectiveness of this technique was tested by modelling technical service elements (modelling policy based networks using differentiated service schemes, alarm based network management system for effective service level agreement monitoring) and key functional elements that determine ISP non-technical service performance (ISP complaints handling, ISP call centre performance variables). The scenarios led to the development of an integrative simulation framework that addresses both user level service quality issues and network system oriented service quality issues. In the past user level service quality issues have been provided with negligible importance. The framework developed can help ISPs to model service attributes and use the results from such simulation studies to make competitive marketing decisions. The issues raised before and after simulation can be compared for effective service design. To achieve service excellence ISPs have to understand the interrelationship between various service quality dimensions such as tangibles, reliability, responsiveness, assurance and empathy and how these dimensions affect customer perception of ISP service quality. In conclusion the research found that discrete event simulation can be used to understand and manage service quality data by internet service providers involving different ISP service operations [1]-[22][23]-[46]

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# List of Acronyms and Abbreviations

**ISP**: Internet Service Provider

**USM**: User Based Security Model

**LCD**: Local Configuration Store

**SNMPv3**: Simple Network Management Protocol version 3

**MIB**: Management Information Base

**RTFM**: Real Time Traffic Flow Meter

**RFC**: Request For Comments

**HMAC**: Hash Message Authentication Code

**MD5**: Message Digest 5

**SHA**: Secure Hash Function

**TCP/IP**: Transmission Control Protocol / Internet Protocol

**CMIP**: Common Management Information Protocol

**LAN**: Local Area Network

**MAC**: Medium Access Control

**UPS**: Uninterruptible Power Supply

**WAN**: Wide Area Network

**RMON**: Remote Monitoring

**UDP**: User Datagram Protocol

**PDU**: Protocol Data Unit

**OID**: Object Identifier

**SMI**: Structure of Management Information

**IETF:** Internet Engineering Task Force

**LDAP**: Lightweight Directory Access Protocol

**DMTF**: Desktop Management Task Force

**DEN**: Directory Enabled Networking

**PING**: Packet Internet Groper

**ASN.1**: Abstract Syntax Notation One

**SQL**: Structured Query Language

**SIMAN**: Simulation and Analysis Language

**PBNM**: Policy Based Network Management

**TSP**: Telecommunications Service Provider

**ABS**: Australian Bureau of Statistics

**TIO**: Telecommunication Industry Ombudsman

**SLA**: Service Level Agreement

**POP**: Point of Presence

**AHP**: Analytic Hierarchy Process

**POTS**: Plain Old Telephone Service

**ISDN**: Integrated Service Digital Network

**OAM**: Operations, Administrative and Maintenance

**OSS**: Operation Support System

**OTC**: Operating Telecommunications Company

**LAN**: Local Area Network

**WAN**: Wide Area Network

**ACD**: Automatic Call Distribution

**CASM**: Computer Aided Simulation Modelling

**CAD**: Computer Aided Design

**ODBC**: Open Database Connectivity

**RED**: Random Early Detection Queue

**VBA**: Visual Basic Application

**OSPF**: Open Shortest Path First

**RIP**: Routing Information Protocol

**BGP**: Border Gateway protocol

# Chapter 1: Introduction

Large IP (Internet Protocol) environments are increasing the difficulty of network management. This has a major impact on an ISPs (Internet Service Provider) ability to meet customer expectations. In the current competitive market it is essential for ISPs to meet customer expectations and win their confidence in order to stay in business [1]-[3]. Meeting customer expectations is no longer simply a competitive advantage but has become an absolute necessity. Current network services management and customer relationship management fail to deliver the expected results due to several reasons. Small ISPs are forced to overcome major challenges like: [3]-[23]

1. Lack of provision of good quality service [3].
2. Lack of ability to cope with increasing (or varying) customer demands and expectation [4].
3. Lack of flexibility in providing services [7].

Failure to cope with these problems results in poor customer satisfaction [7]. Results show that in the past and the present simulation studies have proven to be powerful in forecasting network scenarios and understanding complex network management operations [6]-[9]. Details such as service management statistics, user usage levels, service types for different users, management of user resources and pricing policies can be forecast using such simulation studies [10]-[11]. Such simulation models can also be extended to understand the impact of functional service quality on ISP overall service quality [12]-[13].

## 1.1 Research Aims

This projects aims were to investigate the extent to which such discrete event simulation studies can be used to model functional elements involved in ISP customer service provisioning. In addition, issues which might have positive or negative impact on current customer demands and requirements can also be studied. The research investigated the effect of functional service quality on customer expectations and satisfaction [1][14]-[16].

## 1.2 Research Outcomes and Benefits

The main contribution of this research is the investigation of the impact of functional service quality on small ISP business operations and justification of the appropriateness and effectiveness of discrete event simulation to manage service quality data. It is important to forecast the impact of planned changes on current network management operations and predict if they would have positive (or) negative impact on the current level of customer expectations. This helps network managers to have effective proactive network management strategies.

A service quality simulation study framework, SIMCTS (Simulation Modelling and Analysis of Customer Satisfaction Patterns for Telecommunication Services), suitable for an internal service quality study of planned changes and their impact on current customer expectations and satisfaction levels (possible within an organization) has been developed. The SIMCTS framework is a comprehensive and consistent framework that will help service providers model various service attributes involving ISP network and business operations. This includes ISP call centre operations, complaints handling, network service level metrics (Service Level Agreements Monitoring), differentiated service schemes. The framework is an integrative simulation framework that maps the service quality steps with the simulation modelling and analysis steps to improve the effectiveness of such studies. The main steps include identifying the appropriate service quality data in the model, data collection and analysis, modelling objectives, model coding, experimental factors and "what-if" scenarios, simulation model verification and validation, solutions identification, improvements and recommendations. The framework has been built based on the discrete event simulation modelling and analysis technique. In a network environment it always becomes very attractive to measure and model network operational performance parameters from a regulatory viewpoint. However understanding end users' experience is important for several reasons. This is because the operational parameters collected on various individual network are inappropriate to be used as measures of performance experienced by individual users. End users perception of ISP quality of services is strongly influenced by various factors outside the access network, which includes factors such as ISP behaviour, complaints handling, empathy and responsiveness. Conducting internal service quality simulation studies that involve modelling technical and non-technical service elements can help an ISP identify areas that need improvement and thus avoid exposure to external studies of network services, which Internet Service Providers (ISPs) are not willing to perform for fear of exposing confidential information about their internal policies to external criticism [17]. The framework helps provider model key functional service quality dimensions such as *Responsiveness* (service provider response to customer queries or complaints) and have effective complaints handling procedures that helps them understand and manage customer expectations and perceptions [17]. The key service quality dimensions based on the SERVQUAL [17] model are tangibles, reliability, responsiveness, assurance and empathy.

The benefits from the service provider perspective would be provision of cost effective solutions, which is achieved by modelling various service quality attributes using simulation software and experimenting with different “what-if” scenarios. This equates with a business staying in competition with other competitor businesses. The benefits from the customer perspective would be cost effective technological solutions to problems, variety of choices to choose from, good rapport between customer and service providers and better reflection of expected customer requirements in the solution provided. Together, all the benefits will lead to the establishment and maintenance of a good service provider to customer relationship [18][19].

## 1.3 Research Background

Several lessons have been learnt as a result of the recent decrease in number of service providers in Australia [1][20]-[22][30]. Additional contributing factors include recent mergers and takeovers [7]. Therefore understanding customer expectations and satisfaction levels and providing methods to maximize them becomes highly essential. Consequently investigating if application of modelling and simulation studies can have an impact on achieving improved customer satisfaction levels becomes an important area worth investigating [20]-[24].

## 1.4 Statement of the Problem

There is extensive literature on customer satisfaction for telecommunication services [11][12][15][16][25], such that it is bewildering to make all the choices and know how to proceed. Smaller frameworks are therefore essential in order to model the determinants of customer satisfaction and understand the interrelationship between the service quality attributes required to achieve improved levels of customer satisfaction. Figure 1.1 highlights the research domains involved in this study which include simulation technology, customer satisfaction and service quality in ISP context.

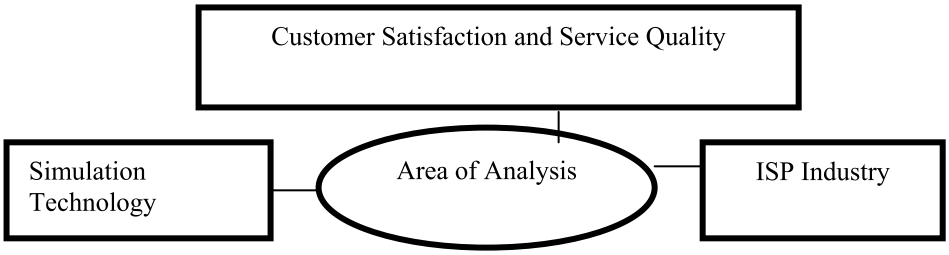


Figure 1.1: Research domains involved in this study

The Australian Bureau of Statistics in its Internet activity Year Book 2003 [59] reported that the number of service providers has decreased dramatically to 571 in March 2002 from 718 in September 2000 [15]-[17][25]-[28]. There is a decline in the number of service providers recorded since September 2000. The number of Points of Presence (POP) declined by 164 over the six month period from March 2002 to September 2002 as ISPs using infrastructure supplied by another provider became more prevalent [20][21]. During this period there was a decrease in number of ISPs by 8, due to mergers and takeovers.

The reason for the sudden decrease in the number of service providers is due to the failure of their services/solutions; much of this failure is attributed to the tough competition from peer ISPs and the inability to provide service as per Service Level Agreements) (SLA) [37][38][41]. This occurs due to the dearth of methods that can predict the impact of new network services and its popularity with customers [47][48]. Simulation studies that would facilitate predictive network management services using a standardised procedure to effectively understand customer satisfaction patterns, will help to provide services beyond customer expectations. Customer satisfaction has become very important in the telecommunications industry as it helps to understand the customer experience when dealing with service providers and serves as a differentiator when customers are selecting an Internet service providers [4] [20]. **Table 1.1** summarizes different ISP types in Australia based on the subscriber size.

ABS. TABLE 1.1: ISP Types In Australia [20].

Please see print copy for Table 1.1

The Telecommunications Industry Ombudsman (TIO) media report [2] shows that city residents are three times more likely to complain about Internet than regional areas of Australia. There were around 38,166 complaints received by TIO [2] in 2003 from major cities in Australia which constitutes 3.15 complaints per 1000 population. It was further stated in [2] that there is an increasing number of complaints from ADSL customers who would like to transfer service to a new provider. Thus, as competition for service quality and price within ADSL market increases, customers are leaving their first provider to seek better deals. This clearly indicates that small and medium sized ISPs need to have a very good customer loyalty and retention program. The TIO[2] report indicates that it continues to receive a steady increase in the number of complaints involving transfer delays and unauthorised transfer . With regard to internet faults the complaints rose by 25% from 472 in September 2003 to 626 in December 2003 [2]. DSL specific fault complaints grew by two thirds [2]. This means small Internet service providers should be able to understand and manage technology specific complaints and provide faster response to their customer complaints.

Increasingly more and more customers look customized service offered by ISPs. Customized services are particularly important for new Internet users who rely on their ISP to solve both technical and non-technical issues. Figure 1.2 shows a steady decrease in the number of very small ISPs between Sep 2002-March 2002 and no noticeable changes between Mar 2002-Mar 2003, a sharp increase since March 2003. Many small ISPs and very small ISPs target niche markets and provide dial-up and broadband services. Small ISP numbers from Figure 1.3 show a sharp decrease between Sep 2000-Mar 2003 and a steady increase between Sep 2003 to March 2005. From Figure 1.4 medium size ISPs show an alternating decrease and increase in number of ISPs between Sep 2000-Sep 2001, Sep 2001-Sep 2002, Sep 2002-Mar 2003, Mar 2003-Mar 2004, Mar 2004-Sep 2004 and Sep 2004 –Mar 2005. From Figure 1.5, large ISPs show an decreasing trend from Sep 2000-Mar 2002 and a slight increase from Mar 2002-Sep 2002. After Sep 2002 there has been a steady decreasing trend until Mar 2005. From Figure 1.6, Very large ISPs show uniform numbers between Sep 2000-Sep 2002 and steady increase from Sep 2002 to March 2005. In general from Figure 1.7, the number of ISPs in Australia has been decreasing between Sep 2000 to Sep 2001 and remained steady between Sep 2001 to Mar 2003, and a noticeable increase from March 2003 to March 2005. The decline in ISP numbers does to lead to a healthy competition as the market has very few players and not many flexible plans for customers to choose from [34][37].

Please see print copy for Figure 1.2

Figure 1.2: A Graph showing the trend in Very small ISP numbers in Australia : Sep'00-Mar'05 Source: [59]

Please see print copy for Figure 1.3

Figure 1.3: A graph showing the trend in Small ISP numbers in Australia from Sep'00--Mar'05 Source: [59]

Please see print copy for Figure 1.4

Figure 1.4: A graph showing the trend in medium ISP numbers in Australia from Sep'00--Mar'05 Source: [59]

Please see print copy for Figure 1.5

Figure 1.5: A graph showing the trend in Large ISP numbers in Australia from Sep'00--Mar'05 Source: [59]

Please see print copy for Figure 1.6

Figure 1.6: A graph showing the trend in Very Large ISP numbers in Australia from Sep'00--Mar'05 Source: [59]

Please see print copy for Figure 1.7

Figure1.7: A graph showing the trend in Total ISP numbers in Australia from Sep'00--Mar'05 Source: [59]

More competition in telecommunications environment leads to a decrease in price and improved service quality through service differentiation. ISPs that went out of the market did not realize the fact that offering attractive pricing deals alone does not help them to survive and that customer experiences and ISP service quality is becoming more important than pricing schemes. Successful ISPs who have grown their subscriber base through mergers and acquisitions have used technology to improve the service experience of customers and provider faster response to their queries [32]. They have also identified the negative impact of technology on attitudes, perception and behavior of customers and that technology should not be used as a substitute for service. Human interaction is central to service encounter and there exists social interaction that underpins delivery of many ISP services. The key challenge here is to achieve service excellence through customer individualization and personalization. The graph in Figure 1.7 highlighting the total ISP numbers in Australia from September 2000 to September 2003 shows a decreasing trend in ISP numbers in Australia, of which most occurred in the small and very small ISP category [20][21]. These statistics act as a base line for this research and helps to justify the fact that small internet service providers are struggling in the Australian ISP industry [44]-[49].

This research focused on small and very small ISP categories as they represent a significant proportion of the ISPs in Australia and statistics show that they are finding it increasingly difficult to thrive in the ISP marketplace [20][21][29]. Anecdotal evidence suggests that the reason for decrease in the number of small internet service providers apart from mergers and takeovers is due to the failure of their services/solutions; much of this failure is attributed to the tough competition from peer ISPs, poor service quality vision, poor responsiveness and the inability to provide service as per SLA . Many new small ISPs have also entered the broadband market with their own unique service selling proposition and targeting niche markets [13][30][33][38]-[40]. The decrease and increase in ISP numbers has to be interpreted in service quality context. The increase in ISP numbers highlights the fact that ISPs are entering the broadband market and focusing on niche market. Service quality becomes essential as providing customized services helps them to grow their subscriber base. The decrease in ISPs during certain reference period highlights the fact that ISPs are struggling to survive and unable to cope with increasing customer demands and expectations. Service quality could be one of the key factors why they were unable to retain their customer base.

*Snapshot of the key issues/problems that are faced by ISPs in Australia are listed below:*

-Small ISP complaints have soared [37].

-Speed and service make up larger proportions of small ISP complaints [37].

-Customer satisfaction, loyalty, retention and service quality has become more important than ever for small ISPs.

-It is becoming increasingly difficult for small ISPs to compete based on price alone and also to distribute interesting contents [34][37]. Access to infrastructure and premium content is important for their survival.

-Integrating systems and domains, maintaining same service levels and support to customers during ISP mergers and takeovers is a huge challenge for small ISPs as many systems are built in-house.

## 1.5 Research Objectives

The main objectives of this project were to investigate the application of modelling and simulation techniques to understand and manage service quality. This was done by identifying the key scenarios that will determine ISP technical and service quality performance and using these scenarios to test factors that affect customer satisfaction and their perception of quality of services provided by the ISP.

**Objective 1:**

Investigation of what effects the SLA will have on customer expectation and customer satisfaction. The importance of keeping up with service levels specified in SLA's and checking the effectiveness of the network alarms in service level monitoring using simulation modelling and analysis. Forecast or predict planned changes and their effects on current network management operations, network resource policies and study if they would have a positive or negative impact on the current level of customer expectations.

**Objective 2:**

Investigate the impact of key service quality dimensions on customer satisfaction, loyalty and retention using discrete event simulation modelling and analysis in ISP context

**Objective 3:**

Investigate the operational benefits that can be achieved by using simulation tools and techniques in modelling service quality elements in ISP call centre context and to come up with a simulation framework for the proposal, evaluation of ISP service quality. To understand service quality issues/problems through internal study of planned business changes using such frameworks and analysing their impact on current customer expectations and satisfaction levels within an ISP organization. These objectives lead to a number of research questions as detailed in Section 1.6

## 1.6 Main Research Question: (related to objectives 1, 2, 3)

What is it that the use of discrete event simulation techniques can contribute to the understanding and managing of the functional service quality data for different ISP service operations?

**Related Research Question 1: (related to objective 1)**

What are the problems encountered in the understanding and managing of service level agreements between customer and service providers for small ISPs?

**Sub Questions: (related to objective 1)**

1.1 How can simulation be used to forecast or predict planned changes and their effects on current network management operations, network resource policies and study if they would have a positive or negative impact on the current level of customer expectations?

1.2 What are the key technical specifications that influence the overall customer satisfaction in a network service environment?

1.3 How can simulation modelling and analysis help Internet service providers to provide flexible service provisioning based on specific customer service needs?

**Related Research Question 2: (related to objective 2)**

What is it that the use of simulation can contribute to understanding and managing key functional service quality dimensions that have a direct impact on customer satisfaction involving ISP operations?

**Sub Questions: (related to objective 2)**

2.1 What can we learn by applying the discrete event simulation methodology to model different ISP service scenarios?

**Related Research Question 3: (related to objective 3)**

What are the benefits that can be achieved by using an integrative simulation framework to model planned ISP business changes involving service quality elements for small ISP sector?

**Sub Questions: (related to objective 3)**

3.1 Why is there a need for simulation framework for proposal, evaluation and decision making of customer satisfaction and service quality for internet services provided by small ISPs?

3.2 How can a service quality knowledge base be established by understanding and managing service quality dimensions?

3.3 What aspects of ISP services can be modelled using discrete event simulation tools and techniques? What benefits can be achieved by conducting such simulation studies?

3.4 What are the key service quality issues that can be identified after conducting simulation studies and the operational benefits they provide for small internet service providers?

3.5 What types of structural data can be used in service quality simulation studies?

3.6 How can we understand and manage the service quality dimensions to achieve competitive advantage?

Table 1.2 below shows the mapping of the research questions with related thesis chapters.

**Hypothesis**

*Discrete event simulation can be used to understand and manage functional service quality data for different ISP service operations.*

Table 1.2: Mapping of research questions to their related chapters

| **Research Questions** | **Thesis Chapters** |
|---|---|
| Main research question | Chapter 1- Chapter 5 |
| Related Research question 1 and sub questions | Scenario 1 in Chapter 4<br>Scenario 2 in Chapter 4 |
| Related Research question 2 and sub questions | Scenario 3 in Chapter 5 |
| Related Research question 3 and sub questions | Scenario 4 and 5 in Chapter 5 |

## 1.7 Research Methodology

The Research methodology process involved two steps:

1. Exploration of a methodology
2. The design of how to conduct the research (using research methods and techniques)

The research methodology chosen is discrete event simulation methodology. This research is also very exploratory in nature and hence all avenues possibly affecting the answers to the questions under study are left open for investigation purposes. By satisfying the research objectives specified, the aim of this research study was to determine whether appropriate steps are being taken by small internet service providers to understand and manage service quality data effectively and investigate the operational benefits that can be achieved by using discrete event simulation technology in this context. In order to meet the objectives of this research study, simulation case studies were conducted to provide insight into the modelling of key service quality attributes that act as determinants of customer satisfaction [34][41]-[43][50]-[70].

In Chapter 1 the separate discussions of this thesis are structured in terms of problems facing the small ISP industry and their impact on ISP business performance. This structure addresses both the technical aspects which is inclined towards optimizing network performance metrics in order to improve network reliability, maintainability and availability and functional aspects which is measuring the ISP service quality by measuring customer expectation and customer perception. Keeping the customers satisfied involves managing both technical aspects and functional aspects in relation to service quality. In Chapter 2 a detailed literature review is conducted on key research domains that are involved in this research and they include customer satisfaction, network service management and service quality. The literature review also includes linking simulation and network management. Chapter 3 introduces the research methodology and a brief literature on discrete event simulation methodology. Justification of the simulation software used for this study has also been covered. Chapter 4 introduces two network scenarios and describes how they helped to achieve the research objectives. Chapter 5 discusses how these scenarios led to the development of SIMCTS framework (Simulation Modelling and Analysis of Customer Satisfaction for Internet Service Providers). The network scenarios modelled using the SIMCTS framework steps are also covered in Chapter 5 . Chapter 6 discusses the research results, analysis and discussion of the simulation studies and how the thesis achieved its research aims and objectives. Chapter 7 presents the conclusion and suggestion for further research.

## 1.8 Significance of this study

The majority of existing research on service quality is system-oriented and minor attention is paid to user-level service quality issues [41]. Customer Satisfaction [37] is either left out or is not given the attention it deserves, leaving many telecommunication network service providers to suffer losses in an increasingly competitive and demanding market where ongoing study of customer expectation and satisfaction is crucial for the survival of their business [43]-[45].

Using customer satisfaction surveys alone do not help providers to understand the key attributes of satisfaction for customers [46]. The attributes surveyed reflect those attributes that are deemed to be of importance to customers. Therefore using the survey alone can mislead providers into believing that satisfaction is achieved by their customer. The service providers should shift their focus from customer satisfaction approach to customer value management techniques and tools. This increases the customer loyalty [47]. Customer value management is "judgement made by customer in mental comparison to the services received from provider and associated cost for service provisioning in respect to that particular provider and its competitors"[47]. Customer satisfaction is a process of measuring satisfaction with service without consideration for assessment of importance placed by customer on each survey attributes [46]. In order to understand and manage service quality in ISP context it is important to focus on some key areas such as network performance, security issues and technologies, contractual agreements and the technical and functional outcome during customer-ISP employee interaction. The service encounter between ISP customer-ISP employee influence the customer perception of ISP service quality and their willingness to participate in the service delivery process. Figure 1.8 below shows the key building blocks of ISP service quality area.

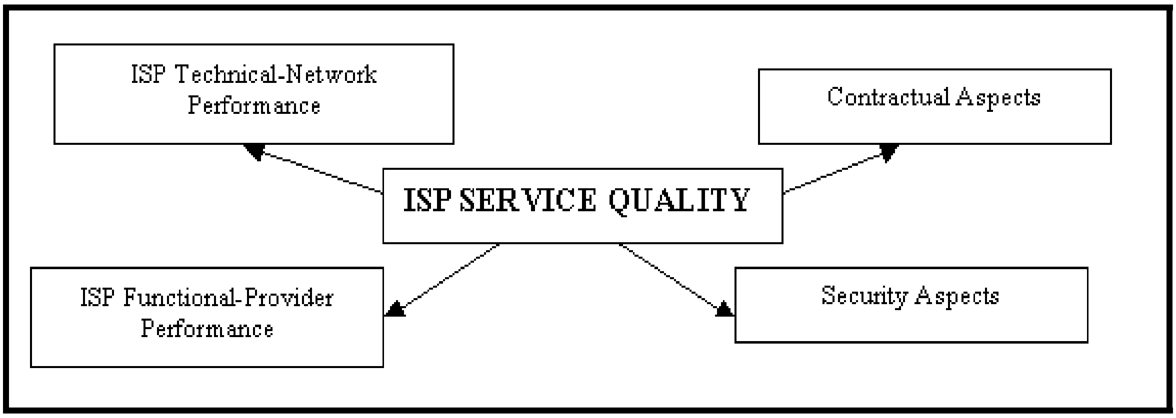


Figure 1.8: Key building blocks of ISP service quality area [1][4]-[5][20]-[23]

The service satisfaction in ISP context involves evaluation of complete service experience. This includes both technical and non-technical service experiences. The majority of customer satisfaction research has focused on satisfaction with telecommunication products and much less work has been performed in relation to telecommunication customers service evaluation [28][32][34][40][45][48]. Applying the traditional approach of service quality such as Expectation Disconfirmation Theory [15] for telecommunications service industry will not be able to capture the multiple comparison activities accomplished with service encounter in which different performance evaluations need to be compared with different expectation levels. Multiple service is encountered by a customer for telecommunication services over time and this has been neglected in the satisfaction theory [48]-[50].

Technical service quality and functional service quality are the two main categories of service quality dimensions. Functional quality is evaluated while service is being performed giving particular attention to the service execution process. It has always been thought in telecommunications sector that technical quality is more dominant in relation to importance than functional quality [46]. Previous work carried out in [135] states that temporary outcome problems in Telecommunications can actually be overcome by high level of functional quality provisions by service providers .

To understand the difference between what types of service dimension the customers are utilizing, providers need to understand the service encounter initiation process where consumer initiate the service encounter to obtain specific technical service (or) functional service outcome. It is very important for service providers to realize that both technical and functional service quality contribute to the overall judgement on satisfaction with telecommunication services. In the lifetime of a customer belonging to the service provider, the service itself will not be permanently tied to technical or functional concerns; instead both services might be demanded by customers based on the circumstances that surround their needs. Thus by considering customer circumstances this approach will help providers set themselves apart from providing general service to concentrate more on individual service provisioning. The service strategy thus requires a continuous face –lift in order to achieve flexible service provisioning process based on specific customer service needs. The specific situation in which a customer complains about a technical dimension to a server demands more responsiveness from the provider, which must heavily rely on the resources available to support this [48]-[50].

The telecommunication industry watchdog, [2], stated in June 2001 that there was a large increase in the number of customer complaints [2][20] received in relation to internet. Some key issues included billing, faults, service provisioning, credit control and contracts. The TIO annual report 2001 [2] stated that a total of 72,264 complaints were received in June 2001 compared with 67,761 in June 2000, and many calls related to internet issues were not dealt with promptly. The increase in complaints means the calls were not dealt with efficiently and ISP staff was not able to troubleshoot customer problems [37]. The same trend has continued through to 2005 which suggests that service providers are not functioning very well in relation to service quality. There was also a sharp increase in the number of complaints involving Internet contracts, customer service and Internet access and speed [2] [46][47]. According to John Pinnock [2] general complaints involve people frustrated by long call waiting times, unhelpful staff and lack of technical assistance. As far as Internet access complaints are concerned speed, connection drop-outs and outages accounted for most problems. There was an increase in such complaints from 26.3% in 2000 to 32% in 2001 [2]. Much of this frustration with Internet access was related to the marketing promises of access speeds made by providers and subsequent failure to achieve those promises. Ninety three percent of the complaints were from residential customers with small businesses making up the balance 7% [2][21][29][37].

In Australia there are more small and medium size ISPs and they constitute 14% of overall subscribers as of Dec 2003 [20]. It is impossible for small ISPs to use the assessment techniques available to large ISPs due to the unique nature of services, different service goals, services quality attributes used as determinants of customer satisfaction and the complex interrelationships and dependencies that exist between them [20][27]. In spite of free deals provided by smaller ISPs, there seems to be a little or no attention on improving customer loyalty and retention [20]. Thus to turn around the losses incurred by small scale providers and make the industry profitable with healthy competition, smaller practical functional frameworks that are evaluated using simulation technology for specific service scenarios are essential. This will lead to correct provision of service quality and accurate modelling of determinants of customer satisfaction [14]-[21].

## 1.9 Limitations of the study

The research was restricted to the ISP industry in Australia and the business performance of this industry. While this may represent the Australian context they may not be totally representative of all types of ISPs and all ISPs throughout the world. The lack of access to ISP industry contacts restricted many industry participants. The case study conducted represented an individual service setting in relation to small ISP scenario. The results from the simulation case study provide a better insight into understanding and managing service quality data rather than providing concrete solutions to handle the ISP industry service quality issues as a whole.

## 1.10 Use of Previously Published Research Papers

The research referred to many materials from research papers previously published in the proceedings of international conferences, national and international journals and chapters in texts. The papers were taken from international conference proceedings, which were peer reviewed. The papers were studied and the materials incorporated along with critical thinking and supporting ideas to make sure the thesis maintains its structural integrity and continuity. The conference and journal papers provided a platform for the thesis and strengthened the actual work carried out as a part of this research.

## 1.11 Publications arising from the research (Refereed International Conference Papers)

1. Karthik Vilapakkam Nagarajan, Peter Vial and Gene Awyzio. " Simulation of Policy based networks through differentiated service levels using ARENA". In Proceedings of the 14th International Conference on Parallel and Distributed Computing and Systems,, Nov 2002, MIT University, Boston, Massachusetts, USA.
2. Karthik Vilapakkam Nagarajan, Peter Vial and Gene Awyzio. "Modelling and Simulation of an Alarm Based Network Management System for Effective SLA Monitoring and Management. In the Proceedings of International Conference on Informatics, July 2003, Florida, USA
3. Karthik Vilapakkam Nagarajan, Peter Vial and Gene Awyzio. "The Use of ARENA Simulation Software to Illustrate Network Operations in an Educational Setting using Case Studies". In the Proceedings of International Conference on Informatics, July 2003, Florida, USA.
4. Karthik Vilapakkam Nagarajan, John Fulcher, Peter Vial and Gene Awyzio. "Application of modelling and simulation to understand customer satisfaction patterns for telecommunication services", In the Proceedings of 6th International Conference on Information Technology (CIT 2003), Bhubaneshwar, Dec 2003, India (Poster Paper).
5. Karthik Vilapakkam Nagarajan, Peter Vial, Gene Awyzio and Srivalli V.N. "Towards Understanding and managing service quality data effectively using SIMCTS simulation framework", In the Proceedings of 9th International Simulation Technology Conference (SIMTECT 2004), May 2004, Canberra, Australia.

6. Karthik Vilapakkam Nagarajan, Peter Vial, Meena Chavan, Tamrat Woldu Tewoldeberhan and Srivalli V.N. " SIMCTS: A Simulation Based Approach to Understand and Manage Service Quality". In the Proceedings of $10^{th}$ International Simulation Technology Conference (SIMTECT 2005), May 2005, Sydney, Australia.
7. Karthik Vilapakkam Nagarajan, Peter Vial, Meena Chavan, Tamrat Woldu Tewoldeberhan, and Srivalli V.N. "Using SIMCTS Framework to Model Determinants of Customer Satisfaction: A Case in an ISP". In the Proceedings of $10^{th}$ International Simulation Technology Conference (SIMTECT 2005), May 2005, Sydney, Australia.

## 1.12 Structure of the thesis

The thesis has seven chapters relating to this study's investigation of modelling and simulation to understand determinants of customer satisfaction and service quality for Internet service providers. The literature review, presented in Chapter 2, presents studies and discussions relating to customer satisfaction, service quality and network management. The nature of relationship between customer satisfaction and service quality in a networking context is studied (some of which have been discussed in this chapter). Chapter 2 also discusses the use of simulation methods to analyse and manage service quality data for customer satisfaction purposes In Chapter 3, the discrete event simulation methodology and research design is presented and includes the objectives of the research, discussion on simulation methodology and justification of the choice of the simulation software. In Chapter 4, the scenarios modelled are introduced and discussed in detail. This chapter also discusses how these scenarios met the related research objectives and mapped with research questions. In Chapter 5, a description of how these scenarios led to the development of the SIMCTS Conceptual framework has been covered The scenarios modelled using SIMCTS steps have also been covered to demonstrate the effectiveness of such frameworks to understand and manage service quality data in ISP context. Chapter 6 reports results of the observations and presents analysis of the research work carried out. It also provides an overview of the study, summary of the results and the finding in terms of the research objectives. It concludes with a reflection on the research design that uses simulation as the methodology for the research topic. Finally Chapter 7 discusses the implications of use of simulation for practice and future research work in understanding customer satisfaction and service quality concepts.

## 1.13 Conclusion

This chapter introduced the research and the relevant background information. The key issues in relation to understanding and managing customer satisfaction and service quality in telecommunications context has been examined in Chapter 1. The research objectives along with research questions and related methodology have been developed in Section 1.5 and 1.6. Justification of the importance of carrying out this research in the current climate has been discussed in Section 1.8. The key limitations of the study along with thesis structure and published papers were also briefly discussed in Section 1.9,1.10 and 1.11. This chapter contributes to the overall thesis as it introduces the research domain and the problem domains and uses the statistics published by Australian Bureau of Statistics to act as a baseline for this research.

# Chapter 2: Literature Review

This chapter presents a review of important literature in relation to topics of customer satisfaction and service quality in network management context. It also reviews simulation and network management and highlights the factors that determine the simulation study's success. The key sections of the chapter include a review of previous research literature of similar studies conducted and evaluating the robustness of some of the popular service quality models for the telecommunications sector. The major service quality issues that need to be handled by small ISPs during mergers and acquisitions are also discussed from the good, the bad and the bottom line perspective. The major problems that face small ISPs are highlighted after conducting detailed literature review.

## 2.1 Background

There has been an increased interest in the application of Quality Management (QM) principles in service organizations [50]-[59]. The service sector in industrialized countries play an important role in the economy and covers a very wide range of organizations such as banking, healthcare, insurance, hotels, utilities, airlines, retailers, consultancy firms, constructions firms, transport and telecommunication firms [50]59]. Service quality can allow an organization to gain a competitive advantage and differentiate itself from others, by improving its service quality [60]-[68]. The role of service quality in any organization is vital, as the organization can increase customer satisfaction, improve sales, and profitability [102] and compete successfully by offering superior service. Customer service expectations are constantly changing and a dissatisfied customer may switch to an alternative service provider.

Until recently, little attention has been paid to quality improvement in service organizations. Most of the research on quality management has been geared towards manufacturing organizations [68]-[88]. The application of QM principles and techniques in service organizations has remained a challenging task. The globalisation of competition in the service industry imposes on ISPs of all sizes the need to become more efficient, more focused on customer demands, and more responsive to changes in their external environments [68][77][78].

Quality management is a comprehensive and fundamental rule, or belief, for leading and operating an organization while aiming at continually improving performance over the long term by focusing on customers while addressing the needs of all stakeholders [104]. Large ISPs generally have a greater capacity to implement quality management initiatives than smaller companies. The implementation of quality management initiatives is an expensive process. While quality management initiatives pay off for most companies, smaller ISPs may be reluctant to risk the resources required to implement a quality management system [102]-[105].

Internet Service Providers (ISPs) have to overcome a number of challenges to stay in a competitive business. These include; the provision of good quality services and solutions, the ability to cope with increasing and varying customer demands, and flexibility in providing services [100]. These challenges can be addressed only if ample time is given to understand the issues involved.

This chapter focuses on understanding of quality of service issues for ISPs. The usefulness of a simulation based approach to analyze and redesign service models for Internet Service Providers (ISPs) is demonstrated in this chapter. The approach aims at providing insight into the uncertainty and interdependences of various service processes within ISP service business set-up. Unlike previous approaches this approach gives full consideration to user-level service quality issues. Various key service quality issues facing ISPs in Australia are discussed and the usefulness of simulation approach is highlighted [88]-[103][105][112][115].

## 2.2 Customer satisfaction and service quality

Understanding how service can be used to differentiate and enhance business-to-business relationships is very important in the telecommunication service industry. The added value that business customers receive by getting into long-term relationships with service organizations comes from superior service and not just from price reductions. Little research has been done concerning how simulations can be used to help the telecommunication industry to know how services can be designed to create, maintain and build relationships between customers and be able to satisfy their requirements and provide good service to them [26]. It is important that telecommunication service organizations understand their customers well through relationship concepts such as length, nature and quality of customer's prior experience with service organizations.

Figure 2.1 highlights the key relationships between interpersonal satisfaction, interaction between inter-organizational satisfaction, perceived value and behavioural intentions

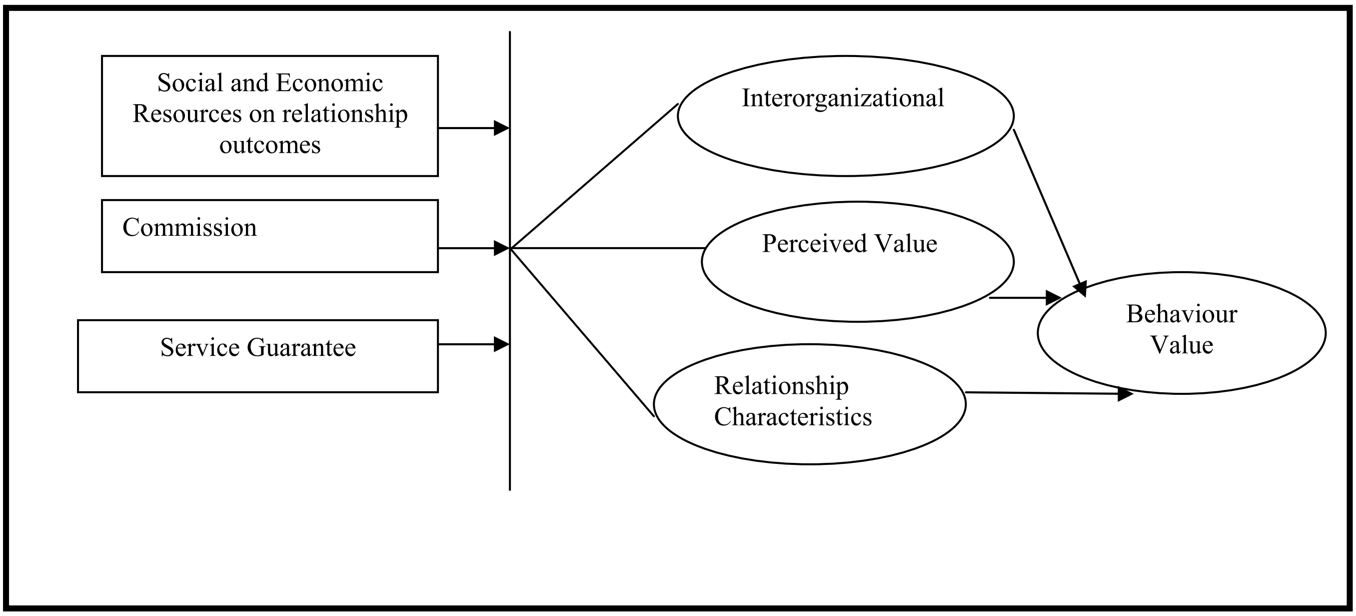


Figure 2.1: Relationships between interpersonal satisfaction, interaction between inter-organizational satisfaction, perceived value and behavioural intentions [21][90][91]

Over time customers who become more experienced and confident in evaluation strategies, give more weight to prior opinion than newly available information. Customers who have long-standing relationships with service providers need fewer social and economic resources to maintain their satisfaction level and their behavioural intentions depend more on attitudes and satisfaction levels . This demonstrates how social and economic categories of service resources influence customer evaluation of business relationships [31]-[33] [103]-[129].

According to [122] social resources are exchanged more than economic resources in personal relationships (service agent and customer) based on resource exchange theory.

Past research work results [122] found that social resources will have more effect than economic resources on interpersonal satisfaction. In terms of inter-organizational satisfaction economic resources will have more effect than social resources. Economic resources have more influence on perceived value than social resource. The findings of [122] also confirmed that social resources influence customer evaluations of business-to-business relationships. Relationship properties such as customer prior experience with service organization will have moderate effect of social and cultural resources on business to business relationships. Interpersonal satisfaction, inter organizational satisfaction and perceived value were found to mediate the effects of social and economic resource on customer behavioural intention.

Thus satisfaction primarily depends on two main factors, expectations and perceptions of service performance. Past studies [31]-[33][85]-[87][90] identified the importance of understating the extent to which customer perceptions and behavioural intentions are associated with actual service performance. These studies highlight the importance of interactive service quality (customer and service provider), service value, interpersonal satisfaction and studies the relationship outcomes. These studies are conducted in various service contexts and service industries with majority conducted across the recreation, transportation and hospitality industries.

Apart from understanding the above concepts and exercising them in the ISP service industry, it is also important to manage key functional elements that determine the internet service providers performance. There are very few studies that relate these concepts within an ISP context [9][103]-[129] . There is an increasing need to come up with effective business models for small ISPs to address key issues related to business efficiency and service differentiation. Business efficiency issues include stiff competition from peers [9], employee motivation and incentives and ISP service efficiency, covering both internal efficiency that is inclined more towards internal ISP service productivity and external efficiency which is customer perceived ISP service quality. Service differentiation issues that need to be addressed are diversity of services and nature of business [103]-[129], flexible service provisioning and service differentiation using a unique selling proposition strategy to identify how their services are unique and also better than their competitors.

Thus in a networking environment where there are numerous services provided based on different technologies, there is an absolute need for ISP staff to be trained and to gain expertise in all technologies and provide good customer support. The business use of simulation technology can help providers to establish an effective business performance model. This is important for the technology intensive ISP industry where there are very specific customer service issues tied to various network technologies (broadband and dial up). Such issues as classified by [100] include billing, contracts, credit control, customer service, faults and service provision.

## 2.3 Customer Satisfaction in Network Management

Work carried out in [140] used two main methods to assess customer satisfaction (CS) for telecommunication services. Firstly, Analytical Hierarchy process (AHP) is used to determine overall index of customer dissatisfaction by placing weights and integrating the CS data (Importance weight*number of dissatisfied responses). The number of dissatisfied response is assessed to show customer satisfaction level for telecommunications services. The level of dissatisfaction for one service item compared to another item varies. Secondly, by categorizing the service into positive and negative comments from the market research, CS survey data can be used more effectively. The model takes into account the customer rating of telecommunication services and service provider solutions to complaints [27].

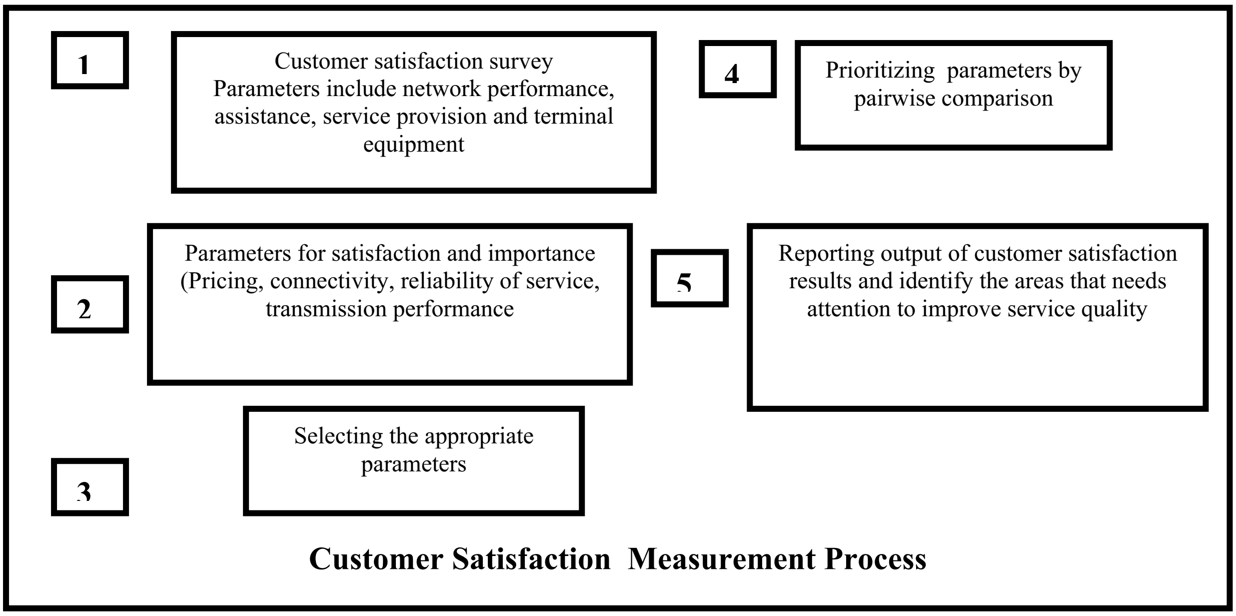


Figure 2.2: Block diagram of important steps involved in customer satisfaction process[9][10][23]

Previous work carried out in [140][150][158] states that customer perception is a very important in determining customer satisfaction. This can be achieved using surveys to get individual opinion and analyze customer perception of service. Overall assessment can be conducted by using service parameters. such as customer service. The rating might differ from one customer to another as a particular customer determines an overall rating by taking all service parameters and other customers ratings are based on different parameters (Figure 2.2).

Work carried out in [27] uses Hurwitz criterion to determine overall assessment

$$S = a * \max(X_j) + (1-a) * \min(X_j)$$

where S is the overall rating and *Xj* is the individual rating for item *j*. *a* is the coefficient where the value for *a* =1 and 0 in the equation states that the overall rating by the customers coincides with maximum and minimum rating among all individual ratings. When we have a situation where a>1 (or) less than 0 it shows that the overall rating improves and deteriorates from maximum and minimum rating. Selecting the right parameters that help to decide satisfaction level is critical. Correlation that exists between all these parameters might be independent from each other in terms of the parameters importance and satisfaction. Different types of analysis such as regression analysis, gap analysis, mean analysis and satisfaction analysis helps to analyze the data collected . Regression analysis helps us to know which individual factors have the greatest impact on customer satisfaction [104]-[109], Gap analysis helps in comparing results with historical averages. Mean analysis allows us to find out highest and lowest rate items. Satisfaction analysis helps to find the relationship between perceived averages of importance and satisfaction with issues assessed by the survey**.** The network services to be provided to customers are increasingly becoming important for overall success of a service provider. Service quality is one of the important factors influencing customer satisfaction. Previous studies [82][84][85][87] on customer satisfaction employed SERVQUAL instrument [87] to assess in-house network services. A key factor in achieving customer satisfaction is the quality of solution the service provider is able to provide for customer business problems. Three key areas that play an important role in customer satisfaction and service quality are identified in [1]-[23]. These are: Service Quality, Solution Quality and Pricing Schemes.

Service Quality relates to understanding customer expectation and perception and providing good services to ISP customers. Service quality data plays a very important role in identifying the expectation and perception gaps that exist between customer and service provider. The popular service quality model SERVQUAL [87] serves as a guideline to conduct SERVQUAL surveys that have service quality dimensions to understand and manage customer expectation and perception. The key dimensions included as a part of this model are tangibles (physical appearance), reliability (providing reliable services to customers), responsiveness (fast response to customer queries and complaints), assurance (assuring customers that service promises will be fulfilled) and empathy (personal attention and caring for customers) [86]-[93].

Solution Quality refers to providing a good service quality solution to customer complaints. If internet service providers do not provide fast responses to customer complaints, then a complaint about a service problem soon turns out to be a complaint about a company.

Pricing acts as a significant factor when it comes to choosing an internet service provider. Apart from considering ISP image, company reputation, technologies offered (reliability, maintainability and availability) and connectivity solutions customers also look out for flexibility in pricing plans and how much value they place on network resources. User acceptance on various usage based pricing model for network service is an important aspect to be studied by ISPs [88]-[91].

Network policies defined based on the goals that are set by the management and the actions to be performed by different network entities. Entities are comprised of users, application services, service providers and network elements [2][3].

Service providers are now realizing that a deeper understanding of the network management operations can be gained through simulation studies [110]. Currently the main focus is on network traffic measurement and performance parameters . Simulation studies that help to verify the results from these studies can then be used to implement SLA, accounting and billing, resource management and network planning. Service providers monitor their network to check if it meets defined SLA levels, however the competitive nature of market pressurizes them to offer the best possible service which could possibly increase customer satisfaction.. Work carried out in [3] highlights that the competitive nature of internet service providers has discouraged industry wide co-operation to measure large-scale network performance. Thus consistent, accurate, scalable and good services need to be provided for which simulation plays an important role [1][4] [7].

The complexity in internet service monitoring occurs due to its size, heterogeneity of the networks and their decentralized nature [3]. Due to the lack of centralized administration it becomes very difficult to have a simple common measurement protocol. As a result of this, using a testing device throughout the internet requires separate arrangements with each individual service provider. Due to the competitive nature of this service industry it become difficult to establish co-operation to enable end-to-end services. Because there is no common measurement protocol, service providers generally do not respond well to external studies of their network performance [120]-[150]. They fear exposure to criticism and prefer to keep such details in highest confidence. One solution is to conduct an internal diagnostic test by conducting several simulation studies to find out where they stand [2][3][7][11][90].

User decision is an important aspect of internet infrastructure and for running business successfully. This is because of the decentralized nature of the internet and also the competitive marketplace. The internet interconnection agreements take into consideration three main criteria, which are user network performance, cost structure and profitability.

User network performance include peering arrangements made between ISPs. Private peering refers to directly connecting two ISP networks and routing traffic between them.

This provides faster speed and reliability as it cuts down the number of hops and decreases packet loss. Public peering occurs through network access points by ISPs entering through interconnection agreements and using a peering exchange to route traffic [7]-[11].

Cost structure plays an important factor as the big players exchange traffic between their networks at no cost. Smaller ISPs have to pay for traffic to use the high capacity trunk line provided by big players. Small ISPs also need to pay for traffic when customers of a large ISP access a site on their network [7][9].

Profitability criteria include service quality differentiation among service providers. This aspect creates great stress upon the various core components that are involved in service provisioning. Private peering helps ISPs to improve network reliability by cutting down the number of hops, packet forwarding and packet loss and plays a very important role when high bandwidth services become ubiquitous. Thus peering arrangements not only allow ISPs to control routing, but an individual peering partner can guarantee quality of service to their business customers. These guarantees cannot be provided in situations where traffic passes through network access points where there is no direct control (public peering). Only through private peering can ISPs have direct high-speed links between them and monitor as well as control their traffic. Thus peering arrangements necessitates ISPs to re-define their business models in terms of pricing, bandwidth allocation and resources[11].

Authors from GTE laboratories [11] indicate that the internet is evolving from best effort service to integrated service, which makes interconnection agreements very important. Various interconnection models explained by [131] therefore need to incorporate integrated service; technology, policy, management and economic factors, which are the assessment, factors determining interconnection agreements. One such example is BGP (Border

Gateway Protocol) where economic policy can be used in the BGP protocol routing process [132]-[138]. Some of the main models for interconnection agreements for ISP are peer-to-peer model, hierarchical model, intermediary model and cooperative agreement model.

The Peer-to-Peer Model consists of two internet networks, which are owned by two different firms that are of same size, experience, technology and customer base. They interconnect through a two party contract governing their agreement (ISP-ISP)[4][12][20]-.

The Hierarchical Model functionality is similar to the peer-to-peer model. However, they differ in terms of interconnection where the two different firms have differences in size, technology and/or customer base. This model places more emphasis on customer and provider relationships than peer-to-peer relationship. For example: a corporate network connecting to an ISP, Internet Access Provider-Internet Service Provider.

The Intermediary Model is applicable where the interconnection point consists of more than two networks that exchange data packets. Administration of the interconnection is done by an external firm that does not operate a network. This external firm may provide network access points, like the Australian Internet Exchange (AUIX). The intermediary firm acts as a trusted source and facilitates communication and promote non-discrimination [12].

The Cooperative Agreement Model is similar to the Intermediary Model, the main difference exists in that cooperative agreement has more than two parties sharing an interconnection point. The operation of the interconnection point is run by a committee of interconnecting firms.

The pricing policies used by interconnection agreements are flat based pricing, capacity based pricing and usage sensitive pricing.

Flat Rate Pricing: This pricing scheme uses a flat rate pricing where a user is not charged for each transmission of data but instead has to pay for the initial costs of the connection and through a fixed, monthly subscription charge.

Capacity based pricing relates to usage by setting a price based on the bandwidth (or) speed of the connection. This pricing policy is based on the expected use of the circuit based on bandwidth and not on actual number of bits sent and received [23][25].

The usage Sensitive Pricing policy includes charges for actual usage rather than only for expected usage. If the accounting is done at the connection level, then billing for network traffic will also be done at this level. This pricing scheme provides flexibility in a sense that pricing can be done by time of day, priority of traffic and hence will prevent congestion. The advantage of this is that users have the flexibility to change their usage patterns to minimize cost [23][25].

Thus, it is clear that changes in interconnection agreements and pricing schemes are always evident due to new services being offered (high speed data services such as audio streaming). Therefore, different models need to be developed to address different scenarios and issues and make interconnection agreements scalable for new applications. Thus different simulation tools, languages and techniques need to be employed based on scenarios to be modelled [22][23][41][50].

## 2.4 Importance of Customer Satisfaction and retention in Telecommunications Market:

Research work done by [135] showed how customer satisfaction and retention are constructed and related in telecommunication industry. The study found that expectations are presumed to be important in formulating levels of satisfaction. The hypothesis proposed in their work states that both confirmation and disconfirmation of expectations and performance influence customer satisfaction. [65] proposed this hypothesis especially for cellular phone service industry in Malaysia. The outcome of this study is that overall performance affects overall satisfaction, which in turn affects overall retention.

In general the research is done in two steps. Initial questionnaires are constructed after discussions with area experts to develop an understanding of customer behaviour and attitudes when using a service and their selection criteria for choosing a service provider. After this stage the survey method is selected in stage two and survey is conducted. The survey method is selected based on the types of research questions and also the variable of interest in terms of data collection. The five main dimensions of satisfaction identified in the study are customer service, service coverage, billing, quality of line and customer service outlets. Thus identifying best measures of performance and satisfaction becomes very important for network service managers

## 2.5 Reasons for customers switching providers: Relationship between Satisfaction and Loyalty

Customer satisfaction leads to long-term business profitability. Attracting new customers involves a lot of time, effort and marketing from the service provider's perspective. The cost of attracting a new customer is five times more than the cost of retaining an existing customer. Service quality researchers [151]-[158] suggest that the longer a service provider keeps his customer the greater lifetime revenue is obtained from their customers. Customer loyalty programs help service providers to realize the value of retaining their customers by exceeding their expectations (customer satisfaction). Because of the intangible nature of various service deliveries, it becomes very difficult to understand customer disloyalty for service businesses [111][113].

Keeping customers satisfied does not always imply customer loyalty. A customer who is satisfied with service might still switch to an alternative service provider hoping to receive more satisfying results. To understand the relationship between customer satisfaction and loyalty, it is very important to understand and manage service quality. Service quality is the judgement factor as personal outcomes related to customers expectations and perceptions lead to high or low perception on quality of services. Thus, loyalty is better understood using service quality than just by the satisfaction score. In order to close the user-service provider gap, both the satisfaction score that highlights customers rating of services and quality score that highlights state of service provider's actions and resources are essential. The quality score will also help to improve those aspects of service that need improvement [102][111][112].

The service quality model SERVQUAL proposed by [140]-[144] uses five dimensions that are tangibles, reliability, assurance and empathy. Several issues identified by researchers in using SERVQUAL [3][86][87] are dimensionality of scale, lack of consistency of factors across studies and inapplicability across various service industries [111][112].

The SERVQUAL [3][86][87] model is a very popular model used to measure service quality in both industry and academic settings. The model helps service managers to know if satisfied customers are always loyal and how service quality is related to satisfaction and customer loyalty [113]. The two main categories of service quality, which are functional and [112] satisfaction ratings do not ensure loyalty. Even though they are co-related, the relationship is asymmetrical. Dissatisfaction guarantees switching providers, while satisfaction does not guarantee loyalty [152]-[177]. The nature of inclination of switching providers is a function of satisfaction rating, technical quality rating and functional quality rating. The above-mentioned dimensions of service quality drive customer satisfaction.

To understand the effects of the two aspects of service quality discriminant analysis technique can be used. This statistical analysis technique helps to identify the factor that discriminates between satisfied and dissatisfied customers [111][112]. Understanding the importance of technical service quality and functional service quality for that particular service set up will help to explain the reasons for customer to switch providers [111][112].

## 2.6 Impact of mergers and acquisitions on small ISP Industry: Functional service quality issues that affect small ISP business performance during mergers and takeovers

Mergers and acquisitions are increasingly becoming very common in the Australian telecommunications industry [20][100]. It becomes very important for the small ISP industry to identify the dimensions of service quality to which customer give critical importance and they can focus on these dimension instead of all. Many small ISPs do not have a dedicated acquisitions team to identify the potential pitfalls. There are no technology monitoring teams to look out for possible mergers and acquisitions. This is because they have access to limited resources and have less capital [20][100]. Many small ISPs who are drawn to a new acquisition opportunity to increase their subscriber base do not realize that they need to integrate numerous systems and domains as many of them are built in- house [177]-[189]. Mergers and acquisitions put a lot of strain on small ISP support professionals, as they need to maintain the same level of service when transferring customers in to their new network. Thus people with high levels of skills in technical support, operational and business processes are required. Some key issues to be addressed here include managing complaints during mergers and takeovers (billing, speed and support) and rotating ISP staff during mergers and takeovers [20][100].

The simulation case studies conducted in Chapters 4 and 5 not only show the application of simulation to model ISP business operations involving complaints, rotating ISP staff in call centre operations, but also the key benefits that can be achieved by using simulation for such scenarios. Figure 2.3 shows the service quality issues faced by small ISPs during mergers and takeovers. It highlights this from the good, the bad and the bottom line perspective.

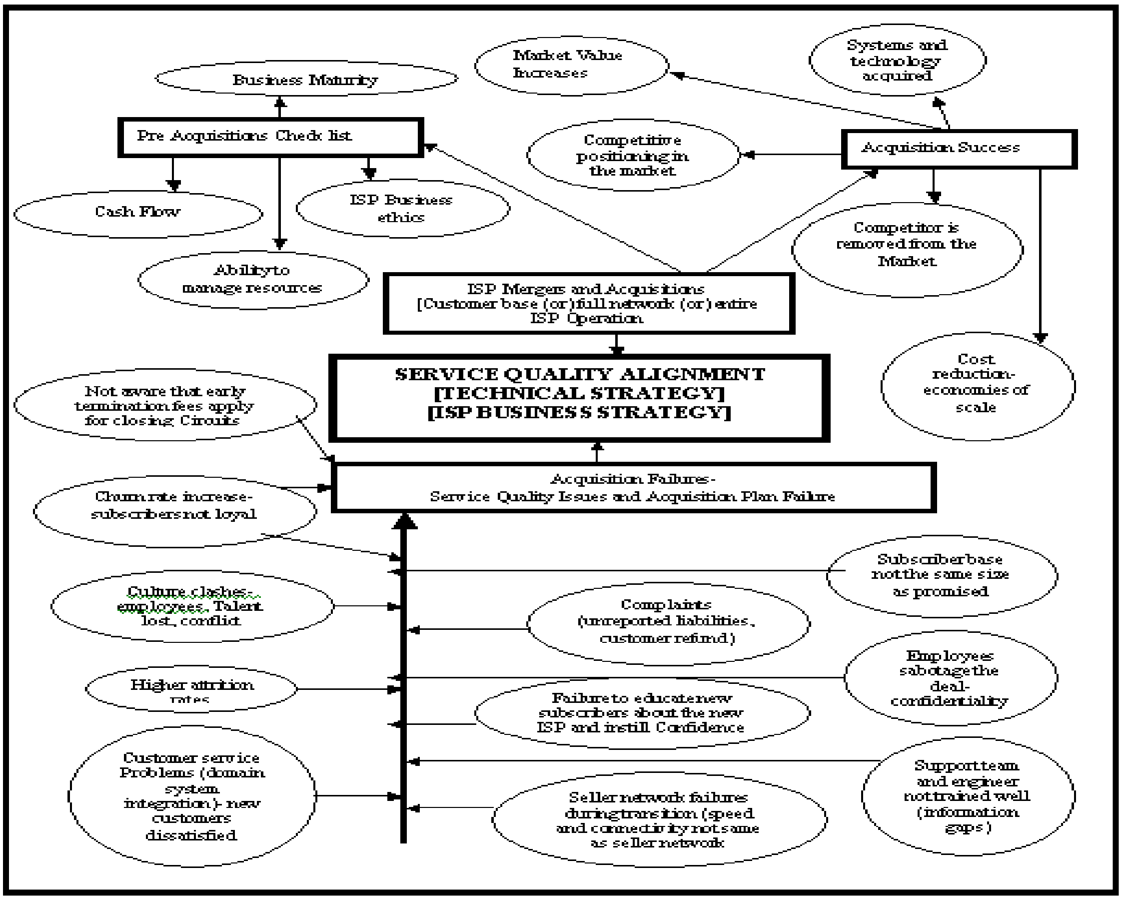


Figure 2.3: Service quality issues during mergers in small ISP Industry: the Good, the Bad and the Bottom line? [20][100][177]-[189]

## 2.7 Simulation modelling and analysis in network management

Simulation softwares have been widely used to model complex network systems. Programming included through procedural languages led to development of general-purpose simulation languages. However some simulation softwares have been specifically created to cater to the needs of organizations in health care, services, telecommunication and defence sectors. Some examples include COMNET and MEDMODEL. This is especially true in the case of COMNET that includes different constructs for different protocols and cables. MEDMODEL was widely used in modelling healthcare services. Some commercial software such as ARENA simulation software (simulation and animation) has built-in modules that can be used to model manufacturing, material handling, queueing systems and also could be extended to model network systems [103]-[129]. This particular feature proved to be advantageous for an applications-oriented simulator [15][16]. Simulation softwares are also able to share information with other applications. They can accept information from databases and spreadsheets and can output data to them as well. The ARENA package is integrated through vendor provided add-on-software that is able to simulate a variety of tasks including call centre simulations, scheduling and input modelling. Thus through an application oriented simulator accessibility of simulation is increased.

## 2.8 Simulation role in understanding various problems related to customer satisfaction for network services

In increasing competitive network markets customer satisfaction plays an important role [103]-[129] it is necessary to know the customer and what they expect. To make good profits service providers must consistently offer services that exceed customer expectations. Simulation modelling helps us to study the effects of different service priorities offered to enhance customer satisfaction [103]-[129]. Network downtime and customer satisfaction are indirectly proportional to each other. The simulation model developed may not suit all situations, therefore we need to model and analyse different scenarios separately and study them in detail. A good example will be where some ISPs provide reduced service levels along with reduced cost for higher profits [8][9]. Simulation has been widely deployed in various service industries [101] to better understand the needs of customers and to construct, validate and maintain simulation models that would help to model a wide range of complex systems. Users will also need to interact with the simulation in order to achieve greater comprehension of modelling phenomenon [70]-[77]. Figure 2.4 details the steps involved in modelling customer satisfaction involving network services.

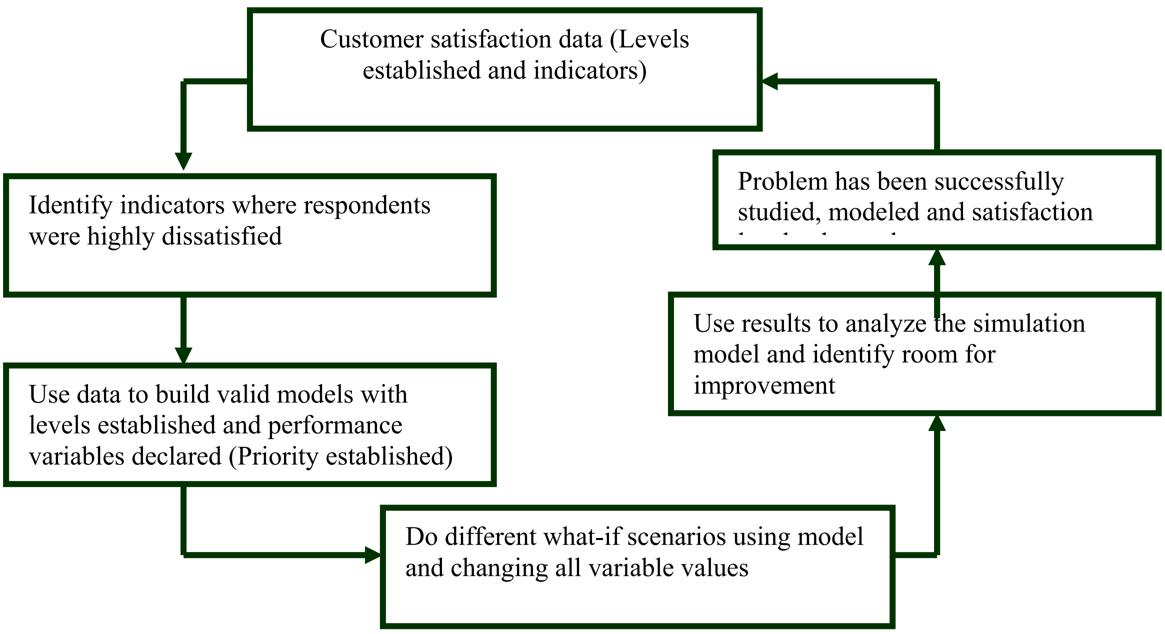


Figure 2.4: Modelling steps involved in customer satisfaction for network services [36][40]

Simulation is employed in the service industry for a number of reasons. Some of the main reasons include the flexibility they provide to the modeller that allows him to model various scenarios and help in the decision making process, provides reliable results and helps in the analysis of the system under study, no need to experiment with real networks and off line analysis can be done [12]-[23][70]-[86]. According to [103]-[129] simulation is used to cut cost and offer solutions to customer needs. They define three main requirements for choosing a simulation software. The software must be quick and easy to use. It must be highly accurate and provide powerful graphic animations of simulation results for presentations to network managers [140]-[177]. The need for simulation in the customer management and service system is to ensure that the system designed meets customer requirements and that the design can be explained to higher management level(s) easily so as to enable them to make business decisions [14]-[16]. Simulation will also help in predicting whether a system will work or not and if it works how well it can be expected to work. Even after the system is delivered, meeting current customer requirements can be continuously enhanced as customer requirement [15][16]. Customer satisfaction has become a very important factor in network management as the Internet evolves from a public network to an interconnected series of private networks which have terms and conditions if they offer connectivity to others such as BGPv4 [166]. Bandwidth, connectivity and service provisioning constitute important factors for the internet currently and this in turn depends on successfully deploying simulations in the right place and provide defined service according to interconnection agreements, or SLAs. Researchers [178]-[182] state that interconnection agreements that are distributed unevenly allow smaller networks to gain more than large networks. Public peering points that facilitate interconnection agreements help smaller network providers to gain more when the network becomes congested. This raises the issues that large network providers are less willing to peer with others which in turn leads to policy issues about network mergers. These issues have to be handled effectively using simulation techniques. Figure 2.5 links the simulation modelling with the network system.

Please see print copy for Figure 2.5

Figure 2.5: Simulation used to offer solution to customer needs [131]

A report published by internet industry [17] indicates that public peering has not been a successful solution due to the disadvantages it causes to many providers because of cost caused by the bad economics of public peering. They also suggest that service providers are not willing to invest in public peering points and those who invest in high capacity for public peering points bear all cost but receive very few benefits. This discourages the investment in higher capacities in public peering points. Also lack of a pricing scheme of traffic at public peering points causes network providers to overuse network resources and increase congestion [18][23][25]. Private interconnection agreements between firms that act as internet backbone services are vital for providing required service. Private interconnection becomes congested very often and service degradation occurs due to this. This creates delays and problems to small networks that rely on public peering points to reach global internet resources. While bandwidth is currently plentiful, not all ISPs have access to huge bandwidth. Large networks that rely on public peering point to reach global internet resources will tend to have better access. That is, large networks are less dependent on public peering points for getting to internet resources because they have their own network infrastructure and global connectivity through global routing tables [17].

The economics of internet services are determined by private interconnection between network service providers. The profit of firms providing network service depends on interconnection agreements which in turn depends on service levels, congestion at public peering points and network size [17][18][23][25].

Simulation project management covers planning, scheduling, reporting and control techniques. These techniques need to be followed in order to standardize the simulation project management activities throughout a company and to ensure very high customer satisfaction for simulation projects [65].

Discrete event simulation tools enhance customer satisfaction as they aim to give network researchers a handle on forecasting network requirements [118]-[122]. As technology advances, users place more demand on network service provisioning, user usage level, and resource reservation, which few network managers can ignore. Instead of using a generalised approach (common sense rule of thumb) in modelling a network it would be beneficial to use simulation software to study different “what-if” scenarios and see which tools best fit the needs of the organization to understand customer requirements [52]-[54].

For example CACI’s COMNET [16][44]-[47] is a simulation wizard for network managers with a good software interface and modelling flexibility. It can be used for modelling network behaviour under various conditions, like congestion, resource priority and policy criteria and onscreen information display regarding results is thorough and detailed. Discrete event simulation tracks every single event occurring in the network and provides a detailed view of network behaviour during that event.

COMNET Predictor [16], which is the latest version, includes flow decomposition techniques that help to analyse network traffic flow, utilization at various queueing nodes such as router and switch buffers on network. It saves huge amounts of time compared to COMNET III as a network model that takes 18 hours to run in COMNET III would take only 20 seconds in COMNET Predictor 1.1 [16]. Thus the simulation software can help us to collect details regarding the traffic volume and individual network event statistics for a thorough analysis [16].

Performance monitoring plays an important role in enhancing the level of customer satisfaction which is achieved by making sure services are provided as defined in the SLA. Even though there are many performance monitoring tools available [141], a combination of ad-hoc measurements methods are still used, which is too limited for next generation network supporting different services. Some of the key reasons why ISPs do not publicize their network performance data to third parties as they are not willing to report internal problems nor do they allow external studies to monitor their network. The investment for any better performance in network is of low priority unless it is highly essential.

Therefore simulation serves as an important tool for the Internet Service Providers to study their own network without having to expose their network details to a third party [56][57]. Parameters like network delays and queue time have a direct impact on customer satisfaction [144]. By simulating a network with known demand, service providers can determine the optimum level of service required to meet their customer demands [144]. Determining optimum level of service by actual changes in the network might result in negative impact on customer satisfaction. Developing a simulation model will allow for an off-line analysis without any changes in the existing network and will also provide better results for analysis and decision making.

## 2.9 Service management in telecommunication networks

The nature of networks themselves has made corporations face difficulties in managing their own networks. The network is typically composed of leased and dedicated public and private components. The network environment is characterized by type of service provided, the service network used, and the switching technology used. Types of service provided may include integrated services and differentiated.

Different types of service (integrated services, differentiated services):

Integrated services and differentiated services are the two standard types of quality of service (QOS) used to support two views of network services. Differentiated services aggregates traffic flow on a per hop basis based on traffic behaviour. Integrated services approaches quality of service from the perspective of supporting traffic flows on an individual end-to-end basis. Only by understanding these services can network engineers optimise their network service performance and maintain flexible performance architecture services [163]-[188].

ISDN connectivity (Integrated Service Digital Network) combines a set of protocols that combines digital telephony and data transport services. The telephone network is digitised to permit transmission of video, audio and text over existing telephone lines. Subscriber services are standardized and ISDN provides user and network interfaces and thus enables internetworking capabilities of existing voice and data networks. ISDN forms a wide area network that provides end-to-end connectivity over digital media services [163]-[188].

Analogue switched service is used for dial up service via the home telephone. It uses a two wire twisted pair cable top connection from the subscriber's handset to the network via an exchange. The network is called the public switched telephone network (PSTN) and the connection is called the local loop. Analogue leased service offers customers the choice to lease a line, which is a dedicated line and is permanently connected to another customer. There is no need for any dialling as the connection is always up due to single line phenomenon in spite of the connection passing through switches in the telephone network services [163]-[188].

Telephone companies offer digital services and they are less sensitive to noises and other interferences than analogue services. In digital transmission the signal is digital and interference is analogue. This allows the signal to be distinguished and separated easily. Switching consists of a switched network, which has a series of interconnected switches. Switches are hardware and software devices that are capable of creating temporary connections between two or more devices linked to the switch instead of being directly connected to one other. Three main switching techniques used are circuit switching, message switching and packet switching. Circuit switching creates a physical connection between two devices such as computers. The circuit remains connected for the duration of the session once it is established. Packet switching refers to data that is transmitted in discrete units of potentially variable length units called packets. The network establishes the maximum length of the packet. The packet contains data, which is actual information, and a header, which contains control information such as source and destination address, priority codes etc. The packets are routed independently of each other and this reduces delays as nodes can re-direct packets if a link is busy using an adaptive network routing strategy (ability to adapt to changing network traffic conditions) [127]-[128].

As a network evolves to support various services to customers, identifying the right simulation software, tools and techniques is important to effectively simulate network operations and facilitate the network manager in defining, provisioning and maintaining network services. This helps service providers to develop proactive network management strategies, identify faults and take corrective actions before they impact network performance.

Customer interfacing is important in network service management. Customer interfacing relates to a process where the organization pays close attention to their customer requirements/expectations and works with and relate to their customer. Simulation has become very important to provide a valid representation of customer network system. Some important guidelines to be followed to achieve good customer interfacing are

(a) Project planning**:** This involves helping customers understand the project and their expectation for the project. This is very important if we are modelling a system that is used to represent customers system where there are multiple customers for the simulation project undertaken. The project plan should include scope, metrics and risks involved. The project plan should be reviewed through group meetings so as to receive each individual's opinion on the project. This will help the modeller to identify project terminology and deliverables. Establishing good customer relations will help the modeller in identifying project terminology and deliverables. Establishing good customer relation will help the modeller in identifying the actual information needed to produce good project plan along with its objectives and deliverables [22]-[32]

(b) Initial data collection: Sufficient information should be collected by modellers to determine correct statistical distributions for associated time elements [22]

(c) Good customer relations involve listening to customers, translating their needs into deliverables and communicating in an effective manner with customer [11].

(d) Set service standards: This involves identifying what the customer expects from the project and what the modeller expects from his customer. This will ensure both parties understand those expectations and help each other achieve those expectations [27][28][30][41].

These guidelines help providers meet their customer expectations.

## 2.10 ISP Industry Problems:

In the last couple of years ISPs seem to have become so prolific as to have saturated the market, which may explain why they struggle to gain customers and revenue. The main reason for business failure identified by the TIO [2] was faulty technical service and poor telephone support, which have confounded small ISPs for many years [100]. Many small

ISPs with no business plans and good pricing plans are out of business services [163]-[188]. Small ISPs have found that value adding is the key factor to attract new customers, despite the fact that they have to charge more than large ISPs [13]. Small ISPs can assist the client in getting online and setting up their network but, once the client is well established and gains sufficient skills in-house, the customer tends to move to a larger providers for the cheaper price [20]-[25].

Smaller ISPs are generally having problems retaining their customers due to lack of resources and training in the customer service departments [106][107]. The ISP market will continue to become segmented, but the most successful ISPs will find a way to provide additional value over and above what is already being provided to their customers. Customer perception of quality is a very important variable in determining business profitability. Retaining the existing customer base by providing good service quality and having creative ways to meet new service demands has become very important for ISPs [4][26][100].

## 2.11 Why use Simulation Solutions in Telecommunication Context?

Simulation "is the process of designing a model of real system and conducting experiment with this model for the purpose either of understanding the behaviour of the system (or) evaluating various strategies (within the limits imposed by a criteria) for the operation of the system" [114].

The changes involved in the business process include people, processes and technology. These changes result in an infinite number of service scenarios that cannot all be evaluated and predicted using static process modelling tools like surveys . Simulation is the only possible technique that can be used when the system modelled is highly complex. The field of service quality has become an integrated part of service business management across various service industries. Small ISPs have realised that service quality is the area where they can attract new customers and gain a competitive advantage over other providers [115]-[118]. Hence there is a requirement to integrate people, process and technology with appropriate application conducted using simulation modelling methodology, tools and techniques [9] [119].

The features of simulation tools such as animation provide a real world edge in modelling customer service scenarios that is missing in traditional service quality studies/models. This technique helps ISPs understand their operations, service strategy and have a balanced approach that emphasises importance of service quality, marketing and human resources management. Various user friendly software that aid in the areas of model development, user dialog support and integration with organizational service quality data has made the model building easier and with no programming required. Apart from the simulation software available in the market to model service operations all service organizations should develop their own business performance framework that helps them to improve service quality simulation usability from organizational context of implementation. This approach helps maximise service performance. Simulation can be employed to identify targets for improvement in business processes and also to evaluate alternative strategies. Simulation solutions can achieve these benefits only if providers understand the components of their business practices and how they work together. This leads to applying the right simulation methodology for their own service scenario modelling.

The main problem in understanding the service quality attributes is due to the uncertainty and interdependency of various service processes within an ISP service business set up. The use of simulation techniques gives ISPs the possibility to gain valuable insight into service model variation and attribute dependencies. The simulation results enable them to predict future behaviour and test various service designs of their customer service management scheme. Simulation helps service providers model the service attributes and also identify the performance indicators that drive their customers.

## 2.12 Importance of Service level agreements (SLA) and Policy Based Network Management (PBNM) in service based networks and their implication on the simulation scenario

Service level agreements play an important role in network service operations as they help us to understand the needs and requirements of Network management software. Based on the needs various priority levels are set up and this helps in properly synchronizing network and business functions. User expectation is one of the key factors included in an SLA. The SLA helps identify the list of functions that particular network can offer and documents the contract between ISP and customers. Key factors defining acceptable levels include response time, downtime and network performance. The SLA helps to set different levels of network service, resource allocation and bandwidth management [130][138].

Many network management software vendors offer IP network centric traffic management software that help us to set the allowable bandwidth limit, monitor user usage level and collect reports on traffic levels that are utilized by users at different service levels. Through this network usage accountability process, effective monitoring of users' usage of network resources can be achieved and this improves the network productivity [139]-[158].

Policy Based Network Management helps us to set policies and determine who will have access to network resources and when those resources will be available. Policies are established through previous network average cost and different levels of service. Policies that are set with regard to network management operations can be identified through units of measurements that are to be rated and billed. The network usage costs include bandwidth parameters like bits/second, bytes/second and duration of usage on the network. Usage based pricing can also be carried out based on different pricing schemes according to applications used by different users belonging to different service levels.

The user policy statement plays an important role in identifying the user expectations, services that will be provided and network policy criteria [130][140].

Thus through SLA and PBNM we can establish various priorities and set expectations of users and senior management by agreeing upon an acceptable standard of performance. This will help us to identify performance of the network to meet various service expectations of users and move from reactive to proactive network management [130]-[140].

## 2.13 Conclusion:

In this chapter a detailed literature review has been carried out on customer satisfaction and service quality in the ISP context. The literature integrates simulation techniques and their effectiveness in exploring different network scenarios in the network management area. Key service quality models and their appropriateness in the telecommunications sector have been discussed. The effectiveness as well as ineffectiveness of the service quality models in network environment is discussed. This is done by understanding the theoretical robustness of the model. The importance of using the right simulation software to model network scenarios has also been covered. The impact of mergers and acquisitions on ISP service quality has been covered from the good, the bad and the bottom line perspective. The good thing about mergers and acquisitions for small ISPs is that they increase their subscriber base, removing a competitor from the market and increasing market share. The bad aspect includes customer churn due to poor speed and reliability when transferring customers to their network and not providing good support services. All these factors create support system havoc. The bottom line is that ISPs should identify potential pitfalls during mergers and acquisitions (many small ISPs do not have dedicated acquisitions team and technology monitoring team as they have access to limited resources and finance).

Small ISPs should have good business practices and continuously expand their service strategy (dial up to broadband). Thus a continuous face-lift is required to survive in the market. The literature also covers the network service management model and its operational elements. This a standard model proposed by ITU-T and covers service provisioning process, customer centric network management and the operations, administrative and maintenance tasks. This model helped us to gain insight in to understanding the service management requirements in technical service provisioning (network service management) and the need for customer interfacing within this model. Key problems faced by the ISP industry in the Australian context is covered and justification of using a simulation solution is highlighted. In the first chapter we introduced the research domain and the problem domain and used the statistics published by Australian Bureau of Statistics (ABS, 2005) [2] as a base line for our research. The literature review done in this chapter strengthens our research ideas and also exposes the key service quality issues that affect the small ISP industry. Chapter 3 covers detailed literature about discrete event simulation modelling and analysis. It also justifies why the simulation software ARENA was chosen to model the network scenarios modelled in this research study. The chapter links the simulation technology and how it led to the model development covered in Chapter 4.

# Chapter 3: Research Methodology

## 3. 1 Abstract

This chapter presents the research methodology used in the simulation studies. The initial case studies focused on key technical specifications that influence customer satisfaction and ISP service quality. They include service level agreements monitoring and management, flexible service design using differentiated services, network policies for priority-based services. Then the key functional elements that focus on ISP business performance were studied. They include factors that influence customer satisfaction outside of the ISP network such as complaints handling, ISP call centre support services and understanding customer expectation and customer perception. The framework that came out of the research work has a clear mapping of discrete event simulation modelling and analysis steps with the proposed SIMCTS (Simulation Modelling and Analysis of Customer Satisfaction for Telecommunication services) steps to make sure that a structured and disciplinary approach is followed in SIMCTS case studies. More detailed information on the framework and the case studies conducted using the framework is covered in Chapter 5.

## 3.2 Introduction

In this chapter the research design is presented, followed by discussions of the discrete event simulation methodology adopted for this study and a brief literature on this methodology. The justification of the simulation software (ARENA Simulation Software) selected for this study has also been covered. The methodology section of this chapter describes how the objectives of this thesis are achieved.

## 3.3 Research Strategy

In conducting this research to address the importance of simulation to understand and manage service quality elements that affect customer satisfaction, sufficient literature was collected from published research papers in the field. This research focuses on some technical specifications and key functional elements that affect ISP customer satisfaction. After examining both these areas and identifying key issues, discrete event simulation methodology was found suitable to understand these issues and also experiment with different scenarios to gain more insight into these issues. Six scenarios were modelled using the discrete event simulation technique [52]-[57][63]-[69]. These scenarios are covered in detail in Chapter 4 and Chapter 5. Table 3.1-3.3 highlights data type, research model and research strategy.

Table 3.1: Characteristics of the data used in our simulation scenarios [52]-[57][63]-[69]

| Criteria | Description |
|---|---|
| Type of study | Simulation case study |
| Nature of Questions | Responsive, open-ended |
| Aim of case studies | To model key service quality attributes that influence customer satisfaction.<br>To help ISPs to understand and manage service quality (customer expectation and customer perception) |
| Purpose of data | Experiment different 'what-if' scenarios (random data used in the model) simulation literature and procedures in published research studies were used in simulation modelling and analysis steps |
| Nature of method | Subjective |
| What does a researcher do? | Explore different scenarios and identify appropriateness and effectiveness of simulation in relation to that specific case study |

Table 3.2: Research Model – Question, Results and Validation

| Topic | Type |
|---|---|
| Type of Research Question | Design, Evaluation, Analysis of a particular instance |
| Type of Research result | Answer, Judgment and Analysis, Report on observations |
| Type of Validation | Simulation validation techniques |

Table 3.3:Research Strategy involving questions, results and validation

| Question | Result | Validation |
|---|---|---|
| Simulation model for evaluation of different “what-if” scenarios (service specific) | Answer, Specific Scenario Analysis | Simulation validation |

Construction of a hypothesis comprises of collecting the facts and exercising bold imagination and guess work on what are the possibly the candidate solutions. Therefore it is widely stated that hypotheses are suggested problem solutions, which are generally expressed as generalizations or propositions [5][10][15][23]. The quality and quantity of the hypothesis depends on (1) The amount of knowledge one brings to perform the research on the problem solutions, (2) the versatility and discrimination with which you select facts, create concepts, trace relationships and organize new and meaningful explanatory patterns, (3) Background knowledge and (4) order and analogy of the process (Figure 3.1).

Testing Hypotheses comprises of deducing the consequences, selecting appropriate testing procedures, confirming the hypothesis which in turn comprises of requirements for confirmation, strength of confirmation and reformulation or the abandonment of the hypothesis [52]-[57][63]-[69].

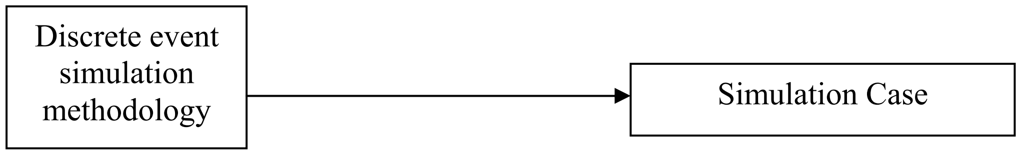


Figure 3.1: Research methodology and Research methods

## 3.4 Research methodology and associated steps

**Step 1: Analysis Stage (Literature Review and Analysis of research methodologies)**

This stage covered an extensive review of the available literature in the field followed by the analysis of the studied material on research methodology. Chapter 2 covers the literature review.

**Step 2: Research Methodology**

The research methodology used is primarily simulation in nature (discrete event simulation research methodology). This research is performed in an ISP context. This research is very exploratory in nature and hence all avenues possibly affecting the answers to the questions under study are left open for investigation purposes. For this reason, the research uses case studies, which provides the flexibility needed in carrying out such an exploratory study.

**Step 3: Simulation Phase (Network Scenario)**

Simulation case studies were conducted in the specific service context involving ISP operations. The case studies employed used discrete event simulation research methodology.

**Step 4: Results Phase (Report on Case Study results)**

The results of the case study are explained and analyzed. Inferences are drawn and future work to be done is identified.

## 3.4.1 Research objectives mapping to related research questions and network scenarios

**Objective 1: (related research question 1)**

Investigation of what effects the SLA (service level agreements) will have on customer expectation and customer satisfaction. The need to understand and manage SLA's and to come up with effective SLA's by analyzing different "what-if" questions. Forecast or predict planned changes and their effects on current network management operations and study if they would have a positive or negative impact on the current level of customer expectations before and after implementing the SLA's.

*After evaluating the current literature on service quality in an ISP context key factors that affect ISP business performance were identified. This includes some technical specifications.*

*The scenario conducted on "Simulation of Policy Based Networks through Differentiated Service Levels" highlights the need for small ISPs to have effective network policies and provide differentiated services. The case study highlights the importance of simulation to provide flexible service provisioning based on specific customer service needs.*

*The scenario conducted on "Modelling and Simulation of Alarm Based Network Management for Effective SLA Monitoring and Management" emphasized the need for small ISPs to meet the objectives specified in SLA (Service Level Agreements) and meet the marketing promises made.*

*These network scenarios look at technical specifications that affect customer satisfaction and the importance of managing these technical elements (Chapter 4)*

**Objective 2: (related research question 2)**

Investigate the impact of simulation studies on different network scenarios to establish current (or) improved levels of customer satisfaction. Highlight the need for improvement of the functional service quality elements to handle increasing customer demands and expectations. The importance of managing key service quality dimensions that have direct impact on customer satisfaction. *After evaluating the current literature on service quality in an ISP context, key factors that affect ISP business performance was identified. Functional elements that affect ISP business performance were identified based on the reports published by TIO (Telecommunications Industry Ombudsman), ACMA (Australian Communications and Media Authority) and IIA (Internet Industry Association of Australia). A network scenario was conducted on modelling dimensions of complaint satisfaction (Chapter 5). The actual time and estimated time in processing customer complaints were modelled using discrete event simulation technique and was found to be an important indicator of customer satisfaction.*

**Objective 3: (related research question 3)**

To highlight the benefits that can be achieved by using simulation tools and techniques in modelling key functional service quality elements in an ISP context and generate a simulation framework for the proposal, evaluation and decision support of customer satisfaction in telecommunications services. This framework is a simple simulation study framework suitable for an internal study of planned business changes and their impact on current customer expectations and satisfaction levels and serves as a knowledge base of past, present and predicted customer expectations (possibly to use within an organization).

*Three main scenarios presented in Chapter 5 emphasizing the importance of having a consistent simulation framework like SIMCTS in modelling service quality attributes involved in ISP business operations were conducted. The case studies involved modelling ISP call centre operations and also the importance of understanding the customer waiting time tolerance zone by modelling customer balking and customer reneging. Steps involved in the SIMCTS case study, modelling SIMCTS elements, simulation modelling and analysis mapping with SIMCTS, SIMCTS testing and validation are discussed in detail in these scenarios.*

Table 3.4: Key questions about SIMCTS were answered in the network scenarios

| |
|---|
| How can ISP organization benefit from SIMCTS building block simulation? |
| Is there a simulation framework in the field of service quality that can help providers to map their service quality model to simulation solutions? |
| What are the requirements service providers demand from a simulation framework for service quality? |
| What are the existing simulation software's in relation to simulating service quality model attributes? |
| What are the main elements missing in the existing simulation software and how do we address these in to the framework design? |
| What are the key performance indicators to evaluate a service quality design model? |
| What structural data is required to simulate service quality attributes? What input data is required and what format does this typically exists? |

## 3.5 Literature review on discrete event simulation methodology: how it works and why it matters in networking context

Simulations are very useful to provide users with practical feedback when designing real time networks. Through simulations we can estimate the correctness and also the performance expected out of design before actually implementing it. By mimicking the actual behaviour of networks we are able to study different scenarios and do feasibility studies and come out with the optimal solution. Simulations have also gained a lot of importance nowadays as they help us to study problems at different levels of abstraction. Simulation also plays a very important role in education for demonstrating networking concepts to students. This is particularly true for ARENA simulation package that makes use of excellent graphics and also animation to dynamically illustrate network operations in an educational setting. Simulation methodology involves a problem statement, improvement approach, benefits and simulation success [70]-[72].

### 3.5.1 Definition of Simulation and Its Importance

Simulation is a representation of reality through the use of a model (or) other device which will react in the same manner as reality under a given set of conditions.

According to [69] a simulation model may be defined as one, which depicts the working of a large-scale system of men, machines, materials and information operating over a period of time in an simulated environment of the actual real world conditions.

According to Banks [186] simulation is a numerical technique for conducting experiments on a digital computer, which involves certain types of mathematical and logical relationships necessary to describe the behaviour and structure of a complex real world system over extended periods of time [177]-[200].

### 3.5.2 Types of Simulation Models

Different models that could be possibly simulated include physical, abstract, analytical and empirical models. Simulation models are mostly descriptive models as they help us to model behaviour of a particular system and choose the best set of inputs to obtain required outputs from the system. Model building is very important as we can model existing systems and conduct different "what-if" scenarios without actually working on the real system. By controlling the speed of simulation we can study the behaviour of system effectively [70][71][101][103] .

(a) Deterministic models: Input and output in these models are not allowed to be random variables and models are described using their functional relationship.

(b) Stochastic models: In this model at least one of the variables (or) functional relationship is given by probability functions

(c) Static models: These models do not consider variable time during evaluation

(d) Dynamic models: These models vary with time varying interaction

### 3.5.3 Computer Aided Simulation Modelling

Computer aided simulation modelling is very popular especially in areas of information systems and operational research. As a general trend we study a real world problem and try to develop a conceptual model, validate it and develop a computer model. The model is simulated for different "what-if" scenarios and then the analyst checks if the model developed reflects the actual system. The model is used as an operational model, after it is validated against real world measurements. In the real world the above procedure is not sufficient. Owners of problems influence the problem that is studied by the analyst. This process is true especially in places where the decision-making becomes very complex. The construction of a logical model that represents the problem is the most difficult task and analysts need to constantly undertake problem reformation. The computer model developed should be checked with the decision making team frequently to check if it models the real world problem [46][49][101][103].

### 3.5.4 Problems encountered in Simulation Modelling Process

Some of the key problems involved in simulation model building and analysis include (i) problems studied and modelled are partly defined. (ii) There never exists a static specification of the problem and/or it is dynamic. Even if the analyst satisfies decision makers there is still a possibility that the same specification undergoes change for complex problems. (iii) It is difficult to validate the model (i.e.) model confidence. It is not possible to validate accurately a model of any size with real world (real world is dynamic) data. A model cannot be proved to be correct. To prove the validity we have to focus on methods that demonstrate model confidence (what it is doing) and the way it is doing it [48][49].

### 3.5.5 Simulation Prototyping

A successful simulation model means that the model is successfully implemented. One of the main reasons behind the success of the model implementation is that the user has good understanding of the mental model of the system. The model should be developed step by step starting from a very simple model, which is a simulation prototype. The simple model created is explained to the user and based on his feedback a detailed model is developed.

One of the important criteria for the simulation project to be successful is whether the results obtained from the simulation are really used for supporting the decision-making process [101][103].

### 3.5.6 Simulation Model Building and Working Process

Some of the key steps involved in simulation model building and analysis has (i) A team of persons (or) user will make decisions based on the simulation model created (ii) The user is the person who actually buys the simulation model to overcome any problems faced (problem owner) (iii)The model builder is a person who develops a computer-based model of a real system. This is done by a single person (or) team of members (iv) For the model implementation we have to focus on user perception of the model. If the user wants to accept the model we have to make him believe that the mental model of the system that he has in mind should have good correspondence with the computer model created by the model builder. However the decision-making person concentrates on some factors in the real system that is modelled and disregards others. That is the computer model will be a representation of the real world system with some important factors included and others disregarded [101][103].

One of the main problems faced in this process is the credibility of the model building. The user's model perception that involves a mental model of the system should match with the computer model. To ensure the users confidence in the model the model builder should make sure that the user has a very good understanding of how the model functions and if the user is not very much satisfied with the simulation model due to some discrepancies in it, the model builder should put some effort in adjusting the simulation model such that it is closer to the mental model of the user [101][103].

Simulation prototype is a step by step approach in model building which starts with a simple model not only improves the user's understanding of the model but also helps the user to stop further development process of the model if he/she feels that the simulation approach is not suitable. There also exists another advantage in this process, the user might be satisfied with the model and avoid additional complexities. This is quite often the case when there is a limit, as a decision needs to be made before the specified time elapses. Even if we get a better answer by developing a complex model, but still it is not a cost effective approach, as decisions often have to be made quickly. This is called " A Quick and A Dirty Approach" to decision-making [101][103].

### 3.5.7 Difference between a Prototype Model and Operational Model

Some of the key differences between a prototype model and an operational include (i)

Not much effort is put in to making the prototype model efficient as it is not run for a very long time, whereas much effort is put into the operational model, as it is important in the decision-making process (ii) The operational model is developed in very complex simulation system as compared to the prototype model which is simple (iii) From a developers' perspective building a prototype model and an operational model might be done by two different persons. The prototype model should be properly documented with assumptions and logic of the model. The knowledge about simulation techniques and time is important as the finish times for the prototype and operational models are entirely different (iv) The user has to properly understand the prototype model. Operational model is a detailed and a complex version of the prototype model. Prototype and operational model should rely on the same assumptions. (v) The prototype model should be simple, easy to understand as well as easy to validate the model. The prototype model should be a base for the operational model. The model logic and assumptions should be properly documented so that it helps different simulation analysts/ Programmers to build complex model based on the prototype.

### 3.5.8 Simulation Software Selection Criteria and Features

Selecting the right simulation software for the simulation study is very important. Factors that need to be considered while selecting the simulation software have been researched and are discussed below. To make sure that the right simulation software is used for the simulation studies the following guidelines need to be followed (Table 3.5)

- Accuracy check
- Simulation language
- Check if you need to use more than one simulation tool.
- Use checklists
- Try trial version of the software (if available)
- Check if you need animation as it might enhance your model building process.
- Check if the simulation language that is embedded within the package is easy to learn and whether it would be useful for your simulation study. [74]

Table 3.5: Simulation software features [74]

Please see print copy for Table 3.5

Table 3.6: The following factors distinguish between simulator and simulator language [52][54]

| **Simulators** | **Simulation language** |
|---|---|
| Development time: Moderate | Development time: Moderate to substantial. |
| Model control and system complexity: Must comply with software constraint | Model control and system complexity: Virtually any complex system |
| Accuracy: Varies depending on assumption levels. | Accuracy: Excellent |
| Training: Moderate | Training: Moderate to substantial |
| Environment best suited to: Complex, medium and specific applications | Environment best suited to: Highly complex |
| Output: Depends on individual packages comprised mostly reports. | Output: User defined, reports and customizable. |

Many discrete event simulators such as ARENA, SIMPROCESS [70]-[77] are usually data driven and do not require any programming skills (programming by experts), however most of the robust simulators have a programming capability embedded within the package. The model that is normally constructed from a simulation package must be within the software framework as there is a scope provided beyond which it is difficult to model. The time required to develop models using simulation packages is moderate. The example models that are embedded within the package to help new simulation analyst to get basic understanding of how to use the modules within package is an efficient way for training students, however the real world problems might be very difficult to model (increasing complexity). Simulation packages are very efficient in terms of modelling real world problems [52][54].

Simulation is used for validating system with respect to correctness of the model. A correct model can be simulated for analyzing different scenarios (Time, cost and quantitative parameters) and its performance is improved (validation is performed again). Therefore it is very important to find an answer to the question of the simulation objective before using/choosing appropriate simulation tools. The quality criteria are very important for the functionality and efficiency of simulation tool. The tools available are important in terms of simulating complex systems. So one needs to understand how simulation tools work and why we decide that a particular problem is more complex than others. Knowledge of modelling languages and algorithms are essential for simulation studies (including mathematics, data structures and algorithms). Simulation plays a very important role in component based system design in software engineering. Thus the simulation tools are integrated in software architectures. Modelling language plays a very important role in performing efficient simulation studies. Simulation is fully based on multiple emulations. To ensure stochastic variation different seed values have to be used in the model running and a complete analysis of results using some statistical tool is essential for any simulation approach [52][54].

### 3.5.9 Introduction to Model Verification and Validation

The main objective of using simulation is for improving the problem solving and decision-making process. The accuracy of results is determined through model verification and validation. The main purpose of developing the model is to address a lot of questions and validity should be determined for each question. The model might be valid for one set of extreme conditions and invalid for other conditions. Accuracy that is required should be determined prior to starting the development of the model. If random variables are of interest, then their mean and variance plays an important role in validating the model [84].

**Model Validation** involves the following process

- Decision Making Process.
- Independent Verification and Validation.
- Using a third parties results to verify and validate the model.

The scoring process, which is not frequently used to validate simulation model is where an overall score is assigned during the validation process and combining scores of various category helps us to determine overall score. If overall score is greater than passing score then model developed is a valid model.

#### 3.5.9.1 Role of Model Verification and Validation in Model Development Process

**(I) Detailed Modelling:** In this type of modelling the verification and validation becomes difficult because of complex nature of the model. Model represents system with assumptions, functions and relations. Simulation is experimentation using the model developed. Validating simulation model results will help us to have deep insight into the model, which would help us to modify the model. Validation outcome in this case should clearly specify the usefulness of the model and how it upgrades the process by which simulation engineering proceeds [84] (Figure 3.2)

**Validation process:**

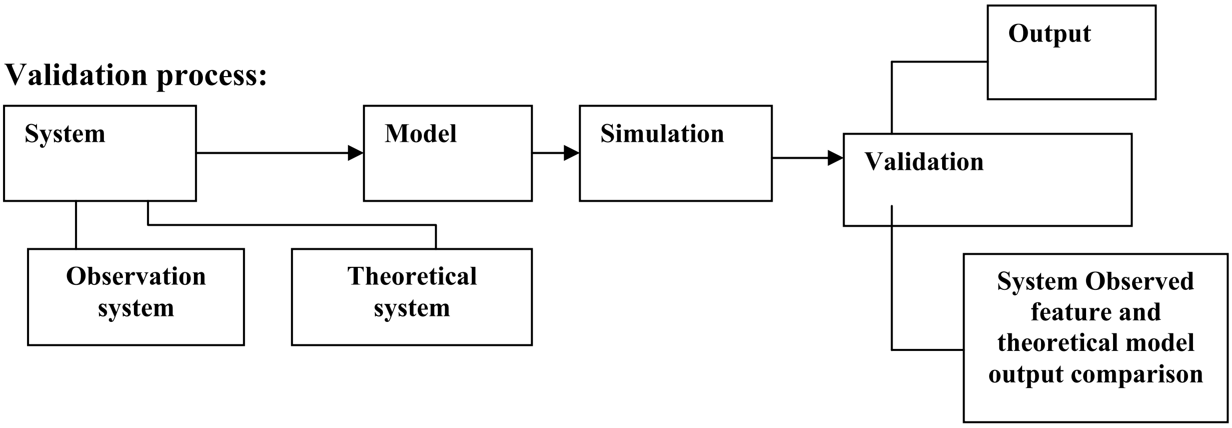


Figure 3.2: Block diagram of validation process in simulation modelling, analysis [84]-[95]

From the above block diagram we can understand the role of validation in model confidence. The system is one that is characterized by language and set of rules. The model defines the system language and system rules. An observation system is one where we observe the system and can alter it even though unaware of its internal functioning. A theoretical system using theoretical language is one where the statement of functioning of observed system is done. Validation involves the comparison of system's observed feature with theoretical model output. Model output should be able to compare against prediction (making predictions and checking output against predictions). Validation helps to set conditions under which observations and calculations are agreed with and the theoretical system will produce agreement in future calculations [84]. The modelling stages are shown in Table 3.7.

Table 3.7: Modelling stages in simulation [95]-[106]

| |
|---|
| Problem entity is the situation, policy that is to be modelled. |
| Conceptual model is the mimic of problem entity developed to study a particular problem (Mathematical model). |
| Computerized model is the problem entity that is implemented on a computer. |
| Conceptual model is developed through analysis and modelling phase. |
| Computer model is developed through computer programming and Implementation phase. |
| Validation of Conceptual model: This includes the process of ensuring the theories and assumptions under the conceptual model are correct and model developed is good (or) excellent representation of problem entity. |
| Computerized Model ensures that implementation of conceptual model is correct. |

Some of the key validation techniques in simulation technology are (i) Animation: Visualization of things that are taking place within model (ii) Comparison to other model: Output can be compared to output of other model and validate them (iii) Degenerate Tests: This involves changing inputs and see if they have considerable effect on output (iv) Events Validity: Comparing events in simulation model and that occurring in real time systems and see if they are same. (With minimal discrepancies (v) Extreme Condition Test: Testing model under extreme conditions. For example the average number in the queue at the server should continue to increase with regard to time when the arrival rate is greater than service rate (vi) Face Validity: Asking experts in modelling whether the model and its outputs are reasonable [check whether logic is correct]. (vii) Fixed Value: Using constants to check the model results against values calculated. (viii) Historical Data Validation: This involves historical data that is collected for testing the model. One part is used to build model while other one is for validating (ix) Data Validation: Having correct data to build conceptual model. Sufficient data on problem entity should be collected for building the model. (x) Operational Validity: Model output is accurate for intended purpose over its actual applicability [84].

#### 3.5.9.2 Conceptual Model Validation

Conceptual model validation involves determining the theory and underlying assumption underlying model is correct. Model representation of problem entity to be studied, its logic, and structure are reasonable [84].

#### 3.5.9.3 Computerized Model Validation

Computerized model validation is to make sure if the computer programming and implementation are correct. It is also to have correct computer program, the design and development process of programs in software engineering should be used. Special purpose Simulation languages will cause fewer errors than general-purpose simulation languages. Through simulation languages we can reduce programming time significantly. After developing computer programs and after all "bugs" are removed it must be tested for accuracy and correctness.

The main tests conducted are Static Test**:** The programmer explains the code step by step to the modelling team until they are convinced it is correct. Dynamic Test**:** Conduct the test under different conditions and check whether values obtained are correct [84].

## 3.6 Important issues that need to be considered in modelling process

Some important simulation issues that need to be considered are time handling, stochastic (or) deterministic modelling, discrete (or) continuous change are some of the characteristics that need to be considered about simulation model. Time handling in ARENA refers to the process where the simulation model that represents the system under study is used to observe system over different periods of time. The change in the simulation output is used to predict behaviour of system for different scenarios. Main advantage of model working process in ARENA is that you can slow down the operation of model and see in detail what is happening (visualize what happens). Deterministic models have their output that is not affected by random factors. Stochastic models are those where the arrival times, length of service plays an important role and output has meaningful results that are obtained as average of simulation runs. Discrete simulation is where all variables are associated with their change in state (ARENA). Continuous simulation is where all variables change smoothly over period of time [72][78][79].

## 3.7 Impact of Simulation Study Failures caused by Simulation Inaccuracy in Network Management

Three main reasons exist for simulation inaccuracy. They are modelling, data and experimentation. In simulation methodology validity of the model clearly means that model is accurate enough for the purpose intended. This clearly means that the modeller and decision-making people expect a certain level of accuracy that needs to be achieved from the model in order to satisfy the objectives. Simulation studies that are done to solve some real world problems require the level of accuracy to be 90% (or) more. The accuracy level depends upon the factors mentioned below. The simulation study to be done is used to better understand the real world problem in which case lower accuracy may be acceptable. To successfully carry out a simulation study and validate the results the following essential criteria are required [68].

Some of the factors involved in simulation study success are (i) Support from the senior management level (ii) Modeller should be highly skilled (iii) Good relationship between modeller and end user(s) (iv) Correct formulation of problem (v) Accuracy of data used (vi)Choosing the appropriate simulation software to perform the simulation study (vii) Communication and time constraints on the study performed. (viii) Credibility of the model

Reasons for simulation studies failures and Steps to be taken to overcome simulation inaccuracy [68] involves (i)Lack of knowledge and essential skills required in statistics, algorithms and system design. (ii) Modeller lacking logical thinking in terms of system being modeled (iii) Lack of adequate time to perform the simulation study (iv) High cost and problems with size and speed of the model.

Some of the main problems that are faced in simulation that leads to inaccurate results are discussed in detail below.

**(a) Modelling:**

Understanding the problem description is very important. If this is not done then the problem is poorly understood which leads to an incorrect model likely to be developed. To overcome this the modeller has to closely work with the management (client organization) to better understand the problem to be modelled. Developing an incorrect model results in a poor conceptual modelling process. So the validation of conceptual model should be ensured by consulting experienced simulation analyst who is actively involved in the study. Converting conceptual model to computer model might result in some errors in model, so model verification should aim at ensuring that developed model is exact representation of problem under study [68].

**(b) Data:**

Poor data collection is also one of the main reasons that lead to simulation inaccuracy. This is due to the fact that sometimes we might not get the required data as the real world system does not exist (or) there is not sufficient time to obtain a large number of samples. Thus this leads to estimation of data that produces inaccurate estimates. Analysing the data collected is also an essential process in good model building. One of the main areas that need attention in data analysis is choosing the right probability distribution in the model. The impact of using wrong distribution in the model in one such example stated in [68] is that changing service time distribution with mean service time of 2 minutes to gamma and normal distribution produces significant error that is less for gamma than the normal distribution. This is due to the fact that gamma distribution is closer to negative exponential distribution (curves skewed towards left). There were varying results in relation to errors based on various distribution used [68][79]-[82].

If the modeller is provided with data already then he should investigate the data source with respect to particular reference and check if there is a possibility of any errors. The modeller should also examine data collection techniques and the way they were collected. Using histogram to represent collected data and identifying any error patterns is an effective way to check accuracy of data. Modeller should be aware of how the data is interpreted by simulation software that is being used. For scenario where real world system does not exist to collect data we have to perform sensitivity analysis (varying data estimates and investigate their effect on final results). Two different options exist here. One is that results may be insensitive to the accuracy of estimates in which case there is no need to take any action. If the results are sensitive to the accuracy of estimates then we have to obtain more accurate estimates. The results obtained from sensitivity analysis must be reported to decision makers who could assess the risks involved and investigate what values the data needs to attain to obtain desired results [68][79]-[82]. Using the right statistical distribution in the model depends on the quality of available data. If we are not sure of distribution to be used we can perform sensitivity analysis that would help us to understand the effects of using different statistical distributions [68][79]-[82].

Transient periods play a very important role in simulation evaluation. Models that do not reach steady state analysis should ignore transients period to avoid any bias in the simulation results. To achieve this, the modeller has to run the model for a warm up period before collecting the simulation results. Insufficient replications also cause inaccuracy in simulation results. Running model for a large number of replications results in more accurate results. Running a model for multiple replications will help us calculate the confidence interval more accurately as the runs are independent. Testing the sensitivity of the results to data about which there are some uncertainties should be done. This is essential as there are always uncertainties in the real world [68][79]-[82].

To overcome the inaccuracies mentioned in experimentation, proper experimental procedure should be used. The simulation should be run for a larger number of replications until the target confidence interval is obtained. Another important point that needs to be considered is to have sufficient time for thorough experimentation. Having sufficient time helps us to test and analyze sensitivity of the proposed solution.

Some of the key reasons for doing simulations are as follows:

- Real time system does not exist.
- Experimenting with real time system is very expensive.
- Experiments are difficult to be carried out on existing system.
- Experiments involve high economical risks.

Thus simulation is important if experimenting with real time system is not possible, it is difficult to assess the system, variables of system are difficult to be manipulated and response of system is very slow. Simulations are also used in education to teach students how a complex system behaves under different scenarios and how to control them in case of extreme conditions.

## 3.8 Credibility Issues in Simulation of Telecommunication Networks

Credibility of simulation studies has become very important in telecommunication networks. There is an opinion among the research community that many of the published studies results are not credible. In [90][142][172] authors state that the results are not credible because they are based on stochastic simulation. Two main criteria's are important for a credible simulation study. They are:

1. Use of appropriate Pseudo-Random generator of uniformly distributed numbers.
2. Analysis of simulation output data.

There are lot of simulation packages, which are user-friendly offering sophisticated graphical user interface and animation. A lot of simulation packages reduce designing simulation models by placing icons that represent functional block of networks. Work done by researchers in [90] surveyed 2246 papers on simulation published in IEEE INFOCOM, IEEE/ACM Transactions on Networking, Performance Evaluation Journal between 1992-1998 which showed that many simulation studies were providing results with insufficient statistical validity (not enough error events). Authors also report that 51% of papers published are stochastic discrete event simulation papers. Building successful network simulation models depends on a valid conceptual model of network with appropriate assumptions, limitations and stochastic properties of processes that will be simulated. The next step will be that the simulation model is used in a valid simulation experiment.

In this step two main issues were addressed by authors [90]. They are

- *Elementary source of randomness.*
- *Analysis of simulation output data.*

These two factors contribute to the credibility of stochastic simulation based experiments. These will now be examined further [90].

*Elementary Source of Randomness*: Algorithmic generators of uniformly distributed pseudo-random numbers are used as source of randomness in stochastic simulation. Authors [142] indicate that most popular generators belong to class of multiplicative linear congruential pseudo random number generators which are based on recursive algorithms in integer modulo M arithmetic. After a very exhaustive analysis 20 acceptable sources of independent and uniformly distributed pseudo-random numbers were obtained. These generators are used in GPSS, SIMAN, SIMSCRIPT II.5 and SLAM II. This would mean there is no problem with selecting a good pseudo random number generator when using ARENA which is based on SIMAN.

Work done in [90] highlights that the above statement is only partially true. Authors identify the serious problems related to pseudo random number generators in real life applications. One of the main problem is due to recent achievements in electronic technology that have led to pseudo random number generators with cycle time of the order of $2^{32}$ becoming obsolete in all simulation studies. Thus we need pseudo random number from generators of much longer cycles for simulation studies that last longer than few minutes of CPU time. The study also identified there is a problem when using uniformly distributed pseudo random numbers from the same generators in parallel simulation because of the correlation between disjoint sub streams of consecutive numbers. The pseudo random number generators in this case have to be used with great care as the results can be incorrect, if hidden correlation in random numbers and the simulated system interfere with each other.

The authors [90] conclude that it is better to use an established generator that has been tested thoroughly than to invent a new one.

*Simulation output data analysis*: Stochastic computer simulation in which random processes are simulated is a statistical experiment and because of this we apply statistical method of analysis to simulation output. Statistical error associated with the final result of statistical experiments is measured by corresponding confidence interval at given confidence level. In good simulation studies the width of the confidence interval will shrink with number of collected simulation output data (duration of simulation). Fixed sample size is where the duration of simulation time is predetermined by length of total simulation time. This is not an acceptable approach as the magnitude of statistical error is high. A sequential simulation technique is used nowadays to control the error in final results of stochastic simulation. This is because run length is not fixed before simulation begins and that would produce a confidence interval with true value and desired confidence level. The ratio of half-width of confidence interval and point estimate is assessed at checkpoints and statistical errors are measured. Simulation is stopped at a point where the error of estimate falls below an acceptable threshold [90] [142].

It is a well known concept that steady state simulations require more complicated analysis than terminating simulations where we have a well-defined specific period of simulation time. Various methods have been proposed to understand the problems and also to analyze steady state simulation. All the methods involve warm-up period determination where initial bias in results can be removed and are not used in calculating steady state estimates. Work done in [90] state that there is a considerable belief that running simulation for very long period of time can help to avoid statistical errors and remove initial bias in results.

The research work [90] indicates that even though this approach leads to acceptable results the results might still include statistical errors. It is also important that for such very long simulation studies pseudo random number generators of an appropriate cycle will have to be used to avoid repeating of sequences of pseudo random numbers.

In discrete event simulation collecting large samples of data is more important than running the simulation for a very long time. CPU (central processing unit) time spent on simulation of telecommunication systems in which no event of interest is recorded does not have a direct effect on statistical accuracy of estimates, which depends on the occurrence of targeted events. When analyzing an event, which is rare, we need to record the minimum number of such events during simulation so that the output is representative. [113]-[122].

Simulation papers in [142] comparison state that majority of papers (76.6% in IEEE INFOCOM, 79.05% IN IEEE Transactions in Networking) did not care about the random nature of output generated by stochastic simulation. Authors also indicate that almost 52% of papers published in IEEE reporting simulation results did not mention to the reader whether there results came from terminating (or) steady state simulation. This might result in wrong results being reported in papers doing simulation studies on telecommunications networks. To overcome this situation the authors in [90] proposes a solution.

Step 1: The results reported in simulation studies should be repeatable which means pseudo random number generators used in the simulation and type of simulation are provided. The time horizon if terminating simulation should be specified.

Step 2: Method of analysis of output data needs to be described.

Step 3: Statistical errors associated with the results need to be included.

Thus the above measures have to be employed in order to achieve credible results and make decision based on the results obtained. This will help to increase the goodness of the model with respect to model confidence and also check if the results are credible.

Some of the key advantages of simulation include (i) Simulation models are flexible and can be modified to variations of the real system. (ii) Simulation is very useful in training people before allowing them to use real systems that are very expensive. Thus the confidence of the users increases and they do not make any mistakes that might lead to equipment damage. (iii) Simulation technique is free from complicated mathematics and thus can be understood by operating staff and non-technical managers. (iv) Before installing new machines (or) equipments the management can study its impact using simulation software and thus can avoid costly trials on real system. (v) Simulation can compress the performance of system over several years and large calculations in a few minutes of computer simulation model running time [113]-[167].

## 3.9 Justification of simulation software and language used for this project and a detail review in to software features

ARENA simulation software was used for conducting networking case studies. The section below covers the key features of this software and also explains in details the model building process and the simulation language. ARENA is discrete event simulation software where model building occurs using the list of modules available in model building templates. The coding is done using SIMAN (simulation and analysis language). ARENA has built in VBA module that can allow users to input various distributions and parameters and experiment different scenarios [71][72][78]. ARENA simulation software is available in different packaging editions to suit the required applications of users. They are basic edition, contact centre edition, packaging editions and professional editions. Thus application specific libraries are available for modelling.

Some of the key steps involved in model building are input data analysis, model building, interactive execution, animation, execution tracing, validation and output analysis.

ARENA has five templates that are used for modelling. The templates serve for different purpose. Blocks, Elements, Support, Transfer and Common. All the templates have different modules that can be used based on user requirement. All the modules are static which means that they do not change during simulation, only the corresponding entities change during the simulation run. ARENA also provides hierarchical modelling. Sub models can be used within main models to reduce the complexity of model and model understanding from external user perspective. The sub model and the main model modules cannot be seen simultaneously, however the sub model is connected to the main model and will do the required task that the user expects it to do. Careful consideration has to be done while selecting the modules. ARENA has an Input Analyzer that helps in appropriate input to the model and an Output Analyzer to analyze output after simulation has run to completion [79] -[95]. Figure 3.3 shows the model development process.

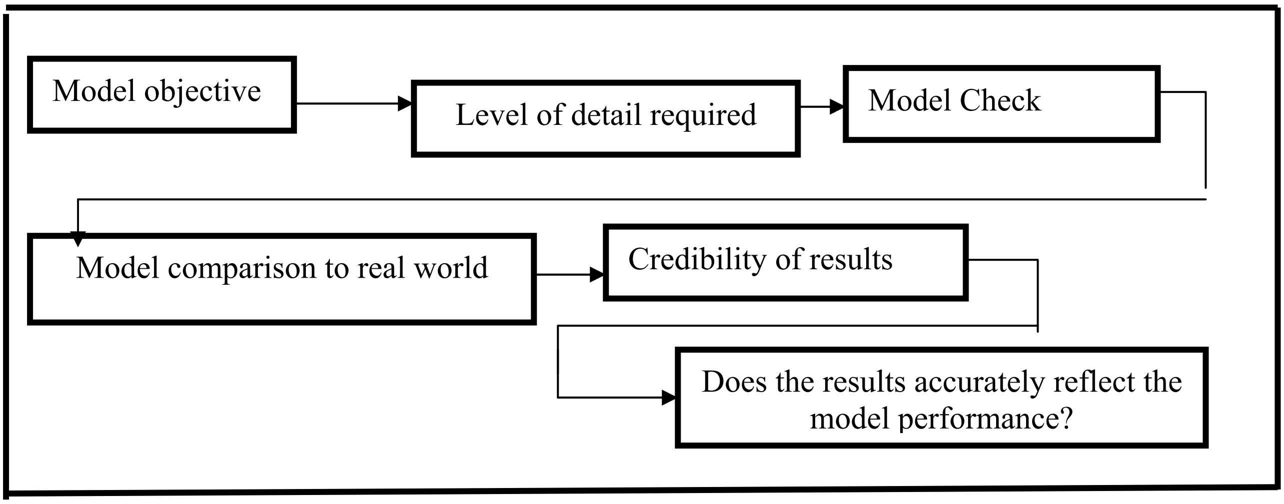


Figure 3.3: Modelling steps to be followed when creating models using ARENA [79][95]

Trace module available in ARENA helps to trace all events that occur during simulation run. We can trace the entity states during simulation run and get brief description about this in trace report (Entity actions that takes place in each and every module) [95].

*Verification and Validation:*

In ARENA it is easy to detect errors in model (both logical and syntax errors can be detected). Run-time errors are also detected and message is displayed to user along with brief description. Errors can also be detected by using SIMAN code. ARENA has visual basic applications (VBA) that helps user to write their own code. Errors in VBA can be detected and cleared. The "Watch" window available in ARENA helps to monitor the changes in variable (or) expressions during simulation [95]. Display features in ARENA include variables, mathematical expressions, logical expressions that can be displayed during simulation run.

*Breakpoints (debugging):*

ARENA has breakpoints that can be set on entity, modules, time and condition. By using breakpoints we can cause particular action on any entity (pre-emptive and non-preemptive) [95].

*Model size:*

ARENA places several restrictions on model size based on the software edition we use. For example the student version of ARENA has limitation such as total number of entities generated should not exceed 150. ARENA also places restrictions on model size by specifying maximum set of blocks that can be used in the *model [95].*

*Output*:

The output is produced as Report: Standard and customized reports. Integration to database, Visio and VB is possible.

*User:*

The user can use available templates and choose modules based on required application. Easy to use as modelling time is reduced due to less programming. User can use VB if advanced modelling is required. Optimization can be achieved using ARENA opt Quest.

***Interfacing with other Software:*** [95]

ARENA is a Microsoft compliant product. The software was developed using MFC (Microsoft Foundation Language) and codes were written in Visual C++. All standard user interface options available in Microsoft are available in ARENA. Through ACTIVE X (previously called OLE) ARENA can be integrated to spreadsheets. ARENA supports Data Access Objects (DAO) and ODBC (Open Database Connectivity) that allows it to be integrated with database systems [180]-[194].

An example module named “SERVER” in ARENA is used to illustrate the concept of building blocks in simulation context.

ARENA: Evaluation-SERVER building Block [95].

ARENA is a flow-oriented simulation tool that uses templates for construction of models. Building blocks as described in [11] are objects that are composed of other objects in a specific way and have well defined interface to user of building blocks. Each building block is a self-contained, interoperable, reusable unit that encapsulates its internal structure and provides functionality to its environment through interfaces. Building blocks involves two main roles. One played by model constructor and other role is the building block developer (Table 3.8 below). Building blocks available in discrete event simulation tool ARENA with the module “SERVER” as example. It consists of four parameters Arrive, Queue, Resource and Leave modules.

Table 3.8: Evaluating the server building block available in ARENA [11]-[32]

| | |
|---|---|
| Functionality | It includes lot of functionalities like Resource Claim, defining failures and schedule of Resource, Queueing and unload Transporter |
| User input settings | Changes according to setting of user. Seven buttons are there that open new dialogs |
| Ease of understanding capabilities during run | User interface is very good. It is easy to understand what the model is capable of doing as Queues, Resource states and station names are shown in model without opening the dialog |
| Building block extensions | Extra logic can be added at one place of the module, but it is very difficult to know when this extra logic is executed |
| Computer resources during run | Conditional compilation occurs that knows which part of logic will be used based on setting in the user dialog. All additional logic are left during compilation and this results in minimized use of computer resources |

The simulation software selection research was performed to make sure that right simulation software is chosen for our research. A variety of simulation software that are currently available in the market was taken in to consideration. Upon detailed research it was found that ARENA possesses some unique features that are not available in other software's. To specifically mention ARENA software gives an opportunity of writing SIMAN code by users that would help them in detailed modelling. ARENA software also has Visual Basic that is a powerful language for creating custom interfaces. An entire description of ARENA software in terms of modelling, tools available, software features, and application areas has been covered in this research. To support this idea different examples are illustrated that gives the readers more outlooks about the ARENA features [13][14][52]-[57][70]-[95]

Some of the key benefits of using ARENA for this research are [57]-[77] (i) Programming time is reduced [greater flexibility with regard to random numbers, probability distribution, simulation time, data analysis] (ii) All the available modules in ARENA simulation software depict the real system in a better format. The flow of entities from simple to complex model is in a clear fashion (iii) Using simulation language like SIMAN we can easily make changes to the model as the code can be changed in a particular block. Verification and debugging tools in ARENA will help to detect errors. (iv)

53 simulation software packages are available in the market, out of which 43 are logistics and 39 provide animation, which would help to decide errors during model building. ARENA has the best animation features that can be used for validating complex simulation models. Real system can be studied in all aspects. ARENA simulation software has been used to perform major simulation studies in areas of network queue management,

business process simulation and industrial engineering. Even though network simulator (ns is very good for simulating network management operations still it does not provide good graphical features as well as effective analysis tools when compared to ARENA). ARENA is best suited for simulating network queueing systems; network routing algorithms and policy based network management systems with priority pricing schemes approach. (v) ARENA has VB that can be used for detailed modelling. Less programming time will make the modeller's job easy as all "Blocks" and "Elements" are hard coded in advanced (vi) ARENA also has ability to model in-process storage that depends on arrival rates and service times. (vii) Some of the unpredictable behaviour like network service management that depends on resource activity time, network queue time, user usage of network resources can be modelled more effectively using ARENA as it supports a variety of network management modules (different network attributes can be assigned). (viii) Even though majority of simulation software available in market support "analytical models", these models are constructed and validated. Once the results are obtained and helps in decision-making process the models are seldom used again. ARENA helps the modeller to change the model (analytical aspect), which can be used for effective operational planning and scheduling. Thus the gap between analytical and operational modelling is bridged. (ix) ARENA is visual interactive software. Entities action at every block in model can be traced and summary reports can be collected [73][88][95] [177]-[203].

ARENA simulation software is one of very few software packages that help in tailorability to any specific application. The software is not restricted to any specific application but can be easily tailored to variety of applications. This was particularly true when ARENA was used for illustrating policy-based networks and routing algorithms that clearly shows that it can even be extended to networking applications. Different modelling requirements for users are available with different templates available in ARENA. If a user wants to model healthcare system then he can use the healthcare template that has different modules to support the required application (Beds, Nurses, Doctors, X-ray). Users who are interested in modelling network traffic flow can use traffic flow template (Resources, Server, Inspect). Thus users can model their own problem and ARENA provides the user the possibility to model it as close to real system as time and complexity allow. This reduces the level of modelling abstraction required by the user [200]-[212].

The simulation software comparison included some of the key parameters such as computer graphics, animation and imaging, output analysis, model size, cost modelling and analysis, optimization process, customer support and training, integration to other packages, model verification and validation and operating system platform supported. The comparison is purely based on author's point of view and will vary for others depending on their modelling requirements. The comparison (Table 3.9) was done based on available information in the listed simulation software website and also referring to the simulation buyers guide and simulation software guide. The criteria category (Good, Moderate, Very Good) was assigned to different software's based on the following features [73] [212][213].

Table 3.9: Simulation Software Comparison on the basis of software features [70] [73]-[90]

| **Software Name** | **Application** | **Features classification** | **Score (Out 0f 10)** |
|---|---|---|---|
| Factor/Aim | Manufacturing systems, Production planning and production scheduling | Good (Industry planning applications) | 7 |
| ROBCAD | Manufacturing systems, materials flow modelling and industrial simulations | Good | 6 |
| Simul8 | Activity based costing | Moderate | 6 |
| SLX | Optimization | Low (not aimed at variety of applications) | 6 |
| Proof animation | Used along with many other discrete simulation packages for animation | Low | 6 |
| GPSS/H | Manufacturing and materials handling modelling, queueing systems modelling | Very good | 8 |
| Micro Saint | process modelling and action view animation | Moderate | 6 |
| Witness | Modelling working environments like distribution centres, restaurants and help desk systems | Good | 7 |
| Call centre maestro | Call centre applications | Moderate (for call centre applications only) | 6 |
| ProModel | Manufacturing process | Good | 7 |
| SDI Industry | Materials handling | Good | 7 |
| RiskOptimizer | Sensitivity analysis | Good | 6 |
| Statfit | Statistical analysis | Moderate | 6 |
| Extend | Business process modelling, network transportation and queueing systems. | Good | 7 |
| SimEngine | Resource scheduling and 3D imaging | Good for graphics application | 7 |
| ReThink | Business process design and analysis | Moderate | 5 |

| | | | |
|---|---|---|---|
| OptQuest Optimization | Industry optimisation problems modelling | Good | 6 |
| AutoMod | 3D graphic simulation | Good | 8 |
| Quest | 3D modelling of complex systems | Good | 8 |
| Factory Flow | Factory modelling. Has interfaces with many CAD packages | Good | 7 |
| Factory Sim | Materials flow modelling and production modelling, material flow visualization, materials queue and batch size | Good | 7 |
| ARENA | Network management modelling, network queue modelling, industrial modelling, resource optimisation, , | Very good (SIMAN language, VBA modules, animation and many successful case studies) | 8 |

The table below shows comparison of ARENA simulation software and object oriented simulation packages (Table 3.10).

Table 3.10: Comparison of ARENA simulation software and Object oriented programming simulation packages [73][88][95][111]-[185]

| **ARENA Simulation Software** | **Object Oriented Simulation Packages (Sim++, MODSIM, SIMTEC, WITNESS, PROMODEL)** |
|---|---|
| ARENA is based on SIMAN language. It does not allow user to create new objects. Even though ARENA is built using OO paradigm, the extendibility of applies only to modules and not to any SIMAN objects. It differs mainly from OO package in a way that it does not allow user to create his own SIMAN objects. | They support creation and description of new objects. |

| | |
|---|---|
| Level of expertise required in modelling is less when compared to OO simulation packages. The main reason for this is because the package itself comes with hard coded modules that can be used for variety of applications (Network management, Mechanical engineering, Material management and aeronautical engineering). | Level of expertise required is very high as the user has to write code for each and every application using OO concepts. |
| Model development requires less programming skills, however users have the option to write their own VB code for detailed modelling. | Model development requires very good programming skills and a lot of experience. This is true if you need to model very complex systems. |
| Animation features are excellent | Animation icons can be created but is highly time consuming process. |
| Modules available are sufficient for simulation study in all areas | Modules need to be coded and all attributes have to be included. |
| Simulation execution: Different speed control tools available. | No speed controls mechanisms are available. |
| Cost: Expensive | Cost: Moderate |

## 3.10 Introduction to SIMAN Modelling Language

A simulation computer program can be written using FORTRAN, and COBOL. However these languages require a lot of experience in programming and are time consuming. Even a simple queueing theory problem involves a lot of complicated details that are difficult to be coded. To overcome this special purpose simulation languages like SIMAN, SIMSCRIPT, GPSS, and DYNAMO were developed. The main aim of these languages is to speed up the conversion of a simulation model to a computer program. Thus different simulation languages can be used for different simulation studies and this makes the simulation modelling and analysis easy for the user [97].

All the modules available in ARENA were created using modelling blocks in SIMAN. SIMAN blocks are available to all users in SIMAN template. Using SIMAN modules we can incorporate detailed system logic in to the model. SIMAN code is written in text editor and linked to ARENA model using link tools. ARENA encompasses object oriented language and hierarchical modelling systems. User can create new modelling constructs from basic model primitives (SIMAN blocks/elements)[97].

Example of SIMAN objects in ARENA includes Resources, Queues, Transporters and variables. Modules in ARENA are classified in to two main types, they are

*Base modules*, which are the low level modules in ARENA [97].

*Derived modules*, which are built from base modules

Queue module in ARENA directly corresponds to the Queue block in SIMAN. SERVER module is a derived module that is built from Queue, Seize , Delay and Release modules. ARENA is employed with SIMAN template for providing graphical model building. ARENA template correspond to base modules from SIMAN template. Single module in ARENA combines several SIMAN modules, so modelling is much easier and with fewer errors [97].

CINEMA is a general-purpose animation designed to animate models developed using SIMAN language. Even though the summary statistics from simulation run play an important role in evaluating simulated network system performance it cannot be used to identify the system status under which bottlenecks occur. This can only be achieved using animation. Animation can be used for model building, verification and validation, bottleneck detection, analysis and presentation to decision makers. Bottleneck analysis is very important in simulated system and animation helps the modeller to observe various interactions of events within model and provides information that are unavailable in statistics (Checking whether model design is correct and visualizing the model working process). CINEMA was developed with three main design objectives. They are [81][111]-[176]

1. Simplicity: CINEMA can be used to master in any detail level of animation quickly as it is simple. Animation does not require any programming experience and so user can fully concentrate on developing useful realistic models and data for analysis.
2. Flexibility: CINEMA is flexible enough to be used to represent animated system for variety of areas such as telecommunications, manufacturing and health care modelling.
3. Effectiveness: Effectiveness is measured based on how valuable graphical images are during different phases of simulation project. CINEMA can be employed in simulation project phases to validate model, detect bottlenecks and many "what-if" questions can be explored [81].

SIMAN is a simulation language that is used widely for modelling network systems operations in a network management set up. SIMAN helps us to analyze different set of discrete and continuous systems. SIMAN program consists of two different types of frames.

They are

1). Model Frame: Represents the main process.

2). Experimental Frame: Represents specific activities [97].

The model file contains logic statements that are used to represent the network systems under study. The experimental file consists of data that is to run the simulation model. When model and experimental file are compiled then error-checking process is done, if there are no errors then the object file is created (file that has required code in the form the computer can understand). Mostly errors can be corrected and files can be recompiled. The only error that is difficult to correct is run-time error. This error occurs when two files link successfully and program files are executed. The run- time error can be corrected using run controller that allows us to step through model execution. After successful running of model, output is saved to print file [97].

Some useful blocks are:

*OPERATION*- Entity operations such as processing are performed in this block.

*HOLD*- this block is used in transporters module to hold entities.

*TRANSFER*- Entity transfers occurs in this block.

*QUEUE*- Entities are queued based on ranking rules.

*STATION*- Entities are processed in specified stations and routed to different stations.

*BRANCH*- Entities are branched and processed in this block.

*PICKQ*- Entities are picked from selected queues in this block.

*SELECT*- Entities are selected based on specified logic and rules.

*MATCH*- this block helps in call centre models in finding out the rank of entity by duplicating original entity and matching the duplicated entity with original entity at specified time [97].

Once a particular model is created using the available modules (Block Diagram), it will depict the way in which the entities will flow through the model. The model linking which is done through "connectors" available in ARENA will help to control the actual entity flow from one module to another. Entities for example, say, Users are elements about which we want to collect data. Attributes can also be assigned to corresponding entities that is a descriptive property of particular entity. Entities that flow through the model undergo change in states. Different states that entities undergo are as follows [97].

The key lists that are maintained by ARENA during simulation run  time are shown in Table 3.11.

Table 3.11: Different states that entities undergo during simulation process [97][101]-[113]

| State | Description |
|---|---|
| Active State | In this state the entity currently moves in to the system. |
| Ready State | In this state entities wait for entering the active state. |
| Time-delay state | In this state entities are delayed until specified conditions are met. |
| Dormant state | Entities are in dormant state so that any changes in model conditions will not trigger them automatically. In this case the modeller is the one who supplies the logic to transfer them back to ready state. |
| Conditioned delay state | In this state entities are delayed until specified conditions are met. |

Current simulation software's have building blocks like Server, Queue, Resource, Transporter that could be used by model builders to build simple models quickly. Research work done in [206] indicates that a lot of user-input is required and there is also increase in overhead in the model. Authors [206] propose building block elements that can be used to produce building blocks that are more flexible require very less user input and reduce the overhead of the model.

Advantages of Object oriented paradigm for developing simulation models are better model maintainability, extendibility and re-use of models and model components, faster model verification process and models can be changed easily to fit different experiments

ARENA is used mainly in measuring the performance of call centres and also make excellent decisions with regard to call routing and capacity management. ARENA helps us to make accurate and better simulation models for call centres. With ARENA simulation package we have got excellent facilities like knowing the call arrival patterns and also conduct various experiments on staffing scenarios and maximize performance and capabilities. Real-time statistics for time interval which are very relevant to our service level goals can be achieved. ARENA simulation technique helps us to develop simulation models that exactly depict the proposed application. With ARENA we can obtain a fully integrated real-time simulation capability and also enhanced data manipulation [88][95][134].

ARENA simulation, like many other network simulation packages like OPNET, can be run, stepped and also paused. This allows us to model areas such as routing networks where network variables like routing tables can be examined at different time periods. One of the main advantages of ARENA is that it is a very generic package that can be used to simulate a variety of telecommunication systems. ARENA was used within School of Electrical Computer and Telecommunications Engineering (SECTE) at the University of Wollongong, Australia to illustrate routing algorithms. The authors have also used the package for illustrating the queueing systems such as M/M/1, M/M/2, M/G/1, M/D/1 and tandem M/M/1 queueing systems that are found in open queueing networks. Sub-models can be used to represent the embedded queueing system within the main network and thus helps us to reduce the complexity of the network [135]-[137][144]-[188].

## 3.11 Conclusion:

In this chapter a detailed review into discrete event simulation methodology and justification of this methodology for our research study has been carried out. Discrete event simulation is a way of building up models based on the dynamic behaviour of a system. It helps analyst to model behavior of the network system as time progresses. There are a number of potential areas for the application of discrete event simulation techniques. However this chapter discovers the application in networking to place the use of this type of simulation in our research context. Numerous examples have been covered in the methodology review section in network technical and functional service areas. Some of the key steps involved in the discrete event simulation modelling are to first understand the overall objective of the study. Then it is important to understand the level of detail that is actually needed. The model needs to be checked if it relates very well to reality. The results should be verified for credibility and whether it reflects the model performance. Appropriate output analysis techniques need to be followed in order to validate the model results and increase the model confidence. The modeller can also use the Visual Basic Application (VBA) available in many simulation software packages to enhance flexibility and maintainability of the simulation models.

The chapter also discusses the simulation software ARENA that is used for this research project. Justification of this software for this project has also been covered to highlight the suitability of this software to model both technical elements and functional elements in the networking area. When constructing the model to simulate a system the simulation analyst has to write a program using the modelling constructs of the simulation language. In this chapter we have shown that even though this approach provides flexibility, it is time consuming. Using commercial simulation software that exist in the market with advanced capabilities (animation, reports, existing models, VBA) it is easy for managers and also analyst to build models faster and also use animation features to visualize the entity flows. A careful consideration has to be made while choosing the simulation software. The number of required features that are essential in our research domain have been highlighted. It is important to strike a balance between cost incurred in buying the simulation software against the operations benefits the software can bring to the organization [122]-[186].

User training and vendor consulting cost needs to be covered as well. Simulation software like ARENA helps the modeller to model the problem with little (or) no programming. This reduces the model development time and also provides the modeller the opportunity to look at example model files in relation to his application domain and gain a better understanding of applying such an approach for his own problem modelling. Its is important to check if the system consideration fits the domain of the simulation software package as selecting the right simulation software is one of the key factors of a successful simulation study. Chapter 4 covers the key technical network scenarios modelled and how it led to the model development process. The SIMCTS model was developed in a number of stages using simulation scenarios. The scenarios used in the development of the final model for this research can be broadly classified into technical and functional scenarios. Technical scenarios are covered in Chapter 4, this then led to SIMCTS framework that was used to model functional scenarios.

# Chapter 4: Model Development

The final SIMCTS model was developed in a number of stages using simulation scenarios. The scenarios used in the development of the final model for this research can be broadly classified into technical and functional scenarios. Technical scenarios include modelling network service operations while functional scenarios involve service quality attributes modelling. The scenarios covered in this chapter include modelling and simulation of alarm based network management system for effective SLA monitoring and management and simulation of policy based network through differentiated service levels. The scenarios were used to test factors that affect customer satisfaction like network admission control, priority based resource allocation, identifying the metrics to be monitored and faults likely to occur by generating alarms and setting the performance thresholds. Scenario 1 on policy based network management was modelled to achieve the research objective 1: "*Forecast or predict planned changes and their effects on current network management operations, network resource policies and study if they would have a positive or negative impact on the current level of customer expectations*". Scenario 2 on SLA study was also modelled to achieve research objective 1: "*Investigation of what effects the SLA (service level agreements) will have on customer expectation and customer satisfaction. The importance of keeping up with service levels specified in SLA's and checking the effectiveness of the network alarms in service level monitoring using simulation modelling and analysis".*

The two scenarios covered in this chapter helped to understand the importance of discrete event simulation technology to model network service operations. The results of this modelling and simulation scenario is presented and discussed in detail in Chapter 6. The two scenarios helped to understand how discrete event simulation modelling and analysis works and why it matters in a networking context. This led to the next step of identifying the elements of SIMCTS framework and develop generic steps to conduct service quality simulation studies using such a framework. The application of SIMCTS framework to model functional elements are demonstrated using 3 scenarios covered in Chapter 5.

## 4.1 Technical service quality modelling scenario using Discrete Event Simulation Technology

### 4.1.1 Background to Scenario 1

Large internet environments are increasing the difficulty of network management [51]-[55]. Network managers face a serious problem in controlling user-based services and packet delays across the network. One of the main areas of concern that requires attention is how to effectively manage corporate network costs and allocate usage based services [57]. Users should be included as a part of the network design. The differentiated service scheme can help providers to effectively manage user usage based resources. The simulation package chosen was ARENA. The simulation scenario modelled has helped to re-emphasize the usability characteristics of users that designers may overlook. Simulations are very useful to understand network traffic patterns in large organizations so that they are able to achieve the best network performance. The differentiated service scheme simulation model collects statistics about users, service type to be provided for various user groups, manage user resources and thus reduces network downtime. Network time based analysis through queueing theory principles helps us to avoid congestion in network and facilitates effective network administration [186]-[215].

The Internet has become a commercial enterprise serving a lot of people across the world [56]-[58]. Usage accounting through differentiated service levels has become an important factor to support network management operations and cost recovery process for the future of internet [59]. Users expect a consistently high quality of service and reliability. Service level architecture helps us to use different service level classes for distinguished packet streams. Usage accounting through various service levels helps us to analyze the traffic patterns of internet, which would help in both operational and capacity planning tasks [60][61].

One of the main problems faced is the resource allocation process for various users at different service levels. Network managers are faced with increasing difficulties of exactly predicting the service expectations of different users at different service levels. This causes the users to have their own expectations, which sometimes are unrealistic, and causes misunderstanding between ISP and users, as they do not provide the guaranteed service. Resource allocation and management tends to become more complex as different parts of the network are owned by different entities and owners need to carry packets from other networks through mutual co-operation and this creates a low response time as different networks may not support the required Quality of service. Due to the above reasons it has become very important to simulate some of the features of this service level process using ARENA simulation modelling software and investigate its impact on network service operations [62]-[66] [68]-[70][111]-[186].

### 4.1.2 Scenario 1 Model Development

A new approach to understand the importance of differentiated service levels in network management platform has been carried out using ARENA simulation software. Network simulation model has been created and various aspects of service level operations have been incorporated in to the model. Investigation of the impact of different arrival rate on network path queue time using graphical analysis has been conducted [71]-[75].

### 4.1.3 Model Objective

The main objective of the simulation model developed in this scenario is to identify the importance of differentiated services in policy based networks and how it helps to effectively manage user usage of network resources. The simulation model investigates user usage level for particular service levels which collects network usage statistics, improves network resources allocation process, ensures user admission control to network and allocates resources through priority queueing process [71]-[75].

### 4.1.4 Main Model Working Process

Two main simulation models were created. One model represents the "Resource allocation process" to various users and other model to ensure "Admission control to network resources". ARENA comes with a lot of pre-defined modules. **Arrive, AdvServer, Resource** modules were used to model system. Priorities are set through Assign button in Arrive module. The user request process takes place in Server module and all statistics about users are collected. The Admission control model uses Arrive, Server, Choose, Depart, PickStation, Tally, Sets, Transporter, Delay, Distance**,** Depart, Recipes modules used to model system. Entities are prioritized using Choose module and level 1 entities are always passed. The entities of second and third level have specific traffic contract and are admitted based on conditions specified. Detailed explanation of these modules is available in [83]-[87] (see figure 4.1)

### 4.1.5 Sub-Model Working Process

Users arrive in **Sub- Model** and they are split according to different priority classes. Network resources are allocated based on the user requirements. Users who require no more than two network resources are served in non-preemptive manner than those who require more than two network resources. They uniformly use resources between 1 and

5. **UNIF( )** function available in time between options in ARENA helps to define this. Halt and Move modules are used to halt entities when transporter is not available and move them when it is ready [83]-[87].

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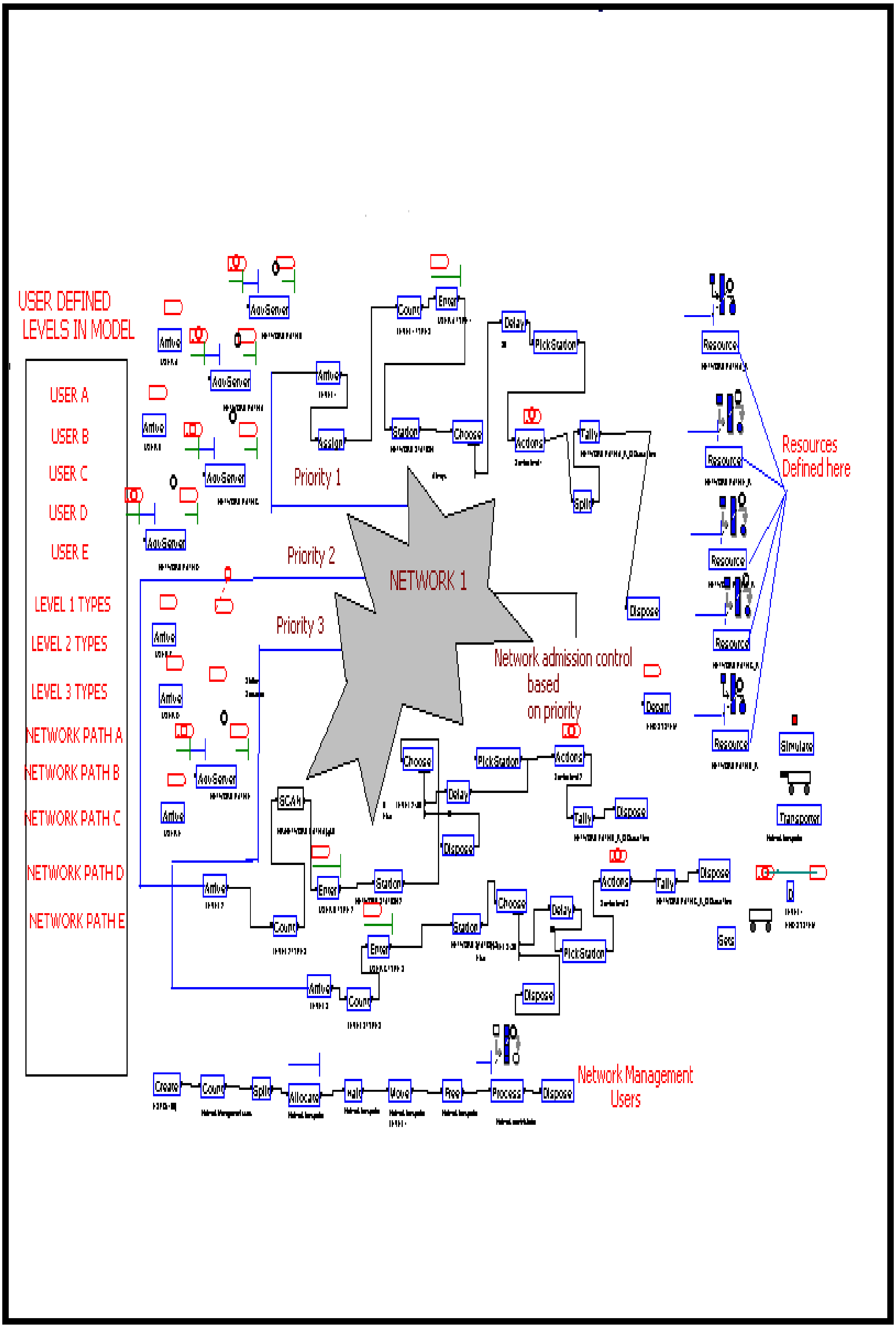


Figure 4.1: Simulation Model of Service Level Policy Network [111]-[182]

### 4.1.6 Achieving improved network resource allocation using Network Admission Control Process

One of the important aspects that has been identified through this simulation is the importance of admission control in efficient usage of network resources. Users are identified based on service class and are allowed to use considerable amount of bandwidth based on service level admission control processes. This clearly indicates that users who request any network service with guaranteed quality of service are processed through admission control mechanism [145].

Level 1 users have their network resources reserved as they belong to highest priority class. The traffic contract for these users clearly indicates that they will be given priority to use network any time they want and will be provided good quality of service. Level 1 users are supported at network level through resource reservation, admission control and traffic engineering.

Level 2 and level 3 users belong to the second and third priority level. When a network connection is requested by Level 2 users the network verifies the user- network traffic contract that includes network performance level, bandwidth allocation, user usage level. If a request is successful and there are any free resources users are served. Level 3 users have to undergo the same process and have to wait for any free resources to be available after level 1 and level 2 users are served. They undergo a phenomenon called *Starvation* as they may wait for a long time. Once a particular level users starts using the resources they can use the network till they wish to terminate their use and at the end of service the packet with highest priority is served next. Thus these users are served in a fair manner as they should be given optimum level of service. If the network has no free resources, connection request is denied and users have to keep trying again and will be served on priority basis[138]. Thus through this process user usage level identification according to different service classes is achieved and this improves the network productivity. The service level policies used in the model will help us to control the network resources and services. Some of the important aspects of the network service policies include connectivity and performance. Thus priority is given in access to buffer space [83]-[89].

### 4.1.7 Background to Scenario 2:

This scenario uses simulation as an important process in improving understanding and analysis of SLA management and monitoring. In general, simulation studies are not conducted by various service providers to the fullest possible extent and this leads to poor customer satisfaction. The phase where simulation needs to be performed is discussed and what aspects of SLA management has to be simulated. A simulation model for SLM is constructed. The study identifies alarms as an important tool in effective network resource management. The modules developed as part of the scenario is used to describe the need for simulation in effective SLA documentation and SLA monitoring. Different scenarios within SLA levels using ARENA simulation software are analyzed and also demonstrate how it helps in identifying end user services and satisfying customer expectations. The model helps to better understand critical areas in SLA such as alarm monitoring, metrics to be monitored and reduce resource overuse. This helps to conduct successful simulation studies, identify the right simulation software for simulating every aspect of SLA management. The model is validated using sensitivity analysis, queueing principles and visualization using animation and hence our experimental results are both valid and reliable [111]-[186].

Service Level Agreements (SLA) are becoming very important in today's world as customers are dependent on ISPs for their businesses and in-house use. SLAs are becoming important to satisfy customers that they are being provided good service according to the defined contracts. A properly documented SLA will not only help the ISP to promote their business but will help the ISP to thrive in a competitive market place. Not much emphasis has been laid on conducting simulation studies on identifying customer requirements and services to be offered to meet those requirements. Simulation studies will not only help to identify the above mentioned facts, but will also help ISP beforehand to check if network meets the desired services to be offered, what metrics need to be monitored during SLA monitoring. This helps in effective SLA creation and also effective SLA monitoring. Many new ISPs who wanted to draft their first SLA find it very difficult as they are not very sure of service level management goals and performance metrics to be included [83]-[87].

One of the key reason of using simulations for SLA monitoring is that it helps to identify different types of customer with different expectations and priorities by doing different "what-if" analyses. By conducting simulation studies ISPs can verify their SLA agreements and check if it meets customer expectations and whether the specified service could be provided. The major challenge in monitoring SLA is to establish an effective SLA and to understand the performance indicators (network delay, response time, network availability, service availability) associated with the network [88]-[91]. This will help to set realistic service expectations that will be guaranteed to users.

### 4.1.8 Problem studied in the Scenario 2

This scenario helps to identify simulation as an important process in documenting SLA agreement. Till now simulations have not been widely used by various service providers to the fullest possible limit and this leads to an SLA that fails to keep up with customer expectations. The description of exact phase where simulation needs to be performed and what aspects of SLA management have to be simulated has been discussed. The model helps to justify the simulation approach which highlights the need for simulation in effective SLA documentation and SLA monitoring. Different scenarios within SLA levels are analyzed using ARENA simulation software and a relation is established showing how it helps in identifying end user services and satisfying customer expectations [91]-[94]. The software is a useful tool for simulation of call centres, telecommunication queueing systems and manufacturing, materials processes. Arena has five templates which allow for the support of a specific application. They are Block, Elements, Common, Support, Transfer. Based on the layout of simulation, modules can be picked up and can be connected. All the information related to that particular module needs to be entered in to its dialog box. Animation is included with many modules and so both the simulation and animation modelling processes can be done. The model jump wizard in ARENA help us to quickly build the models and helps to specify the key parameters for models like entity, number of stations . SIMAN blocks are available to all users in the SIMAN template. ARENA is built using this SIMAN simulation language and integration via DAO (Data Access Objects), ODBC (Open Database Connectivity) can also be done. ARENA has an input analyzer for determining appropriate input to a model. The output analyzer facility help us to view the simulation results after the simulation has run to completion. It also helps provide graphical display through histogram, plot and meters. Real-time controlling and monitoring is done through ARENA RT for the purpose of making the simulation model to interact with external clients[95]-[98].

### 4.1.9 Importance of Alarms in Network Management

Alarms perform a routine check to make sure all the operations taking place within the network are going on smoothly, however if a check fails a process gathers information about type of check that has failed, time of the day and the level of importance. Three main levels exist within the alarm monitoring feature based on the importance and nature of failure - Critical, Major and Minor. Alarm surveillance is used to monitor the condition of the network usage thresholds set through SLA devices. One of the main areas of focus is the usage levels that help us to identify a particular resource usage and determine its availability. Alarms can be generated for different SLA violations (using more bandwidth, heavy traffic, congestion in networks) [99][100] [121]-[167].

Representing adequately and correctly the system under study was given the primary importance while modelling. “How to effectively configure alarms” in network management requires good simulation study with proper simulation software. This will help us to experiment with different thresholds for different customer levels, which is an important factor in SLA documentation. Inaccurate simulation study will not only cause service degradations to customers (service not being provided according to SLA), but will also cause poor SLA monitoring as correct threshold patterns are not identified and right performance metrics are not monitored. The main aim is to study the appropriateness and effectiveness of using simulation software to solve problems related to SLA management and monitoring [101][103]

### 4.1.10 Neglecting simulations studies leads to service failures

One of the main reason why Service providers fail to provide defined service according to SLA specifications is due to negligence of conducting simulation studies. Simulations are not done either due to lack of time, rush to be first in the market, pressure from customers and finally competition in the market place. This leads to service measures that are not identified properly. Some important factors that needs to be included when conducting SLA simulation studies are [104]

Do the simulation study results help to find out whether the desired network can support wide range of customers who have different thresholds in terms of availability, response time and service guarantee.

Can the network handle e-business applications that might increase the network load due to transaction between the web server and database server?

What type of applications require monitoring check to check if the service provider is providing service as per SLA?

Can the network set up be able to cope up with additional load when there is increase in number of users?

It is suggested that simulations should be used in the first place to do different "what-if" analysis based on which service levels have to be established (should also consult vendors (or) suppliers) and then SLA agreement should be created for customers. "What-if' analysis helps us to check the service performance limits and identify misbehaviour in network configurations. Thus corrective measures can be taken before services failures occur. Other reasons include lack of resources for monitoring and reporting services [105]-[107].

The following objectives have been identified while studying this scenario [107][108][167]-[176]

-Service provider will be committed to service being provided to customers.

-Ensuring user satisfaction by checking whether the network can meet end user requirements.

-Identifying the metrics to be monitored, which particular area where faults are likely to occur and generating alarms by setting thresholds and prioritizing the alarms based on their importance.

-Record the different scenarios examined using simulations and analyzing the output and validating the model.

The following types of simulation study have been identified.

What type of service each group of customer needs to be simulated?

How important is the service to be used is to the customer (Business (or) personal use).

Additional service to be provided to each group of customer based on the service level priority.

SLA needs to cover all essential service metrics that will be monitored and detailed explanation of various policies used.

The successful running of ISPs depends on variety of factors but to be more specific proper planning, good simulation studies, right monitoring tool and good pricing scheme [100]-[103].

### 4.1.11 Model Development: Service Level Management Process Module

In this section investigation of the service level policy implication on network users is covered. Users arrive in the **Arrive** module and then are sent to the **Server** module for the intended service they require. Using the **Branch** module helps to control the user entity flow through a set of branches. A user entity arriving in branch module is checked for a specific branch condition and then sent to next module specified. Probabilistic branching involves assigning the probability ratio for entities. In the model 0.65 probability criteria that most of users choose the policy service type A in as the SLA is reasonably good (assumption of good network service, resource allocation). The rest of the users choose policy 1 as it has two main processing levels. A **Duplicate** module is used for implementing this process and users can select payment on monthly as well as weekly basis and then entities go to the service agreement level in the server module. If the first two types of policies are not suitable then users have no alternative than to choose policy 2 that has various resource limitations such as Number in Queue less than 50, (NQ(select policy 2_R_Q) <50 the network cannot accomodate users above this limit). User requests are processed based on network availability and are allocated resources accordingly. [101]-[105].

### 4.1.12 Alarm Module

Alarm based model study identifies the importance of experimenting with different threshold queue and resource patterns. It is possible to generate alarms using multiple VBA modules. Many alarm situations can occur. For example an alarm situation where a queue exceeds some threshold can be visualized. When this occurs in a Random Early Detection queue (RED), a message is generated and a warning is sent to the customer's equipment to indicate that SLA agreed levels are being used up too quickly or that congestion has occurred in the network. Such an approach has been installed in ATM and Frame Relay protocols in the past. The packets that enter the VBA can be coded to indicate what type of warning has occurred. An investigation of how the number of replications, queueing thresholds and simulation run time affect the model has been carried out. This is will be particularly useful in major SLA network simulation studies where ISP have to experiment model under different network scenarios and increase the model confidence. Failure to understand the nature of model, assumptions, working process and number of replications to be used will cause simulation inaccuracies and result in simulation study failures. Some of the scenarios include experimenting with different processing time for network users, different arrival rates and thresholds patterns. To specify threshold conditions and raise alarms if the condition is exceeded "SCAN" and "VBA" modules were used. The variables module was used to set thresholds like Queue time, Response time, Server processing time. When a user entity enters the VBA module the code VBA_Block_1_Fire( ) code is executed and an alarm is raised. The simulation model created using ARENA includes status alarms and threshold set for threshold generated alarms where an increase in threshold causes alarms to be generated and equal to threshold causes warnings. The variables for which the threshold value is set helps to find if the router is becoming very busy and check if interface utilization is too high [101]-[105].

All statistics about packets can be collected using count and tally modules. This is important to identify those users who generate heavy traffic and violate SLA regulations. ARENA helps us to collect the Packet busy time, Packet availability, Packet queue time and number of packets that are waiting in queue, packets lifetime in network system and packets affected by congestion. Thus, every packet processing stage can be traced throughout the simulation. The arrival rates of packets were varied and their impact on the router's availability (busy or not) to reduce the network downtime was studied. The simulator parameters eg., number of customers with SLA's versus number of sources using TCP/IP default such as best effort were varied, and then ascertain the best mix of different quality of service requirements in an internet was ascertained[101]-[105].

### 4.1.13 SLA Process Module

The main aim of developing a SLA simulation model is to understand the working process of network SLA level service operations. The main problem faced in this process is how to effectively process network entities requesting for resource allocation and trace the entities that generate heavy traffic due to overuse of network resources.

The model has arrival of users in the network management system. Once the users arrive they are sent to the network server for resource allocation based on network SLA level. Here VBA in ARENA was used to allow the users to enter their processing time thresholds and study different threshold patterns. This will help us to understand individual users threshold waiting time period that would help us to set processing times based on outcome of the experimentation. The model uses Delay module where user entities are delayed and assigns the network state based on resource allocation outcome. Four main variables in the model namely FINISHING, STATUS CHANGE, DONE, TO BE DONE are based on resource processing for user entities. The entities are delayed based on their status change. The variables are declared using the variables module.

To check the user SLA level another model that has arriving SLA level users was used. Probability logic is used to specify entity destinations using the "Chance" module [101]-[105] (See Figure 4.2). The model is experimented with probability logic for packet level 1 type and use Else for packet level 2 types. Attribute named TYPE 1 is used to distinguish the packet type based on defined level. Packets are signalled to proceed and are batched based on the TYPE value specified. To prioritize packets belonging to level 1 attribute called TYPE is assigned and defined the packets to be "First". In level 2 packets are given attributes value of "Last". Packets are delayed and higher priority packets are signalled to proceed and lower priority packets are grouped and split for processing based on SLA LEVEL 2 policy.

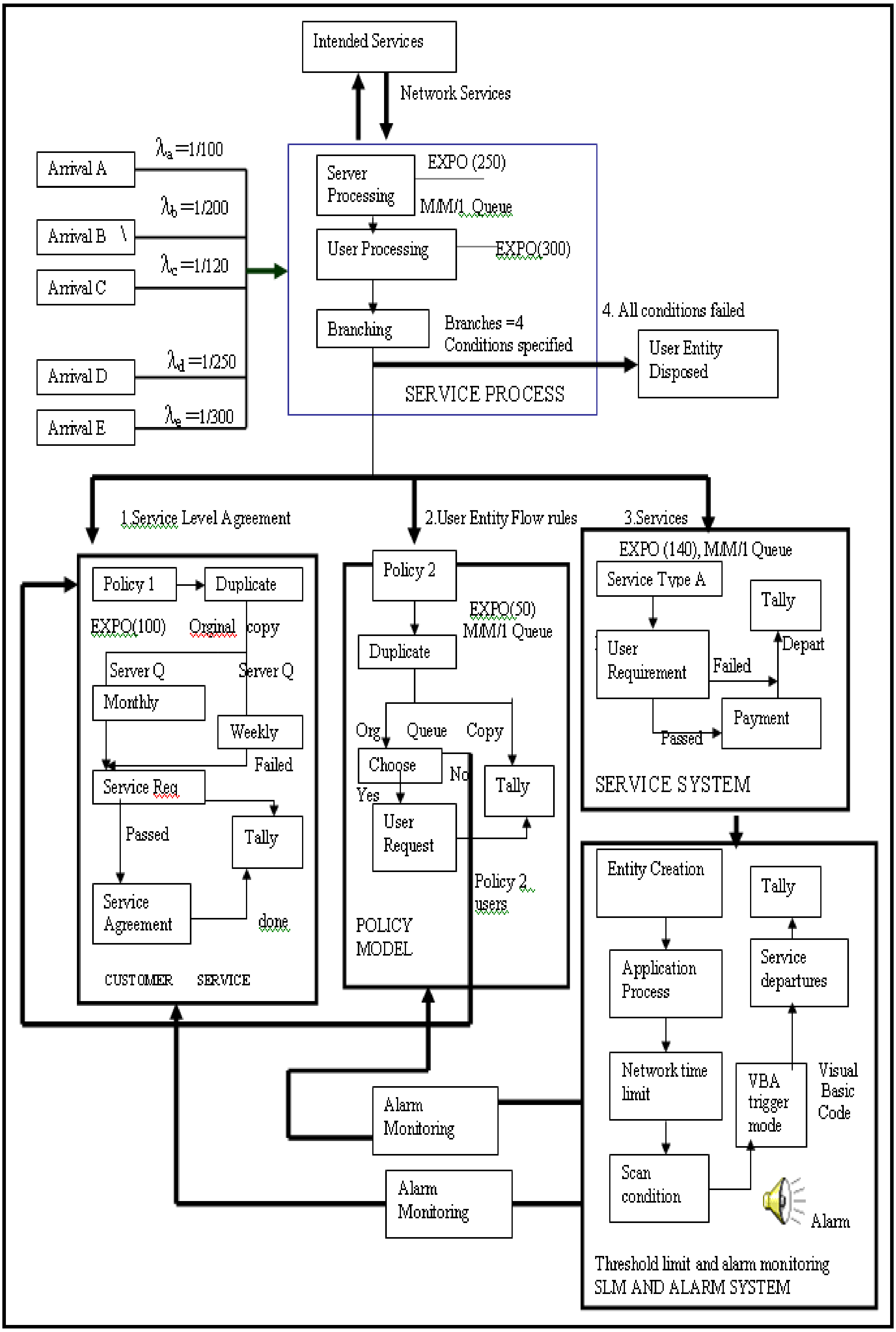


Figure 4.2: Functional Block Diagram of Alarm Simulation Module [113][188]-[215]

“AdvServer” module uses Station Set defined in SETS module. It also uses Resource Set defined in SETS module. Process time is defined using the statement Time(Type, SetIndex). It depends on the Type of packet. This is done by assigning attribute named Type for two packet level processes and giving different values to them. SETS module defines a group of similar elements that are referenced by common name and Set Index. A variable named Time is defined in the variables module with initial values set. A counter Set is used to count number of packet 1 and packet 2 routed. The sequences module helps in defining the router characteristics for Packet Level 1 and Packet Level 2 routing with status as router available, router busy, router working [101]-[107].

## 4.1.14 Network User Inspection Process Module

A module has been constructed to illustrate and study the importance of processing the end user services and providing services as per defined SLA conditions. The model has an “Arrive” module where service arrival entities arrive and are exponentially distributed. Once the users arrive they are sent to the server for specific service provision. Different service arrival rates are used and the process time for these entities is declared in Server module. The entities are then routed to the Inspect module to check the type of SLA process that the network offers and whether the service provision required by the user satisfies it. Based on pass and failure of inspected data the entities are routed. All the entities undergo specific queueing delays during the routing. All unsuccessfull entities are reworked (processed once again) before they are disposed. During the rework inspection the capacity type is specified as schedule with process time and failure probability defined. Based on pass and failure of inspected data entities are routed to collect statistics (Figure 4.3).

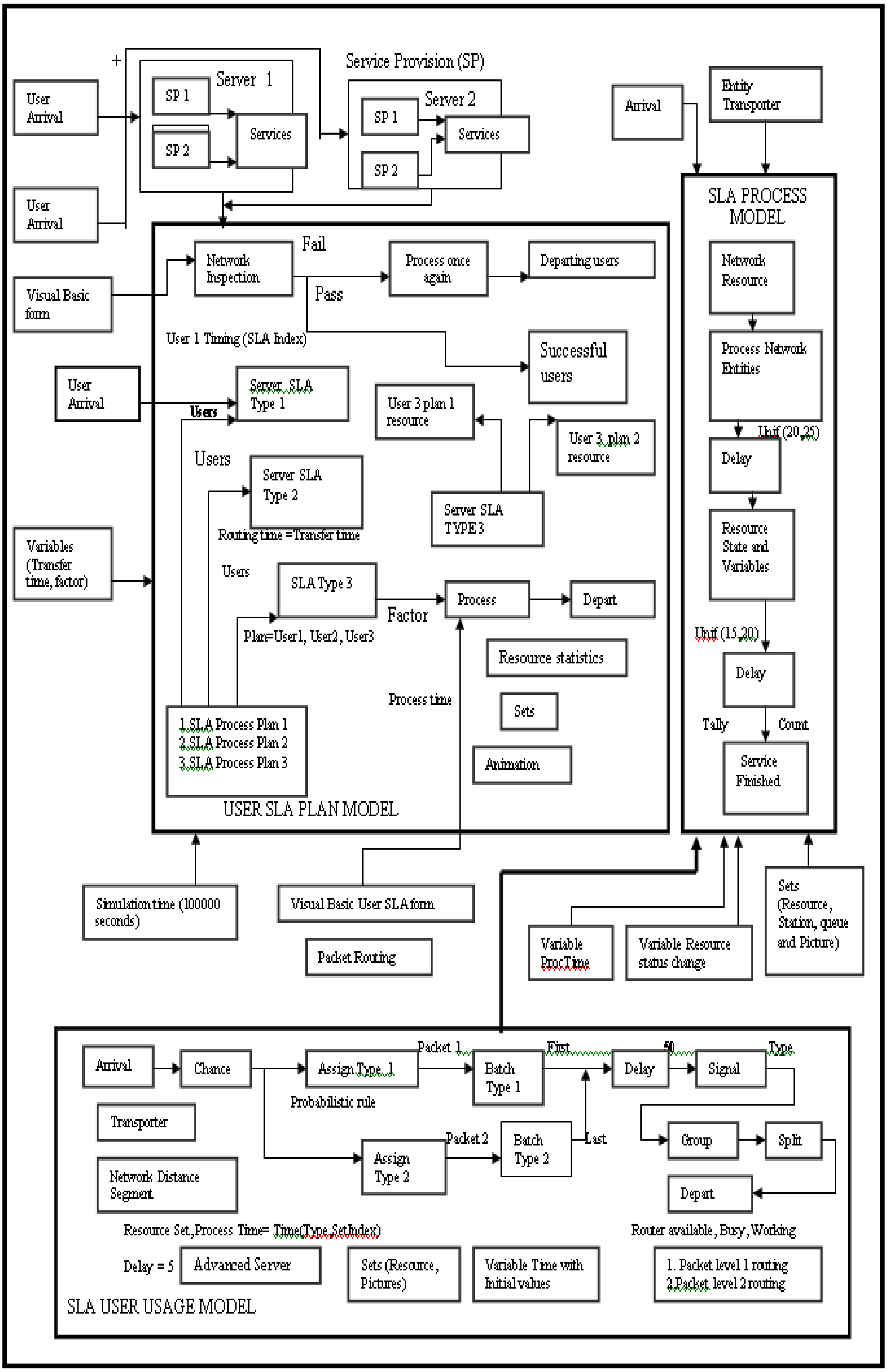


Figure 4.3: Functional Block Diagram of SLA module [50]-[100][102]-[167]

The statistics module used in the model helps to collect time persistent statistics based on queue data object. Animation was employed to visualize the entity flows and thus helps in validating the model. Visual basic applications in ARENA are used to display a form where user is allowed to enter a value for network user inspection time and failure probability. This helps us to store information in modules and run simulations. Thus simulation helps to check whether appropriate network service provision can be provided as per SLA and satisfy customer expectations [101]-[105].

### 4.1.15 User SLA Process Plan Module:

The system is modelled with user arrivals and SLA network system and departures. User 1, User 2 and User 3 are processed according to their corresponding servers specified. The module uses two SLA plans for User 3 the old plan and the new plan. The difference between User 3 and the other users is based on resource transfers for the users (SLA plan Type). The model uses user types and process time defined. The interarrival time is exponentially distributed with a mean of 50. For the verification purpose user entity is allowed to enter the model and trace the entity and check if the model logic and data are correct. The Step feature available in ARENA is used for this (stepping the model). To control different user entity types discrete distribution that is used for user type with specific SLA user types is replaced. The validation involves 95% confidence interval approach (assuming gaussian distribution) used to check if the model is working as intended [101]-[105].

## 4.2 Conclusion

The simulation study that was conducted on SLA identifies the importance of modelling and simulation in alarms based network management system for effective SLA monitoring and management and problems in coming up with effective SLA’s. The Service provider needs to come up with effective SLA’s which can be delivered.

Over promising and under delivering can lead to dissatisfied customers. SLA's guarantee to customers that service provider will deliver the services as indicated in the SLA. This study answers research question 1 *"What are the problems encountered in the understanding and managing of service level agreements between customer and service providers for small ISPs?*" and sub question 1.1 "*How can simulation be used to forecast or predict planned changes and their effects on current network management operations, network resource policies and study if they would have a positive or negative impact on the current level of customer expectations*?".

The other study on simulation of policy based networks for differentiated services highlights the importance of having a flexible service provisioning strategy based on individual customer service needs. This strategy works by implementing differentiated services scheme using priority based queueing system (network queueing policies). This simulation study answers sub question 1.2 *"What are the key technical specifications that influence the overall customer satisfaction in network service environment?"*and 1.3 "*How can simulation modelling and analysis help service providers to provide flexible service provisioning based on specific customer service needs*?" The study identifies the key network service parameters like network queue time, resource allocation, queueing policies, network traffic and their impact on overall customer satisfaction. This study also highlights the importance of differentiated services using policy based network management for flexible service provisioning. This chapter justifies the effectiveness of discrete event simulation techniques to model network scenarios and to manage network services. This research found that apart from managing key technical parameters and identifying room for improving network performance metrics, it is also important to provide good functional service (customer support, billing, service provisioning, credit control, complaints). By aligning technical service strategy and functional service strategy ISPs can create satisfied customers and keep them loyal. This is very important as customer satisfaction is influenced by factors outside the ISP network (empathy, responsiveness and ISP staff morale). Many small ISPs fail to provide good customer support services as they lack training and good business plans. The reports published by Telecommunications Industry Ombudsman [2] highlighted increasing technology specific complaints data in small ISP industry. Some of such complaints issues re highlighted in Chapter 1. This chapter provided us motivation to carry out further research and the need to come up with a structured simulation framework that will help small ISPs to understand and manage service quality data.

Simulation is an effective way to understand the underlying principles of the network management system. Simulation of service level policy networks is usually seen as a complex task, but in this chapter the justification of how ARENA simulation software could become an effective tool in simulating service level networks and understand the underlying principles has been covered (scenario 1 modelling). The importance of differentiated service levels that helps us to establish traffic priority for different packet streams has been identified. The importance of different service levels on the performance of queueing systems was also briefly investigated by performing this simulation User usage level and resource reservation is one of the key factors in the Policy Based Network Management System. The simulation model developed helps us to better understand the need for policies in networks and how it helps in efficient usage of network resources. This is definitely new and an alternative approach to study a policy based network management system. The simulation results obtained can be verified using simple queueing theory principles, therefore the validity of results achieved is extremely reliable. Thus discrete event simulation technology was found to be a appropriate method for modelling technical quality scenarios [86]-[89].

The usefulness and importance of conducting SLA simulation studies using discrete event simulation software like ARENA has potential benefits for service providers for not only running the business successfully but also effectively managing and monitoring the network as per SLA contract. The simulation model developed in scenario 2 modelling provided reliable results of SLA network under study and thus the results helped very much in validating model and performing successful simulation study. The importance of performing effective SLA simulation studies using discrete event simulation software ARENA was briefly discussed. Neglecting simulation studies not only causes service failures but also conflict between ISP and customers [100]-[103].

# CHAPTER 5: SIMCTS: A Simulation Based Approach to Understand and Manage Service Quality Data

This chapter presents the proposed SIMCTS framework and also discusses the objectives of the framework. A separate section on the application of the framework in managing service quality by understanding customer expectation and perception has been included. The key elements of the framework along with its benefits and various steps to be followed in the simulation case study conducted using SIMCTS has been included to highlight that a structured and disciplinary approach was followed while modelling service quality attributes. The chapter presents three simulation case studies that identified the appropriateness and effectiveness of using a consistent framework such as SIMCTS to model service quality attributes involved in ISP business operations. The first case study highlights the use of SIMCTS framework in modelling ISP complaints satisfaction dimension such as Responsiveness: which is ISP response to customer complaints (or) queries. The case study measures the actual time and estimated time to resolve complaints and found that there is strong correlation between the actual time and estimated time as a function of satisfaction. The second case study describes the importance of understanding the customer tolerance for waiting and models two main factors which are customer balking and customer reneging. The key benefits that can be achieved by simulation in modelling these service elements in ISP call centre context are also discussed. The third case study highlights the importance of using simulation to achieve optimal call centre service model in relation to call centre schedules, resources and operators. It identifies the benefits that can be achieved by cross training call centre operators where operators can handle different calls addressing different issues. The importance of simulation to re-structure the call centre and improve the call centre efficiency has also been clearly presented [70]-[100].

## 5.1 Introduction to SIMCTS Framework

The main goal of the SIMCTS framework is to establish a win-win situation for both the ISPs and the customer. The SIMCTS framework will help the small to medium sized service providers find a means for understanding customer satisfaction patterns for telecommunication services using simulation studies more effectively and also improve the service quality of simulation studies done in this area using effective modelling and analysis techniques. Success of simulation projects depends on three main factors, credibility, validity and acceptability of simulation projects. To increase the chances of successful outcome out of these simulation studies customer focus (what service patterns to use), constant service process improvements (Identifying areas of improvement by measuring service processes) and total commitment to provide good service to customers is essential. The service quality data obtained from running simulation models as part of SIMCTS framework will clearly help in answering the following questions: 1. Who will benefit from the results? 2. Different "what-if" scenarios used to achieve these benefits 3. Service metrics to be collected for decision making [5].

## 5.2 Objectives of SIMCTS Framework

The following are the key objectives of SIMCTS Framework:

(i) Ensure that simulation study performed to improve the service process objectives leads to any observable benefits. ii) to ensure the credibility of the results (output analysis) and results are at acceptable levels. iii) effective implementation of changes to existing service process based on simulation results and implementing the solutions and making sure results of simulation study are relevant.

Simulation has emerged as an effective technique for studying business applications and as a result provides better services to customers. Service providers are however, often not aware about the service quality issues they have to deal with and probable impact they can have on customer satisfaction. Service providers should collaborate with each other and exchange various service quality issues. Simulation framework will help service providers to be aware of various additional problems related to service quality, customer loyalty and retention. While developing and building the composite elements of SIMCTS framework clearly we have used a pragmatic way of thinking. The simulation model developed addresses these issues. Refer to Figure 5.1 for the components of SIMCTS framework [10][11][77]-[95][177]-[215].

The effectiveness of these models will be evaluated using surveys. The model will help service providers widen their approach to handling service quality conflicts and thus help in having a clear and realistic service quality vision. The simulation will potentially help small and medium size ISPs to study a specific question/problem and the results of which can be used for operations valuable for long range planning [10]. A generic problem in service quality is to understand its role in the business decision-making process. It becomes very important to collect the right set of data and have a structured approach to identify the service quality issues surrounding ISPs. Further research in providing insight is highly essential to create awareness of various service quality issues and make them discussable[172]-[215].

## 5.3 SIMCTS used to measure discrepancy between customer perception and expectation for service

The Introduction of new services and their success will depend on the service providers justification that the development of higher service applications and their use will be welcomed by customers (enough customers to use the service). Although the benefits of simulation have been identified in numerous areas, simulations are not employed to understand customer satisfaction patterns in telecommunication services and this leads to poor customer satisfaction. Simulation can help service providers understand the effect of implementation of new services and their demand in residential and enterprise customers[171]-[215].

The service industry comprises many small to medium sized businesses that are not able to run their business successfully due to the above-mentioned reasons. Even if simulation is used to understand customer satisfaction patterns, there is some anecdotal evidence that suggests that simulation studies fail to achieve their potential (the right simulation tools and modelling languages have to be used to model each scenario)

Research work in [60] states that some services are intangible ie they cannot be measured which makes it difficult to understand how a customer perceives and evaluates the service. We believe that simulation can be used to overcome this limitation. Even though we cannot measure the service directly we can atleast understand what impact it has on customer behavioural patterns. As performance is heterogeneous in nature (varies from one service provider to other) it becomes very important to model a variety of scenarios and find room for improvement by employing simulation.

A customer's perception depends upon service delivery process and what is communicated to the customer about delivery of service. There are two main levels of customer service expectations. They are desired level and adequate level [60]. Desired level is the level where the customer hopes to receive the service , while adequate level is the level where the customer finds the service acceptable. Desired level and acceptable level are separated by a zone of tolerance. If perceived performance of service level falls within zone of tolerance then it is a competitive advantage. If the perceived performance of service level falls outside the tolerance zone it is a competitive disadvantage. If performance exceeds desired service level it means increase in customer loyalty [60].

To measure the discrepancy between customer expectations for service and perceptions, SIMCTS framework becomes highly essential. This framework will be a guideline to do simulations of customer satisfaction patterns for telecommunication services and will also help to know how to have a measure of quality for simulation projects done in this area. The SERVQUAL instrument [215] is based on transient services where service processes are only brief (banks, telephone companies) while simulation requires more protracted service process

**Important areas this framework will address**

(1) To develop a comprehensive and consistent framework that would help us to understand the requirements for customer service simulation projects.

(2) To apply this framework to various aspects of network service management.

(3) To understand the various issues relating to design and management of network service operations.

SIMCTS framework can be used by service providers to evaluate the services they offer, identify the room for improvement, effective modelling of the problem identified using simulation tools and understanding the problem in detail, identifying right tool to simulate different service patterns. The stages highlighted in Figure 5.1 have been applied in network simulation scenarios studied in this chapter. With so many factors involved in customer satisfaction process it is important to have a frame work that can be used to understand a variety of service scenarios and use simulation to model these scenarios. Even though it is impracticable for a framework to cover all scenarios, but still the framework will cover most important and complex scenarios and it can be refined after testing with number of service providers.

## 5.4 SIMCTS and its functional elements

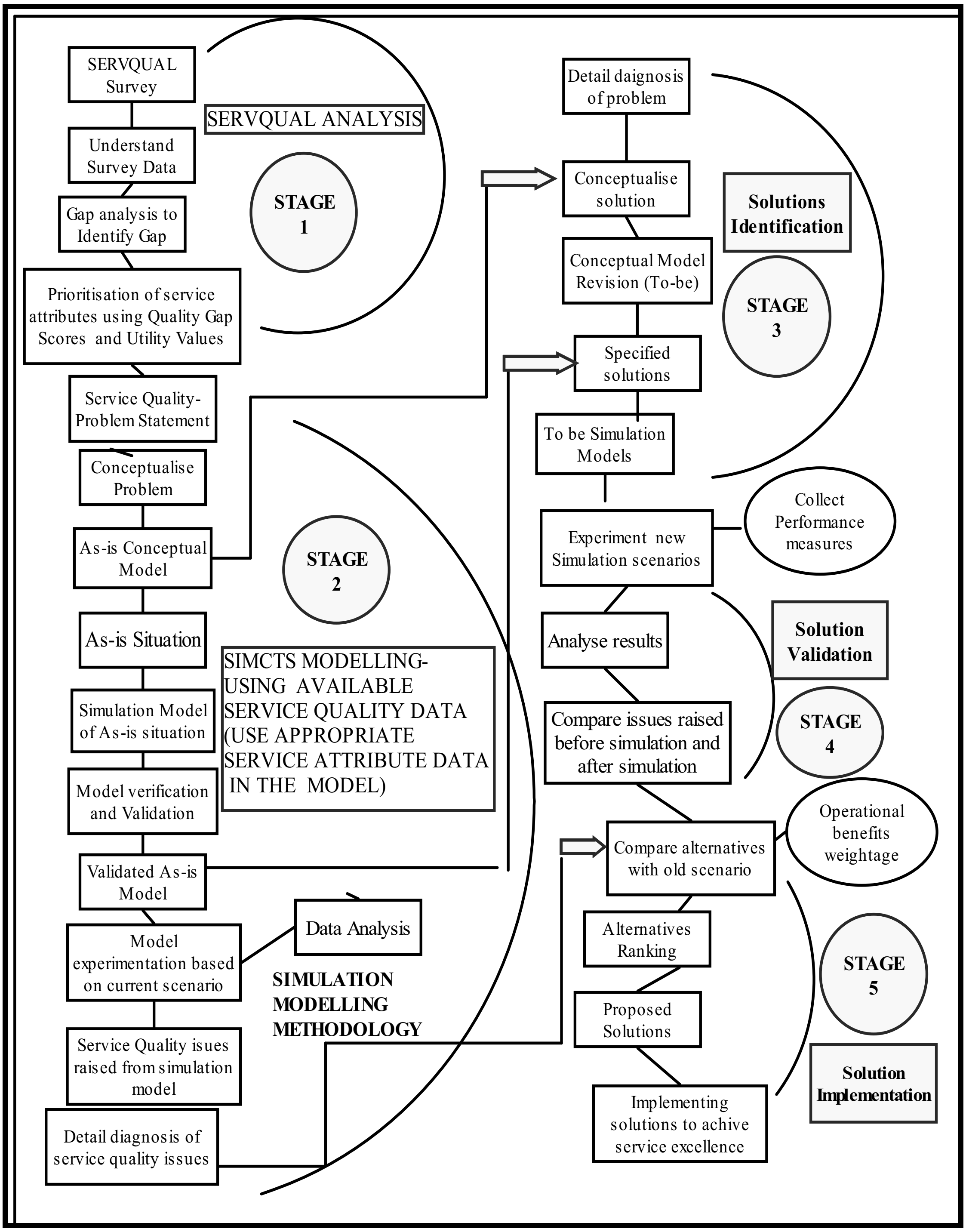


Figure 5.1: The functional elements of SIMCTS Framework [100]-[122][155]-[215]

The main aim of SIMCTS framework is thus to (i) ensure that simulation study performed to improve the service process has achieved its objectives and there is a observable benefit in customer satisfaction level (ii) to ensure the credibility of the results (output analysis) and results are accepted (iii) effective implementation of changes to existing service process based on simulation results (iv) implementing the solutions and making sure results of simulation study are correct. Figure 5.2 covers the various areas of analysis [177]-[215].

**Closing the Loop (Model –Survey - Model)**

Please see print copy for Figure 5.2

Figure 5.2: Closing the loop using SIMCTS Framework [111][181]

SIMCTS framework can help to build required models using service quality data obtained from survey and using them as data inputs to the model. Data collection and model analysis could always be time consuming. It is essential to decide the required type of data and required amount of data immediately after problem formulation. The SIMCTS framework consists of several individual building blocks that act as a reference for ISPs to clearly understand the required service quality data for modelling specific service scenarios involving customer satisfaction modelling (Refer Figure 5. 1). Service providers can be asked to complete survey questions about usability and additional value of simulation models upon usage of the SIMCTS framework. Their comments on the degree to which the simulation model and simulation study framework provides operational benefits to them will also be used to revise the SIMCTS framework [6]. The application of this framework is highlighted in a case study which involves modelling ISP call centre operations (network scenario 5).

## 5.5 Benefits of SIMCTS framework

**(I)** The benefits from the service provider perspective would be provision of cost effective solutions, increased profits which leads to growth, popularity and seeding in confidence in the minds of the customers and (all this means staying in a competitive business).

**(II)** The benefits from the customer perspective would be cost effective technological solutions to problems, a variety of choices to choose, good rapport between customer and service providers and reflection of true expected customer requirements in the solution provided. Altogether, benefits will lead to the establishment of a good service provider to customer relationship. The aim of the SIMCTS framework is to establish a win-win situation for both ISPs and customers.

## 5.6 Generic steps involved in SIMCTS Simulation case study modelling

Table 5.1: Steps involved in the SIMCTS simulation scenario modelling [181]-[194]

| |
|---|
| Step 1: Identification of the problem |
| Step 2: Definition of the problem |
| Step 3: Exploration of solution/ improvement necessary to solve/mitigate the problem |
| Step 4: Select several key elements as part of the solution |
| Step 5: Build a model and identify the interrelationship between the elements and their dynamicity on the problem |
| Step 6: Identify the functions of the elements defined in selection to the problem |
| Step 7: Develop a generic model- (SIMCTS) using simulation studies – (Technique to |

| |
|---|
| study the benefit of such a framework) |
| Step 8: Build and model SIMCTS elements |
| Step 9:Simulation study involving ISP complaints modelling |
| Step 10: Verify and validate the results |
| Step 11: Iterate the model based on several outputs from several case studies |
| Step 12: Keep revising the model towards the ideal values of determinants of customer satisfaction |

## 5.7 Application of SIMCTS framework in modelling ISP business operations: SIMCTS simulation models, analysis and validation

The proposed SIMCTS framework has been tested in modelling the call centre scenarios involved in ISP operations. With the increase in the types of network services provided which are tied to different technologies (broadband, dial up, satellite) call centre operators will be asked to troubleshoot a wider range of issues [100]. Thus expertise is required across multiple technologies. There are also technology specific complaints that are recorded by telecommunications ombudsman [2][100] and hence ISPs providing multiple technologies need to have effective complaints handling procedures in place. This is achieved through a case study that has been conduced to show the importance of the service quality dimension “responsiveness” as a means to understand and manage dimensions of complaint satisfaction (actual time and estimated complaints handling time as a function of satisfaction).

The other case studies that are covered in this chapter defined the service quality issues involved in ISP call centre operations and the key challenges to be faced. After this the keys service attributes that are determinants of customer satisfaction are modelled. Different ‘what-if’ scenarios are modelled to gain insight into the service quality issues that were identified. The results help us to investigate the question “can discrete event simulation techniques serve as an effective tool to understand and manage service quality data for different ISP service operations ”. From the results of the case studies and subsequent validation of the simulation model we conclude that discrete event simulation is an effective approach to understand and manage service quality data in ISP sector.

### 5.7.1 Importance of using SIMCTS Simulation framework to understand and model service quality dimensions in relation to ISP Complaints

Complaints help us to gain better insight into the customer’s mind. Complaints help us to know why customers are dissatisfied and what steps can be taken to solve them. ISP industry report [18] indicates that information collected through surveys are past information indicating customers experience with the service and are subject to distortion. Complaints, which is unsolicited feedback, are current, real and not subject to any memory distortions. The report highlights [18] that complaints provide us with an opportunity to have good service quality procedures in place ahead of competition and move towards exceeding customer expectations. Thus *actionability* plays a very important role in whether the information collected leads to continuous improvement.

Customers do not complain due to the uncertainty about whom to complain, a sense of futility and also due to the complicated procedures involved. In order to elicit genuine complaints it is important to have a designated person to handle complaints, have a toll-free customer complaint number and an official management response to complaints. Thus increasing management knowledge about the complaints is very important. To counteract employee reluctance to pass on the complaints to higher management anonymous procedures and various proactive procedures should be followed. One of the proactive approaches is to employ simulations to model the complaint process. Then check with the available human resources whether the management is able to provide a quick response and has strong commitment in meeting the customer needs on time. A good complaint elicitation system should provide a quick response to customers. When a response to a complaint is delayed it is natural for the customer to assume that nothing has been done about it. Thus it reinforces more dissatisfaction with the network service provider [102].

One of the main difficulties in measuring service quality is determining which employee is delivering how much of customer service. It is important to know how satisfied the providers are with the resolution of the complaints issue? And how well the department handled the issue? Research work carried out in [168] states that in an increasingly competitive market the ultimate competitive advantage is to learn in order to respond and change faster than competition. He also states that service quality is the key factor on which to collect feedback and also it has a strong influence on overall quality and is the most difficult factor to manage [102].

It is very difficult to manage service attributes, which is not measured as a part of service quality. Therefore measurement of service quality and customer satisfaction is very important for service management and improvement. This measurement can be done using service indicators, standards and performance targets. The most important attributes that are difficult to manage should be a focus of service managers so as to operationalize the measurement approach [102].

Complaint dissatisfaction has the potential to stimulate negative word of mouth and will drive customers to their competitors. Thus it is very important for small and medium sized ISPs to understand the construct of complaint satisfaction and understand the expectations of customers who complain. It is also important for ISPs to know which aspects of the company’s response customers evaluate. If the service managers of ISPs are able to identify the determinants of complaint satisfaction and know exactly what the relevant service quality dimensions of complaint process are from the customers perspective, they are able to improve the complaint process and bring complaint satisfaction and customer loyalty [102].The customer who complains has certain expectations regarding the company's response and the desired solution.

Perceived complaint response: The expectations for complaint response are the comparison standard for the company's reaction. Complaint satisfaction occurs if the expectations are exceeded. Complaint dissatisfaction occurs if the perceived complaint response falls below the expected complaint response.

The determinants of complaint satisfaction fall in to three main groups, which are customer related, problem related and quality of the companies' complaint management [102]. Several factors that depend on these three groups include *Prior experiences of complainant*, *Customer loyalty, Service quality*, *failure severity, organization commitment. perceived service quality and service guarantees* (See Figure 5.3)

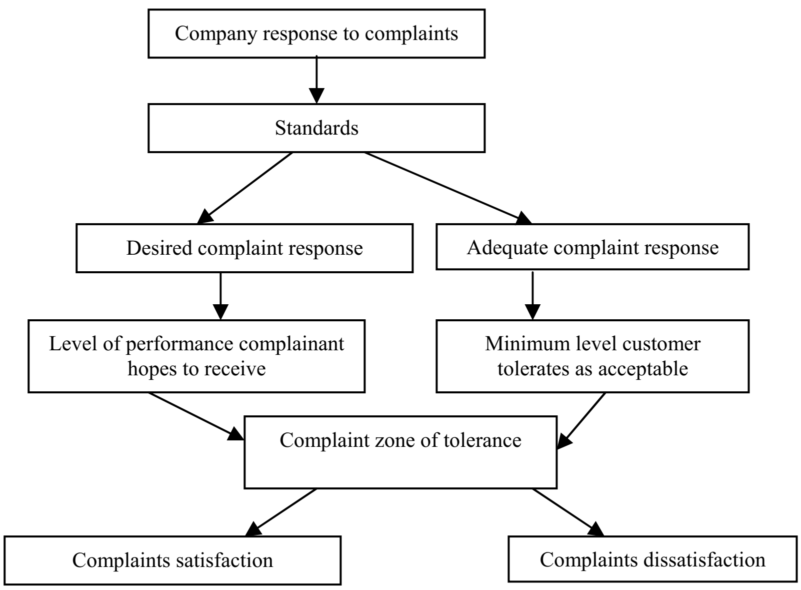


Figure 5.3: Disconfirmation model of Complaint satisfaction [120]-[140]

Dimensions and attributes of complaint satisfaction play an important role to know what elements of the complaint the customers evaluate. Thus ISPs have to know what the dimensions and attributes of perceived quality of complaint management are, and then they can make a decision to improve their service processes. Several attributes of complaint satisfaction include *reliability, Speed of response, Empathy, Friendliness, Access to complaint procedures and fairness of the outcome.*

Outcome complaint satisfaction and process complaint satisfaction are the two important dimensions associated with the above attributes. Outcome complaint satisfaction is to the evaluation of what the complainant gets from the ISP (technical quality). Process complaint satisfaction refers to the evaluation of how customers complaints are handled (functional quality) [102].

### 5.7.2 Appropriateness and effectiveness of using SIMCTS Simulation framework to understand and manage service quality issues in ISP call centre scenario

Simulation modelling facilitates test analysis of different scenarios to understand their impact on a broader 'system' or provide 'proof of concept' evidence before moving forward with implementation plans. It enables managers to determine the likely consequences of investment, operational decisions and process changes before they are implemented. Such a capability is increasingly important as the number, complexity, and cost of technology and process alternatives grow. Simulation also helps managers demonstrate to executive management the positive and negative impacts of such decisions on a contact centre. Spreadsheet and Erlang C tools can be used to optimize simple contact centres, whereas simulation can be used in a complex and dynamic situation [12]-[123].

Simulation modelling uses several techniques to reflect reality and to assure accurate comparisons between different scenarios [121]

- Events happen in a pseudo-random manner, which is what happens in reality.
- Multiple simulation runs makes the results more representative.

There are a number of reasons to use simulation instead of analytical models in contact centre management. First of all, analytical models provide averages, and not variability and extremes. Simulation can provide dynamic information of any complex system. Simulation can handle randomness. Secondly, analytical models cannot identify process bottlenecks or recommend design changes. Static results of analytical models are insufficient. Thirdly, analytical models often cannot provide sufficient detail to identify interaction. Animation, which is used in simulation, is a better method of demonstrating interactions and results to management [124]-[139].

On the whole, simulation is an effective methodology when dealing with complex operation, accuracy is important, variability is high, animation is needed to sell concepts to management, more than just averages are needed to understand the implication of process changes, and process bottlenecks are to be identified [124][125].

**Opportunities for using simulation modelling in contact centres** [121]-[126]

- Skills based routing development.
- Conditional call routing/call scripting testing and analysis.
- Work flow/Business Rules changes.
- 'What if' planning/analysis of contact types, volumes, and arrival rates.
- Multi-media contacts (email, web chat, etc.), process and resource development.
- Call volume analysis based on Website activity (callback, emails, etc.).
- New IVR application analysis.
- Existing IVR application analysis and improvement.
- Contact Centre consolidation analysis.
- Contact Centre virtual networking analysis.

- ROI analysis of technology implementations (IVR, CTI, etc.).
- Customer service satisfaction estimation.
- Validation of existing design efficiency.

**Key performance measurements looked at in contact centre management are:**

- Reduce waiting times.
- Efficient customer support.
- Improved customer satisfaction.
- Reduced queue times.
- Improve trunk tracking.
- Reduce telephone costs.

Additional performance indicators include average speed of answer (ASA), agent utilization, abandonment rate, average length of call, and percent answered without waiting [123][124].

There must exist a balance between costs, service quality and employee satisfaction when managing contact centres. To achieve the balance, simulation is an effective methodology. It can help estimate the costs that can incur given a benchmark for service quality and employee satisfaction [126] (Figure 5.4).

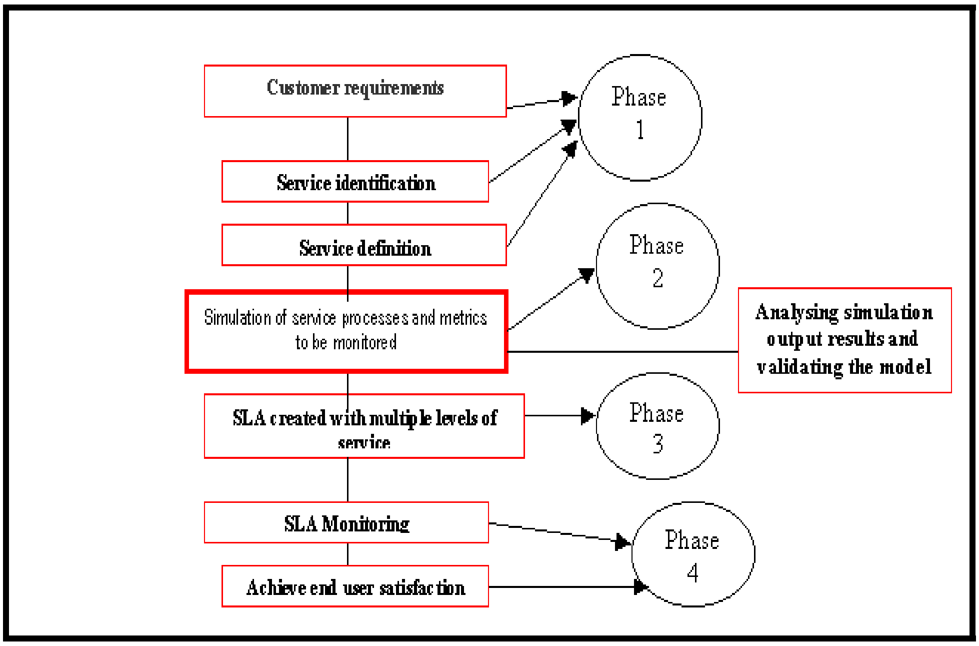


Figure 5.4: Various phases involved in service quality simulation [122]-[140]

The current contact centre industry is increasing in its complexity; the management and design of the modern contact centre is becoming extremely complicated due to rapid enhancements in technology, reengineering initiatives, and call-routing strategies [121]. As mentioned above, there is also constant pressure to reduce costs while still maintaining the service-level objectives. To handle the complexity, dynamics and variability, there are numerous simulation software products available in the market. These simulation software are not all the same; they have different features, way of modelling, and requirements. For instance, some simulators are embedded within contact centre applications and others are standalone applications. Embedded simulators have the advantage that there is no need to copy the call centre operation map to the simulation environment manually. However, the type of experiment that can be done is limited. Standalone simulation software, on the other hand, have the advantage that any type and amount of experiment can be conducted (See Figure 5.4). Therefore, it is always wise to consider and select simulation packages that fit the specific requirement of the system. For call centre simulation, we outline here the important features that are required from simulation packages.

Work done in [121] [206] provide a framework for simultion software evaluation and selection. The framework consist of seven categories: (i) vendor, i.e. related to the evaluation of the credibility of the vendor, and to some extent the software; (ii) model & input, i.e. is concerned with a simulation model, (iii) its development and data input; execution, i.e. include features used for experimentation; (iv) animation, i.e. includes features for creation, running and quality of animation; (v) testing & efficiency, i.e. is concerned with features for testing, debugging and efficiency of the package; (vi) output, i.e. features for displaying results of simulation run; and (vii) user, i.e. deals with some specific user needs and circumstances. Some of the features considered in each category are the following [126] (See Figure 5.5).

Model development: includes features like model building tools, reusability of libraries, coding aspects, conditional routings, queuing policies, and other related aspects.

Input modes: includes input modes such as interactive mode, batch mode, and from external files (spreadsheets, database, text files, etc.).

Testing and efficiency: include debugging features, error control, reset capability, interaction with user (in running mode), multitasking, and running backwards.

Execution: includes features such as multiple replications, automatic batch run, warm up period, and reset capability [122]-[186].

Animation: includes animation development features, animation running features, display features, and icon development.

Output: include features used for displaying outputs either in terms of numbers or business graphics. It also includes capability to communicate with external packages.

User: include cost, compatibility of packages with different operating systems and hardware, package application area, modelling approach.

Vendor: includes pedigree, maintenance support, documentation, pre-purchase facility [123]-[140].

Even though there are many features that are relevant, for contact centre simulation, in one way or the other, here we list those that are very important. Existence of these features is a must to accomplish successfully, effectively and efficiently contact centre simulation projects.

Contact centres usually have huge databases of user profiles and details, which gets updated or changed frequently. Information in these databases provides useful information with regards to customer satisfaction and other relevant parameters (e.g. resource utilization and costs). Simulation models of contact centre can make use of this data effectively and efficiently if the simulation environment provides adequate features to import from databases, ERPs, and CRMs. In addition, to approximate the raw data as a distribution to be used in simulation models, the simulation environment needs to provide rich library of statistical distribution such as Normal, Triangular, and so on. Having an additional tool to process the data into distribution (e.g. ExpertFit, StatFit) is a plus. Complex arrival processes and/or varied service times can be represented accurately with rich statistical distribution library and random number generators, that are tested theoretically and statistically [124]-[126][140]-[158].

For a simulation model to be used as a decision support tool, then it needs to have rich, customizable, and flexible business graphics and report generator. Using the report generator, user can generate automatically selected results (e.g. agent's utilization, waiting time) approximated with the required confidence interval. In addition, they are able to display the results either in pie chart or histogram or other type of graphs to get more insight into the situation. Another very important feature is debugger and error control feature. As contact centres and their operations increase in complexity, the complexity of the simulation models constructed also increases. In such situations it is difficult, if not impossible, to trace errors in validation and verification of the simulation study without using debugging features (Figure 5.5) [122][123].

Please see print copy for Figure 5.5a

Figure 5.5a: Simulation software selection criteria [121][123]

One feature that facilitates simulation model development is the existence of contact centre building blocks library. For instance, ARENA simulation environment has contact centre library that helps the user build fairly complex models in a quite short time. The availability of such ‘application area’ focused library can greatly reduce model development time. Another feature that reduces the time of contact centre simulation study is scenario manager. This feature can help in conducting several experiments parallel with various experimental parameters. No matter how good a simulation environment is, it is only suitable for large contact centre simulation projects if it has good documentation and maintenance support [121][122].

### 5.7.2.1 Call centre simulation software:

There are several call centre simulation software in the market. To mention a few, ARENA Contact Centre Edition, Extend industry suite, SAS, Service model, North Highland call centre simulator and Simul8. ARENA Contact Centre edition is one of the popular package for call centre simulation. It can help companies to design new contact centres and accurately predict their performance prior to implementation, or can design competitive strategies to manage future growth and organisational change. ARENA Contact centre is an application solution template (AST) built on top of Arena and inherits and leverages its key functionality, including VBA and MS Office compatibility. It has building blocks such as Calls, Agents, Scripts, and Schedules, designed for quick model representation. It also provides seamless data transfer from workforce management tools through commonly used interfaces such as Excel and Access. In addition, it also features a call flow or script generator, a schedule editor, and a call pattern editor to describe graphically call-arrival patterns across the planning horizon [126] [140]-[158].

## 5.7.3 Network Scenario 3:

### Explanation of Service Quality in this scenario context:

Service quality measurement and customer satisfaction are increasingly becoming important for service firms to stay in the business. Service quality measurement process differs across different industrial domains as the service managers account for unique nature of services, different service attributes acting as determinants of customer satisfaction, complex interrelationship and dependability that exists between them. Several service quality models such as SERVQUAL [171], SERVPERF [171] are used by different service industries to measure service quality. To achieve excellent service quality it is important to understand the interrelationship between various service quality attributes and their dimensions. Internet service providers (ISPs) should exercise more effort to understand their customer well through relationships concepts such as length, nature and quality of customer's prior experience with service organizations especially in the context of a highly competitive market [8].

Understanding how service can be used to differentiate and enhance business-to-business relationships is very crucial for telecommunications service industry. Service quality involves customer perspective that is based upon both customer perceptions and expectations. Service quality factors that influences customer can be determined using statistical survey techniques. Both qualitative and quantitative approaches can be used to measure service quality factors. For service quality monitoring process assessment customer expectations followed by subjective as well as objective analysis of customer perception is necessary. *Work done in [177]* states simulation modelling helps to show business process as a whole, and identifies bottlenecks in the execution of the process. The changes involved in the business process include people, processes and technology. These changes results in infinite number of service scenarios that cannot all be evaluated and predicted using static process modelling tools like surveys etc. Simulation is the only possible technique that can be used when the system modelled is highly complex (Table 5.2) [177]-[197].

Table 5.2: Current scenarios and problems facing small and medium size ISPs [20]-[80]

I. Source: ABS/Year Book 2003 – Australian Bureau of statistics [2]
**Scenarios and Problems:**
Number of service providers decreased from 718 in Sep 2000 to 571 in March 2002 and the same trend continues in 2003 (small and medium size ISPs)
14% of subscribers serviced by small to medium size ISP. No difference in loyalty and retention inspite of free deals, more offers and savings, price reduction.
Number of points of presence (POP) declined down by 164 over 6 months period (March 2002-Sep 2002)
Reduction in number of small and medium size ISP by 8 from March 2002-Sep 2002. Mergers and take overs were the predominant reasons
**Reasons:**
**1.**Failure of service providers services and solutions **2.**Tough competition from peer Internet Service Providers **3.** Failure to keep up with SLA (Service Level Agreements) **4.** Poor understanding of customer requirements **5.** Lack of flexibility in proving services **6.** Inability to cope with increased customer demands and expectations
II. Source: TIO/ 2001-2003- Telecommunications Industry Ombudsman [93] [172] [173]
**Scenarios and Problems:**
Strong increase in number of customer complaints (Access Speed and Service)
72,264 complaints in June 2001 and 67,761 in June 2000. Increase form 26.3% in 2000 to 32% in 2001. The same trend has continued in 2002-2003 according to several published Industry reports
**Reasons:**
Poor service quality, customer service, unhelpful staff, lack of adequate tools to understand technical and functional quality aspects of ISPs. Failure to achieve and deliver marketing promises made, failure to stop escalation of complaints

#### 5.7.3.1 Importance OF User Level Service Quality Issues in Network Management

Majority of the past research on service quality is system-oriented and minor attention is paid to user-level service quality issues. Customer Satisfaction is either left out or is not given the attention it deserves, leaving many telecommunication network service providers suffer losses in an increasingly competitive and demanding market where ongoing study of customer expectation and satisfaction is crucial for the survival of their business [128]-[132].

### 5.7.3.2 Service Quality Issues facing small ISPs: [Customer Complaints Handling Scenario]

In a customer driven organization the main goal of maximizing customer satisfaction is achieved through service performance. It is essential to know the service attributes that customer think are very important. Theoretically minor decrease in service level of service attributes leads to decrease in customer satisfaction. A good example would be when a customer complains about service quality of internet search engines, it is very important to know which particular service attributes was rated as poor in the SERVQUAL [171] survey by the customer. After this the corresponding dimension should be identified and improved (if the customer complains that the response to the search results is very poor then the dimension "Responsiveness" as part of SERVQUAL[171] dimension should be re-evaluated. Thus the ISPs have to be good in technical service quality (service quality of search engines) and functional service quality (service quality of ISP response to customer who complaint about search engines)[27][33][171][181]-[191].

### 5.7.3.3 Simulation Model of ISP Complaint Management process

We now discuss our way of modelling showing how we employ discrete event simulation technique to construct the elements of SIMCTS framework. Waiting time might be perceived as an essential part of service quality and has an implicit cost associated with it. Customer satisfaction suffers if too many SLA violations occurs (not meeting the agreed upon conditions). The success here depends on the ability to quickly offer response to service complaints and tailor needs of customers. The simulation model helps to know how to economically staff these services to ensure better services [128]-[132].

### (i) Service Quality Attribute and Dimension focussed in the Simulation Scenario

We particularly focus on the dimension **Responsiveness** which can be operationalised in " Waiting time for processing the different levels of customers complaints" (Service Quality attribute).

### (ii) Modelling the generation and Handling of Complaint Process: Explanation of various modules used in the ISP-Customer Complaints model

**Model 1:**

We would like to discuss our way of supporting the SIMCTS framework using *ARENA* simulation software and *SIMAN* modelling language. **Arrive** module is used to model the arrival of the entities. Long-term customers and short-term customer complaints arrive. The inter-arrival time is based on expression *ArrSched(Day)* which is declared in advanced process panel expression spreadsheet. Different values in this correspond to 7 days of the week. Day is incremented by 1. Variable which is an indexed value changes based on days of the week. Control logic in ARENA was used to update variable every day. Number of variables corresponding to complaint level checks are declared in **Assign** module (Refer Figure 5.5a). Complaints are classified as major and minor complaints. The **Decide** module uses 2-way by chance process (50%-50% chance) to categorise complaints [88][95].

Please see print copy for Figure 5.5b

Figure 5.5b: "ASSIGN" Module in ARENA used to assign variables, attributes based on different complaint types [113]-[140]

Processing is performed on all complaint entities. Complaints are handled and have processing delays. Entities are delayed as they travel through the model. All resources are allocated to perform the processing. If the service managers want to answer a customer complaint process he seizes the resource and will use it until processing is done and after that he releases the resource. Thus the **Process** module covers 3 main actions, which are seizing the resource, delaying it and releasing it. All the statistics about the utilization and availability of the resource are collected. Delays follow a Triangular distribution *TRIA(10,15,20)* with minimum, most likely time and maximum time. Refer Figure 5.6 for model diagram [88][95].

Some complaint processing needs resources for three separate processes, which are defined in sub-model. For this the model uses 3 **Process** modules. First module seizes the resource and delays it for the set processing time. The second Process module will delay for the delay of the set processing time involving second complaint processing stage. Third Process module uses delay release process for processing time of the third process and then releases the resource. Thus in case of very serious complaints that needs quick response the resource is busy for entire duration of processing from Process 1 to Process 3 [88][95]. The complaints cannot be fully resolved at the point of occurrence. The model uses the service recovery processes in to the customer feedback system where complaints are recorded based on level of importance and are automatically routed to the higher management level (senior service manager) if they are not resolved within the specified time period. Thus the model uses service process monitoring data to typically improve the internal performance measures within an organization such as waiting time, system-up time and service reporting.

Complaints forms are prepared and service manager is contacted to fix the complaints. After this the information is reported to the service department. Then customers are notified that the problem has been fixed and the duplicate entity is registered in service department, after which complaint book is closed. Every time an entity arrives in the record module, time interval statistics are recorded. It takes the value of current simulation time and subtracts it from the value of the attribute specified which is the Entity *CreateTime (Time In).* Thus it helps us to know how long the customer entity took to get from one stage to another [88]. An attribute named Estimated time has a value of [88][95]

**Estimated time= 20 + NQ(Seize Service Queue)*20**

After this Satisfaction time is calculated as [18]-[26]

Satisfaction Time = Estimated time – (TNOW-TimeIn)

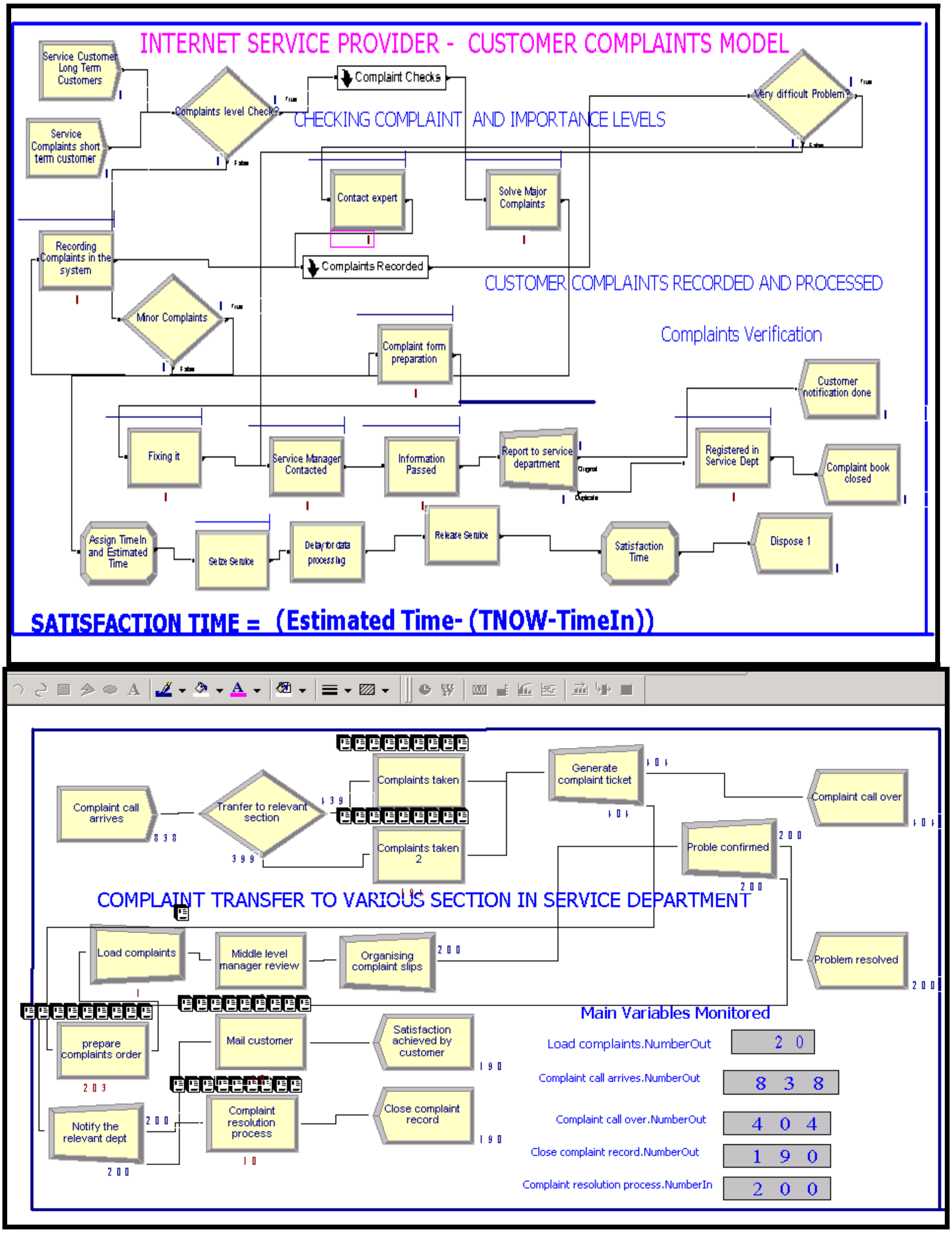


Figure 5.6: Simulation model of ISP Complaint handling process: Model 2 (Running mode) [88]-[99][113]-[140]

## (iii) Complaint transfer to various sections in Service department:

**Model 2:**

**Model Assumptions:**

The conceptual model assumption includes process where time between arrivals during peak periods (peak customer complaint times) is independent and exponentially distributed. Refer Figure 5.6 for model diagram. **Create** module is used to model arrival process. The module uses entity type and time between arrivals follows an Exponential distribution with mean 50. Every time an entity is generated it is passes to **Assign** module where it is assigned a variable "complaint number" which has a value of complaint number+1. The first entity arriving has a complaint number 1 and second has complaint number 2. An attribute named *"My complaint*" has been assigned value of 'complaint number" in **Assign** module so that it is carried along with entity and is referenced to match the appropriate customer with its corresponding complaint number [88][95].

**Decide** module allows the entities to be branched based on certain condition. All complaints are routed to proper service department based on the type of complaint received and the complaint tickets. In the complaint processing stage a process module and a sub-model is defined. The entities pass through this module and also proceed to submodel and execute the logic within. This will help us execute more processing stages required in our model. All customer entities have an associated attribute such as due date of response, priority level and different animation symbols to indicate them separately. Same attribute has different values for different entities based on their priority level. Thus they are local variables for individual entities. Both built-in variables in ARENA and user-defined variables are used in the model. Built-in variables include number in queue, resource busy time, simulation time. User defined variables like *Transfer Time* was used to indicate time taken to move entity between different service departments for complaint processing.

### 5.7.4 Network Scenario 4:

#### Explanation of the Scenario:

Among the most important of the service models currently in wide use, are Karl Albrecht's Service Triangle and the Servqual Gap Model, developed by [182]. More recently, [183] proposed the Service Profit Chain a model for enhanced profitability through developing true customer loyalty. The literature offers three alternative conceptualizations of service quality - the attribute theory, the customer satisfaction theory and the interaction theory. The attribute theory assumes that service quality primarily reflects the attributes of the service delivery system, and it applies the product quality framework to services. An attribute theory perspective on service quality assumes that management has substantial control over the input defining these attributes [185][188][207]. A customer satisfaction theory approach defines service quality as the difference between service quality expectations and the perceptions of reality [182]. The customer satisfaction theory places primary importance on customer perception, while the attribute theory places more importance on the technical aspects of production. The interaction theory approach to service quality defines service quality as a "shared experience of gain" by all participants in the service encounter. Service quality emerges through the experience and need satisfaction of the participants - customer and contact employee [186][187][190][191].

Quality is a multi dimensional phenomenon. It is necessary to determine the salient aspect of quality in order to ensure product or service quality. [192]-[194] argued that there are three dimensions of service quality - the technical quality of outcome, the functional quality of the service encounter and the corporate image. [188][189] states that service quality has three dimensions: Physical quality which includes the physical aspects of the service (eg. equipment or building); corporate quality which involves the organization's image or profile; and interactive quality, which derives from the relationship between the organization' personnel and the customer, as well as the interaction between customers. They also argued that it is necessary to differentiate between the quality associated with the process of service delivery, and the quality associated with the outcome of the service. [182] proposed the following determinants of service quality – tangibles, reliability, responsiveness, empathy and assurance. [182] also developed a validated instrument called SERVQUAL for measuring service quality as perceived by customers.

Conceptualisation and measurement of service quality and the relationship between service quality, customer satisfaction, and purchase intentions were investigated in [55][128]. They tested an alternative method of operationalising perceived service quality and the significance of the relationship between service quality, customer satisfaction and purchase intentions. The results suggested that a performance based measure of service quality may be an improved means of measuring the service quality construct, and that consumer satisfaction has a significant effect on purchase intentions. They argued that the marketing literature appears to offer considerable support for the simple performance measures of service quality.

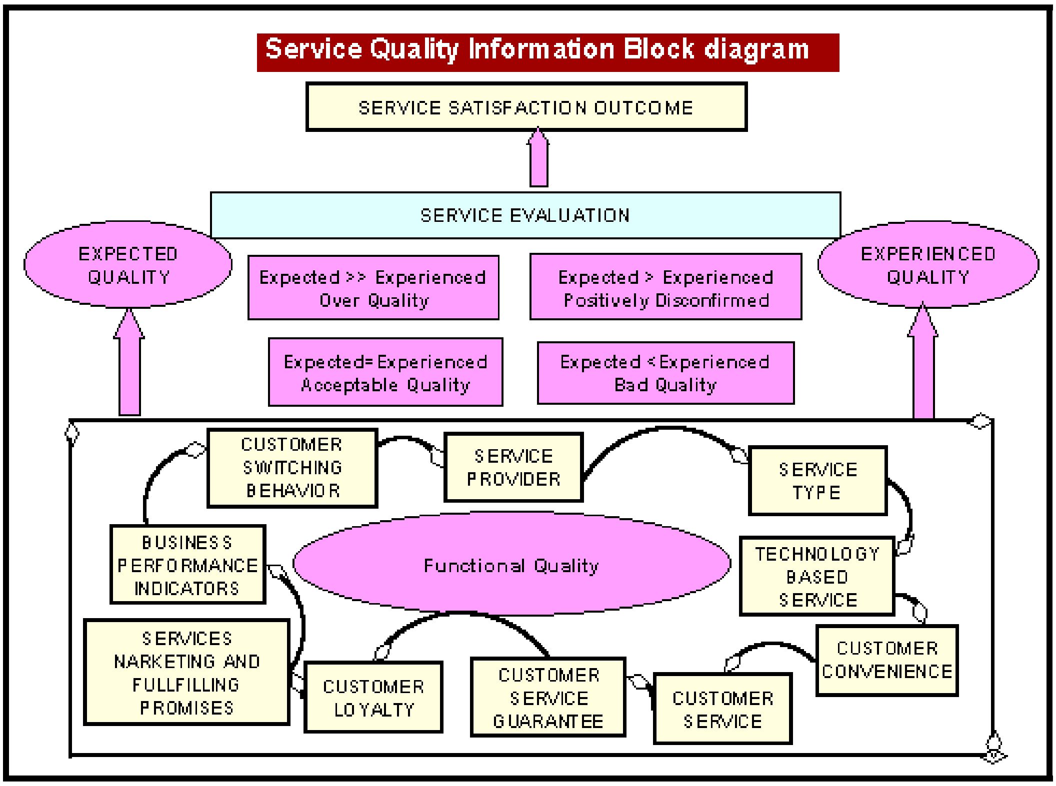


Figure 5.7: Service quality information building blocks [181][185][188][192][194]

They also questioned the efficacy of the 5-component conceptualisation of service quality offered as discussed in [182] (See Figure 5.7). The overall criticism of service quality management research at present, is that it rests too heavily on delimited and aspect-oriented studies and frames of reference; the unit of analysis is normally restricted to service quality as perceived by the customer. In order to gain an understanding of service quality, it is necessary to consider the service processes, not only in the service encounter but also within the company. In order to overcome some of the limitations discussed above, we developed SIMCTS framework which is a simulation based approach. Various service quality information types for Internet Service Providers are shown in Figure 5.7. Nine dimensions of quality management in service organizations have been conceptualized from the literature which are top management, quality policy, employee participation, training, supplier, quality cost, service design, quality techniques, benchmarking and customer satisfaction. These dimensions are combined with simulation approach in our framework. The framework articulates that these quality dimensions will enhance the organizational performance, which comprise service quality, scheduling and service delivery and customer satisfaction performance.

## (I) Factors Determining the Success of New Services for ISPs

A telecommunication service succeeds only if all three factors are satisfied. Technology must be available for service implementation in a cost-effective manner. Government regulations must permit the services to be offered. In [206] author states that availability of technology to implement a service itself does not guarantee its success. Technology plays an important role in determining the services that can be offered. As the given technology approaches saturation, various innovative ideas that provide the same capabilities but within a new technology arises. The trend towards deregulation of telecommunication services has taken place in Australia, New Zealand, UK and has given rise to novel approaches to provide telecommunication services in a competitive environment. However, inspite of deregulation telecommunications will never be entirely free of government regulation [203][206]. The market for a new service determines the success of a new service. This depends upon the customer's willingness to pay for the service (cost, usefulness and appeal of service) [206]. "The usefulness of service depends on there being a critical mass of subscribers" [206]. Standards are agreements with industry wide, national and international scope for interoperability. Standards are extremely important as the value of a network is to a large extent determined by the size of the community that can be reached. The existence of standards enables small ISP companies to focus on developing a limited set of key service products that guarantee to operate within the overall network. This results in increased rate of innovation and evolution of both technology and the standards [20][100] [203]-[205][208] (Figure 5.8).

| Service Quality Information Building Block | Associated attributes and information classification | Quality Type |
|---|---|---|
| **Service provider** | Name of the provider | Quality provision |
| **Service Nature** | Service quota | Technical |
| **Technology based service** | Dial up, broadband, cable modem and wireless | Technical |
| **Customer convenience and needs** | Internet access, connectivity options, speed of services, technical assistance and help desk, pricing policies, downtime, free access, service outages, long term membership rewards, reliability, security aspects | Technical and functional |
| **Customer satisfaction** | Service provision level | Technical and functional for overall satisfaction judgement |
| **Customer loyalty and retention** | Customers who will be retained by their providers through good service quality | The evaluation of services includes both technical and functional as multiple services are encountered by customers for telecommunications network |
| **Customer switching** | Pricing, customer service, speed of services, reliability and security, service policies, and connectivity options for new customers, downtime, internet access availability | Independent judgement as individual customer priorities of both technical and functional quality varies. Ex New users give more priority to functional quality such as telephone support in case they need any assistance |
| **Customer feedback** | Service quality of search engines, competitive pricing policies, interesting content provision, availability and reliability, marketing promises, help desk and support, flexibility in service schemes | Improve both technical and functional quality aspects |
| **Business performance indicators (Voice of customers0** | Customer loyalty and retention, customer service satisfaction, realistic service quality vision, financial strength, effective marketing and promotion, appropriate strategic alliance | Customer voice helps to establish effective business performance framework |
| **Customer service guarantee** | Service guarantee policies | Needs to include both technical and functional policies |
| **Customer service** | Billing, Pricing, customer service, faults, disconnection, credit control | Understand and manage all elements of technical and functional quality |

Figure 5.8: Various Service Quality Information types for Internet Service Providers [20][100][196][197][199][202][203][207][208][212]

### (ii) Service Quality Trends and Service Provisioning in Call Support Services: Australian Scenario

The role of call centres is to act as the door" between the customer and the organisation so that the relationship is positively managed. The quality of these transactions is critical to the success of the organisation because when a customer contacts a call centre they already have a range of preconceived service expectations such as the call being answered promptly by a courteous CSR (customer service representative) who has full knowledge of the products or services. They also expect their problem to be resolved or query answered during this one call as if the matter were being handled face-to-face [210]. [209] points out that customers' expectations of the service may relate to both tangible dimensions such as reliability standards or intangibles such as feelings or perceptions. In a service environment, such as a call centre, both tangible and intangible aspects of service quality need to be addressed by coaches if service quality, from the customers perspective, is to be achieved by the call centre. Figure 5.9 and Figure 5.10 compares current service industries trend in Australia in call centre context and some recommendations provided. An ongoing Canadian call centre benchmarking study as reported by [210] found that true indicators of service quality were not necessarily being gathered because data collection concentrated on the tangible aspect of quality such as average call time and not on customer perceptions and feedback. In the absence of data on intangible dimensions of customer service, the innovative introduction of the coach to the call centre means that data on intangible dimensions can now be collected by coaches performing the role of a proxy' customer. This is accomplished by the coach applying internally designed, service quality criterion benchmarks based on the organization perception and interpretation of the customer service quality expectations.

Please see print copy for Figure 5.9

Figure 5.9: Service waiting time across all service industries, Daily Telegraph, June 23, 2004 [214]

| POSITIVE | NEGATIVE |
| --- | --- |
| People's choice Org | New Firm |
| High no of customers | Low cost strategy |
| No upgradation of CCC | Ineffecient Management |
| Restructrure | |
| Reliable organisations | |
| Established Organisations | |
| Proven services | |
| Indespensable saervices | |

| BEST IN CATEGORY | Suggestions |
| --- | --- |
| ANZ | Outsource callcentre |
| Vodophone | Upgrade |
| Countrylink | Coaching |
| NRMA Roadside assist | Consult |
| Lifeline | Decentralise call service |
| Wizard | Alternative arrangement of scheduling calls and informing customers that assistance will be provided at a particular time and your details have been noted. |

Figure 5.10: Proposed changes and recommendations [195]-[198]

A quality call consists of 28 call handling and technical skill criteria (see *Figure 5 .11*) that need to be demonstrated by a CSR in every call so that a complete and accurate response is provided to meet the customers needs and service expectations. These criteria expand on the ten dimensions of Parasuraman et al SERVQUAL model [182]. Quality dimensions of customer call centres to ensure that the skills relating to intangible service quality dimensions are available for use and to achieve a balance between the already available and widely used tangibles dimensions [211].

The process of collecting the quality call data is obtained during call monitoring. This is where the coach monitors or listens to the CSR actual call. The coach records CSR call performance using a check list of the 28 criteria (Figure 5.11), referred to as a Call Observation Sheet. A gap analysis, based on each criterion definition is undertaken to determine if the CSR has provided the customer with a complete and accurate call response, thus achieving the quality call'. When a quality call is not achieved, CSRs are provided with informal or formal feedback, depending on their call performance gap and coached in the areas they need to further develop to achieve a quality call. The four weekly monitoring cycle concludes with up to 10 monitored calls for each CSR and the standard of quality is reported as either, a pass or fail representing the reliability of the call. The data is used by management to obtain an overall measure of the Call Centres quality call performance [211].

In a call centre environment customer interacts only using telephone, thus allowing the service to be delivered anywhere in the world. [212] states that efficiency of call centre is very critical to the image of organization. Efficiency and service excellence are the two main goals in relation to call centre. Efficiency involves speed of delivery and cost optimization to remain competitive. In this process customer service representative performance is key factor. They are judged by how quickly they deal with service inquiry and the number of calls they handle. [212] indicates the transaction calls are simple and well defined to be delivered through service encounter. Sales calls are based on revenue and results, while technical solution calls provide technical services giving personalized attention to customers. Transaction calls: key factor is efficiency; Sales calls: service and efficiency; Solution calls: customer service.

1. Greet and acknowledge client
2. Active Listening
3. Telephone skills
4. Recap and clarify key points, actions and outcomes
5. Offer of further assistance closing statement used
6. Friendly and professional closing statement used
7. Allowed client to hang up first
8. Appropriate call time for this enquiry
9. Personalised the call appropriately
10. Effective call control displayed
11. Acknowledged client concerns
12. Maintained helpful manner throughout call
13. Voice quality maintained throughout call
14. Language and vocabulary tailored to client
15. Any long unexplained silences present in call?
16. Derogatory comment about other offers/areas of the organization
17. Positively represented the organization and accepted ownership of the call

Technical Skills

18. Nature of enquiry correctly identified, including CSR understood the question
19. Were the correct questions asked to identify all relevant facts and issues
20. Appropriate and complete identity check
21. Privacy guidelines observed
22. Effective use of systems
23. Provided correct and current information
24. Provide clear explanation, including was jargon present?
25. Provide complete explanation, including alerted client to relevant surrounding issues
26. Negotiated a mutually acceptable goal
27. Correct escalation/referral
28. System updated correctly

Figure 5.11: Call observation sheet [209]-[212]

Simulation " is the process of designing a model of real system and conducting experiment with this model for the purpose either of understanding the behavior of the system (or) evaluating various strategies (within the limits imposed by a criteria) for the operation of the system"[45]. ISPs can be asked questions about their learning experience with simulation and critical, analytical thinking. Service manager need to be trained in using simulation tools, and key questions, dimensions need to be answered [200][201][212].

Coaches act as customers and evaluation of service needs to be consistent with that of customer. If not there exists a gap in service quality due to difference between management perception and customer expectation. Training process impacts on service quality. Models can be used by service managers to outline simulation benefits, applications and educate potential business units.  SIMCTS models helps to achieve service quality with a reasonable cost associated with this. Thus poor service quality can be avoided by increasing efficiency and effectiveness using simulation techniques [199] [200]-[205].

Apart from time and operational constraints influencing the decision of coaches to provide CSRs with informal feedback, coaches confirmed that their confidence and lack of experience and skills in people management prevented them from properly addressing CSR issues in a timely manner. This was partly due to coaches' lacking confidence in their skills and not being reassured by management that they were doing the right thing when coaching CSRs on various issues [20]-[25]. The need for reassurance is demonstrated by [181][197][211]-[213] research findings that continuous feedback is needed so that people know not just what task to do but also how well they are doing it. Coaches also confirmed that they had received limited training to increase their knowledge and skills in handling CSR issues. They felt that their development and growth needs were not important to management, further eroding their confidence in handling customer problems. These findings align [198] case study of on-bound' British call centre organizations that for many managers, the support they seek to provide to their staff is not so forthcoming for themselves, leading to isolation and an absence of continuity'.

The research confirms [210] findings that all monitoring and call coaching are good concepts' and this supports the research sites quality call concept. [210] found these good concepts typically fail on implementation'. The research findings clearly demonstrate, from the coaches' perspective, how difficult and yet how important the intangible people aspects of service quality are. With limited successful application of the intangible dimensions of customers perceived service quality being addressed, the Call Centre quality call objective was not fully realized. This invariably has a profound impact on the ability of the Call Centre to continuously provide high quality service to match customers' perceptions of service quality. The tangible dimensions of service quality were more easily achieved in the research site as in other independent studies by [196] and [213] because they are physical tasks supported by statistical data that substantiate performance achievements.

Previous research work carried out by authors include simulating ISP customer complaints handling process. The authors were primarily involved on modelling dimensions of complaint satisfaction. This included understanding customer perception of waiting time and developing simulation model that measures actual time and expected waiting time as a function of satisfaction.

## SIMCTS in Action: A Call Centre Balking Model to Model SIMCTS Service Quality Attributes

## (I) Customer Balking:

The Erlang formula are not suitable for today's call centres. The main assumption that all calls entering do not abandon the system is not true for today's call centre environment. It is important to understand that there is always a individual tolerance for customers to decide either to balk (or) stay in the queue to be served. Another important concept called skill based routing strategy is where operators differ in their skills levels and time taken to handle calls. In [182] author indicates that erlang calculation overestimates staffing needs. Today's call centre costs are mainly related to staffing and human resources. Simulation provides a complete solution in relation to staffing issues, balking behavior in service model and call routing strategies. It helps to analyze business questions faced by call centre analyst and managers [88][94][208][209]].

Simulation staffing analysis—call operators, skills, technology, call management technique are related to operational issues and business decisions [182] [184] [210][211].

SIMCTS Call satisfaction variables: [197] are: level of service provision; consolidation of call centre services; efficient call handling; dynamic call routing strategies; reduced abandonment; call return priority; staffing schedule.

### (ii) Model Significance (Unique Service Proposition)

The model compares customer expectations prior to receiving service and their perception of service experience. Customer’s perception can be managed during the service delivery process using tolerance zone. Zone of tolerance is service performance range that a customer finds satisfactory. The outcomes lead to three states that are delighted, satisfied and dissatisfied. It thus distinguishes between desired level and acceptable service level. The service process is satisfactory within the tolerance zone, delightful above tolerance zone and dissatisfactory below the tolerance zone. Thus these three outcomes help to distinguish acceptable outcome, unacceptable outcome and more than acceptable outcome [88][94][208][209]].

ISP managers should understand and distinguish the tolerance zone using service experience of customers. Customers with minimal knowledge about service have wider tolerance zone. Customer with great level of service experience has narrow tolerance zone. Thus tolerance zone for various service set up needs to be understood. In our service model “responsiveness” was the most important factor and had narrow tolerance zone. Simulation helps service managers to experiment the tolerance zone during service delivery process. Thus the dynamic nature of this service process can be very well understood. " Is it possible to visualize the queue alarm thresholds during service delivery process"- yes, the model allows managers to visualize the customer queue psychology factors and the impact of balking rate and reneging time on service performance [195][200][208].

### (ii) Simulation Model Objective, Criteria and Model building

In the simulation model two main queue psychology factors will be investigated. They are customer balking and customer reneging. Balking is a situation where arriving customer does not join the queue. Reneging is a situation where customer joins a queue upon arrival, but has a associated zone of tolerance to wait till he is served. In the simulation study ISP customer receives busy signal if all the lines are in use. [94] states that balking is a very complex process to be modelled and that it is entity dependent (ISP customers decisions are based their own evaluation of service situation- entering queue (or) balk). In terms of entity reneging the customer zone of tolerance plays a very important role. The tolerance threshold depends upon the importance of service being provided. The customer decision to wait in the queue is influenced by the fact how long he has already spent in the queue? [88][94][209].

To model customer queue psychology it is highly essential to understand the entity relationship within the model, availability of resource and service queue length. ISP service managers can investigate various threshold patterns and evaluate the system conditions [186]. The SIMCTS model is a approximation of real system. Thus this is useful in training situations.

**Modelling Objective**

Study the impact of service time delay process on call server utilization, customer balking and reneging using the existing service parameters. Study the approach of consolidating service reviews of email and telephone service operations.

**Model Limitations:**

The main difficulty we faced in simulation was representing the human interaction with an service system. It is difficult to predict the behaviour of customers when queueing in call centre service system. The decisions are dependent on the individual and so it is practically impossible to come up with service design that fits all situations. In our model we use VBA to raise queue alarm thresholds. Figure 5.12 shows a snapshot of the model.

**Model Explanation**

The customer arrive in the call centre model. All service quality attributes such as renege time, server queue capacity, customer tolerance are assigned in the model. After this entity is sent to server queue. If the serve is available it is seized, delayed by service delay time and customer serviced. If the server is busy and balk limit is more than number in queue then entity is balked and disposed. To model renege time a duplicate entity is created , delayed by renege time and the queue position of original entity determined (this is the entity sent to server queue). If the entity has been already processed then the duplicate entity is disposed. If the queue position is determined and is less than the tolerance zone then the entity exits the system. If the queue position is greater than the tolerance threshold then the duplicate entity removes original entity and itself. All renege entities are recorded [88][94][209] (Figure 5.13).

Please see print copy for Figure 5.12

Figure 5.12: VBA application in the model [140]-[176]

VBA application in ARENA was used to trigger alarms. This helps us to visualize queue threshold pattern in the model. A VBA form is also displayed that asks user information about parameter of interest (service delay time). The model will run using the data distribution value specified. Model also helps to determine the break point utilisation in the model. This is the point were the utilisation reached 100% (See Figure 5.12).

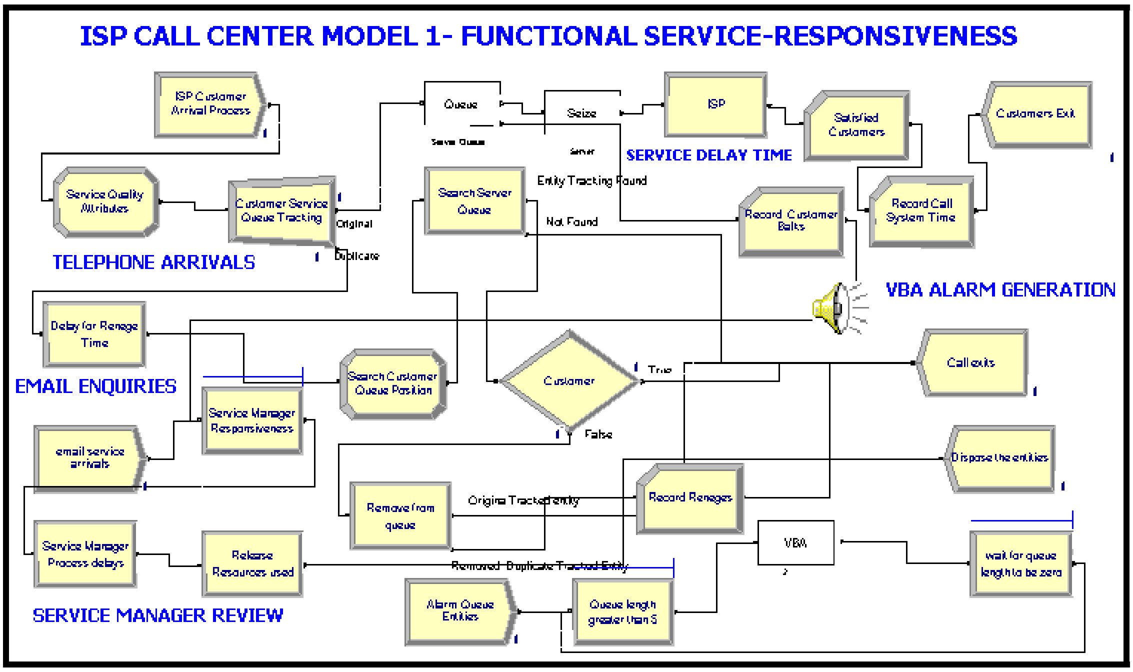


Figure 5.13: Customer balking and reneging VBA alarm model [88][94][113]-[140]

### 5.7.5 Network Scenario 5:

#### Explanation of the Scenario:

In this scenario study we develop a call centre simulation model that shows how data from ISP call centre operation can be used within simulation models and perform different "what-if" scenarios. The applicability of the SIMCTS framework to model ISP business scenario is discussed in detail. The simulation model reveals that the dimensions of service quality have huge impact on customer satisfaction and also provide valuable insight in to gap analysis of customer perception and expectation. Various key satisfaction variables in relation to call centre are modelled using SIMAN simulation language and ARENA simulation software. The simulation case study investigates service quality dimension, technical (or) functional service quality and their role in evaluation of overall satisfaction judgment. The simulation model collects transient performance measures which can be used to make competitive marketing decisions.

#### (ii)Customer Satisfaction in Relation to Call Centre Environment

The goal of ISPs providing service is to meet customer needs and satisfy them to build long term partnership with their customers. For instance, service quality is associated with customer service, complaints handling, customer loyalty and retention [100]. Broadband service providers are cutting down subscription prices in an effort to attract new customers. In a recent report published by Zanthus [211], which is a leading telecommunications consultant  it was stated that to build a stable and profitable subscriber base price cut alone is not enough. Providers need to collect larger payments every month. This is accomplished by having value added service for customers and introducing bundling packages that includes broadband service with other services such as mobile phones, television .  The customer services should not only troubleshoot broadband issues, but other services as well. The customer service representative will have to answer queries from multiple customers who encounter multiple services. They need appropriate tools to respond to customers on several service fronts. Thus there is always a need for increased knowledge of multiple technology (broadband, wireless, cable tv etc). This puts pressure on call centres. The industry faces several challenges arising out of high staff turn over, lack of problems analysis and resolution tools and inability to share best service practices across various levels of customer service representative (CSR) ability [211]-[215].

### (ii) Customer Service Guarantee and Service Awareness

With the rise in the usage of telecommunication services it is important to raise awareness and knowledge of various telecommunication issues. The ACMA (Australian Communication and Media Authority) survey taken in 2002 [31] about the consumer awareness of communications issues and information highlighted that there was a substantial increase in the number of internet connections particularly among small businesses. The high speed internet connections are increasing and constitute a growing component of internet market.[31]. The telecommunications industry has changed a lot over last few years with new providers entering the market and some providers merging and other ceasing operations. Thus small Internet Service Providers should be prepared to support new technology based network services that influence the transformation of telecommunications industry.

Some of the important information that needs to be collected from consumer awareness survey are identifying the gaps between information provided and the demographic areas these gaps apply, developing customer information strategies that make sure they are very well informed about service guarantee and also monitor them to see if they have raised consumer awareness and collect information related to attitudes towards competitive environment. Internet service providers in Australia need to comply with the Customer service guarantee standard that was developed by ACMA to encourage various improvements in service delivery and also guard consumers against poor service quality. It involves managing operations, quality, marketing and human resources. The service providers who fail to deliver the performance requirements as stated in customer service guarantee are required to compensate their customers. It is important for small and medium size internet service providers to identify what determinants of service quality when managed properly leads to indications of greater satisfaction among ISP customers [181]-[212].

Currently the high speed internet connections are growing at a steady rate and are the preferred option for customers who intend to have internet connection in next 12 months . The study in [212] found that the consumer awareness about various telecommunication issues were positively correlated with gross annual income, employment and level of education. Small ISPs who serve their customers on a regional basis should be aware about the speed and reliability that customers expect from them. It is also important for them to understand the changes in customer requirements over time and when ISP expand their services they have to make sure customers are able to pay extra for speed and reliability. Service guarantee can convey to customers benefit they get from using a service and convey to employees the results they are expected to produce for customers. It also helps providers to recognize and re-design service process for service failures. For marketing service quality and achieving it, service guarantee is a powerful tool. Service guarantee also affects the performance of providers in several ways. Using defensive and offensive marketing affects both customer complaints, customer retention and relationship with customer in shaping their expectations. There are significant costs and risks associated with service guarantee policy [211]. Thus serveability has become very important aspect to study. This decides service guarantee and helps to understand its relationship to quality, marketing strength and business success [211].

### (iii) Definition of Call Centre Within the Context of this Scenario:

Customer call centres (CCCs) have emerged over the last decade as a competitive tactic based on the development and improvement of customer relationships . The strategic objective behind the concept of customer call centres is to gain the competitive advantage through improved customer standards and delivery. This emphasis has customer call centres becoming one of the most dynamic and expanding industries of the 21$^{st}$ century. The implications on society, now and in the future, are therefore substantial and warrant investigation [186][193]. Customer call centres can be conceptualized as interactive service work mediated by telephones and computers. Here rows of office assembly lines are depicted by operators receiving inbound calls concerned with transactions, customer service, complaints and inquiries [188][194]-[198].

Call centres can be broadly classified as outbound call centres and inbound call centres where (a) Outbound call centres are associated with telemarketing and sales targets; and (b) Inbound call centres are concerned with transactions and customer service, complaints and inquiries. Inbound operators CSRs  can be conceptualised as interactive service workers [188][193][195].

This study investigates inbound call centres and takes the stance that their defining feature “is the interaction of a termed Customer Service Representatives with a customer to deliver a service,”[193] via telephones and computers. The nature of the interaction from the

CSRs' perspective is to answer incoming customer service queries in relation to such activities as billing, collections, transfers, new orders, product information etc., while simultaneously inputting information directly into the computer in relation to the issue/s raised by the customer . The role of a CCCs within an organizational context is to improve the performance of the organization [195].Therefore the function of CCCs can be depicted as a "tool used by companies to enable their employees to make the most of every contact with customers, to achieve customer loyalty" [198]. Placed in a broader organizational context "call centres cater for customer demands with organizations improving their day to day operations and service performance" [196]. Recent call centre based on skills routing, electronic channel and interactive call handling require more sophisticated techniques. In [212] author states that in call centre customer experience determines the real personality of their business.

### (iv) Key Dimension Operational Definition Within the Context of This Study

*Courtesy* is tested to determine differences in personal service, friendliness, tone of voice, greetings and conduct of CSRs towards customers. *Convenience* is tested to determine differences in flexibility of services such as extending payment options, transaction choices, transfer of calls to different departments. *Accuracy* is tested to determine differences in CSRs' ability to provide correct information to customers, accurately record information such as name, address and inquiry type. *Responsiveness* is tested to determine differences in CSRs' ability and velocity to reply to the inquiry. *Problem solving* is tested to determine differences in CSRs ability to solve inquiries, provide solutions to problems, apply solutions to customer's satisfaction. *Empathy* is tested to determine differences in CSRs' effectiveness to truly understand a customer's feelings, needs and ability to reflect an understanding back to the customer. *Timeliness* is tested to determine differences in call centres velocity to answer calls, amount of time. Call centre performance analysis includes staffing, trunking capacity [200]-[215].

### (v) ISP Call Centre Service System: Simulation Strategies and Methodologies in Customer Satisfaction

Simulation " is the process of designing a model of real system and conducting experiment with this model for the purpose either of understanding the behavior of the system (or) evaluating various strategies (within the limits imposed by a criteria) for the operation of the system" [215].

The simulation case study will reveal the dimensions of service quality that have huge impact on customer satisfaction and also will provide valuable insight in to gap analysis of customer perception and expectation. By understanding the simulation results ISPs can develop effective marketing strategies that will maximize service performance in line with their customer needs. This in turn will improve the customer loyalty and retention for ISPs. The results helps managers to check what services are delivered and how it is delivered in relation to SLA. Using the service quality data obtained from simulation models managers can do different "what-if" scenarios to compare the relative importance of various service quality dimensions (Tangibles, Reliability, Responsiveness, Assurance and Empathy) in predicting overall service quality perception and quality expectation. Majority of simulation studies in quality arena are related to quality control process rather than quality management studies. Thus very limited literature on use of simulation and design indicates a potential left unrealized in design and implementation of service quality management system [211][212]. Case study employs SIMCTS framework shown in Figure 5.1 for modelling process.

A ISP customer receives a busy signal if the entire capacity is utilized (all 32 trunks are used). The service system for this ISP involves recording 3 types of service options. They include technical support service, ISP information service and telecommunication product order . Based on the data used in the model they were classified as 52%, 23% and 25% respectively. The estimated time here is UNIF(0.4,0.8) min [88][94][188]-[194].

After consultation with the experts and referring to ISP whitepapers it was understood that any caller who chooses technical support goes through 3 main call types. Based on expert judgement the statistical distribution was UNIF(0.4,0.6) mins for this study. The types included are classified as 41%, 29% and 30% respectively. Technical support person currently available for selected support service answers the call. If there is none currently available customer is placed in the queue until the person becomes available. The distribution here follows TRIA(4,9,12) mins. In the model particular scenario involved a situation where 26% of the ISP calls required further investigation after completion of the call. The questions that need to be answered are routed to higher level which prepares a response. Based on the expert judgement the responsiveness service nature of customer technical support is EXPO(80) mins. Support person needs to return the call to the customer that has estimated time of TRIA(3,5,8) mins. Any customer service call request that couldn’t be processed same day is given first priority the next day. The return call gives priority over incoming calls in the above case. Eleven operators are in technical support calls services.

Customer departs the system once his service request is fulfilled. Because of privacy reasons it was not possible for us to exactly get the percentage of complaint calls made as part of technical support services. However it was generalized that complaints did fall under one of the types of service. The calls that deal with ISP info follow a TRIA(4,15,18) mins. The operators provide information to new customers. The call is terminated after the customers are served [94][97][188][214].

Popularity of internet, new technology and increase in customer expectations has made the management and design of call centres very complicated [effective call routing and staffing strategies]. In the call centre system, all customers who arrive after hours can leave a message in the ISP interactive voice response unit. Operators can then return their call next day. All call operators have different call handling skills. Customers level of service request determines whether operator can handle his call and provide service (or) route to higher level. "Time" is the most critical resource in call centre system. In current telecommunications market nature of business keeps changing rapidly. Thus there is a change in call patterns, serving times. This complicates things as ISPs are under pressure to redefine the customer serving processes [214]. Apart from eleven technical support operators six operators are dedicated for ISP information services [94][188] [214].

Customers who request to find out the status of their telecommunication product orders over phone follow a estimated transaction time of TRIA(10,15,20) mins. Nearly 15 % of users required further information on product and are routed to ISP information line and have to wait for a representative to answer their call. The waiting time here is estimated as TRIA(12,14,19) mins. The ISP doesn't have 24 hour technical support service , however customers are encouraged to visit their website to solve very commonly occurring problems (After 7 p.m). Few skeletal staff operate between 6-7 p.m. Nowadays self service has become very important as part of real time internet services platform [94][188].

## (vi) ISP Company Objectives:

(I )Achieve high service level, (II) Understand customer needs, (III)Offer products, (IV) Provide service solutions and support, (V)Manage customer service time, call volumes and waiting time effectively, (VI)Allocating operators in short period of time, (VII)Provide appropriate information to caller in a most efficient manner (call handling time). Call centre: Serve, interact and transact with ISP customers. Self-service: Solve problems before user calls (Technical malfunctions.)Assisted service: Solve problems when a user requires assistance (Functional service) [212].

*Customer satisfaction Determinants in the case study*: [88][94] [97][212].

Number of busy signals, customer waiting time for service provisioning. Investigating the service strategies to minimize the number of customers receiving busy signals and reduce waiting time until call reaches appropriate person.

*Key factors affecting customer satisfaction* [88][94][97][188][212].

Performance indicators describe the system performance. These indicators need to be managed properly to avoid inefficiency in service process. Number of available lines, Staffing schedule, idle time of the help desk person, type of support that has a huge waiting time and call abandonments.

*The call centre model uses the following assessment process*

-Select the types of calls whose quality need to be assessed.

-Select the number of calls to be subject to different types of quality related measurements (representative samples).

Thus by measuring customer perceptions for various aspects of service quality elements helps service providers to fulfill customer expectations.

If the perceptions measurement is carried out properly with appropriate tools and resources then service providers can strengthen their market position. A number of different aspects of service quality needs to be integrated to achieve improvements of the standard of quality offered [97].

*Some of the key assumption is that customer return call takes priority over incoming calls.*

*The model service data definition is indicated below.*

Call volume: Arrival rate of incoming calls, calls per period of time, time between calls, call spread across day, call arrival based on input distribution specified.

Service time delay: Identifies the delays in processing calls, call handling time (or) routing delays.

Routing process: route calls to appropriate support section.

Schedule: To model resources it is important to identify how many resources are available throughout a time period.

*Call routing strategies used: skills based routing.*

In [4] author indicates that it is important to understand how changes to be made affect call centre, which technology is best for serving customers?. So this ultimately leads to answering the question "what tool is available for decision makers to experiment with technology without having any real impact on their business?"—SIMCTS simulation [212]. Various contributing factors became evident as the model service quality data was used and further research was required to better understand their impact on the call centres quality objectives. These include deeper consideration of the implications of call centre type on customer expectations and the appropriate management style for this type of call centre. Development of behavioural management skills by coaches and associated support infrastructure within the Call Centre to enable them to put these skills into use needs to be investigated.

After further research it was understood that call scheduling was a important and difficult task. The benefit of simulation in relation to call centre scheduling has been widely covered in literature. [212] used heuristic approach to simulate scheduling operation. The heuristics approach covered three main scheduling methods that are hourly scheduling (dynamic optimisation), daily scheduling (batch optimized) and call sequence (heuristics). In our model some of the outcomes such as wrong party contact, where customer is not available to take return calls were not covered. However the right part contact for customer whose queries were processed next day and call returned by same representative was modelled. The data in the specific schedule in Figure 5.14 generates calls based on scheduled nature. The sensitivity analysis results discussed later in the paper indicated that improvement in the number of customer, serviced and resource utilization were based on service delay time. However the operational benefits need not be uniform throughout the day, but will help to decide the situations where the resources are busy most of the time."REPORTS" feature in ARENA was used to record balked entities on a 30 minute basis [88][94][211][212].

Effective agent schedules help to increase the call centre productivity. Simulation model helps to analyze the current schedule and identify bottlenecks and assess the performance of system against ISP management goals [88][94][210][211]. The model also covers cross-trained agents that will help ISPs to save time and cost (a single agent can handle different support types) [211].

| Arrival Rate | Time slot | Repr 1 | Repr 2 | Repr 3 | Repr 4 | Repr 5 | Repr 6 | Repr 7 | Repr 8 | Repr 9 | Repr 10 | Repr 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 225 | 1 (8 a.m) | Yes | No | Yes | No | Yes | Yes | No | Yes | Yes | Yes | Yes |
| 231 | 2 (8:30) | Yes | No | Yes | No | Yes | Yes | No | Yes | Yes | Yes | Yes |
| 191 | 3 (9:00) | Yes | No | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 63 | 4 (9:30) | Yes | No | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 45 | 5 (10 a.m) | Yes | No | Yes | No | Yes | x | Yes | Yes | Yes | Yes | Yes |
| 170 | 6 (10:30 a.m) | Yes | Yes | x | Yes | Yes | Yes | Yes | x | Yes | Yes | Yes |
| 100 | 7 (11 a.m) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 140 | 8 (11:30 a.m) | x | Yes | x | Yes | x | Yes | x | Yes | Yes | Yes | Yes |
| 200 | 9 (12:00) | Yes | Yes | Yes | Yes | x | Yes | Yes | Yes | x | Yes | Yes |
| 25 | 10 (12:30) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 210 | 11 (1:00) | Yes | x | Yes | Yes | Yes | Yes | Yes | Yes | Yes | x | Yes |
| 132 | 12 (1:30) | Yes | Yes | Yes | x | Yes | Yes | Yes | Yes | Yes | Yes | x |
| 140 | 13 (2:00) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 123 | 14 (2:30) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 261 | 15 (3:00) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 70 | 16 (3:30) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 68 | 17 (4:00) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 43 | 18 (4:30) | No | Yes | Yes | Yes | Yes | No | Yes | No | No | No | No |
| 61 | 19 (5:00) | No | Yes | No | Yes | No | No | Yes | No | No | No | No |
| 295 | 20 (5:30) | No | Yes | No | Yes | No | No | No | No | No | No | No |

Figure 5.14: Technical operators call schedule and call inter-arrival rates [140]-[144]

According to [211], simulation studies achieve 50% beneficial aspects just from the conceptual model alone. Modeller needs to have a very good understanding of the service operations system in order to develop simulation models. By using a consistent framework like SIMCTS modellers can seek for appropriate information on service quality elements and the requirements to build simulation models. Thus credible and valid simulation models can be built by using SIMCTS framework. Using simulation technology to model various elements of SIMCTS service quality conceptual model increases the framework robustness [2111][212] .

Using simulation software helps modellers for rapid model development , make prototyping more feasible and have greater level of iteration between conceptual modelling and computer modelling. The simulation model represents a real world system and needs to have a experiment frame that highlights the conditions under which system was observed. The framework is software independent and ARENA simulation software was selected to model the SIMCTS framework elements. The five main qualities of an effective model are validity, usability, value to providers, feasibility and aptness for problem situation [97][211] (Figure 5.15).

It is also very important to avoid the development of an over complex model. The aim is to keep the model s simple as possible to meet the simulation study objectives [212].

### (vii) SIMCTS Steps involved in the Scenario Modelled:

In the project specification it is important to have a means for representing the content of the conceptual model. The logic flow diagram shown in Figure 5.16 is used to represent the model logic. It is very important to understand the cause and effect relationship. If customer support services are understaffed (cause) then it leads to poor customer service (effect). We found that increasing the resources alone cannot lead to increased levels of customer satisfaction. What is actually required is the change in business process [210][211].

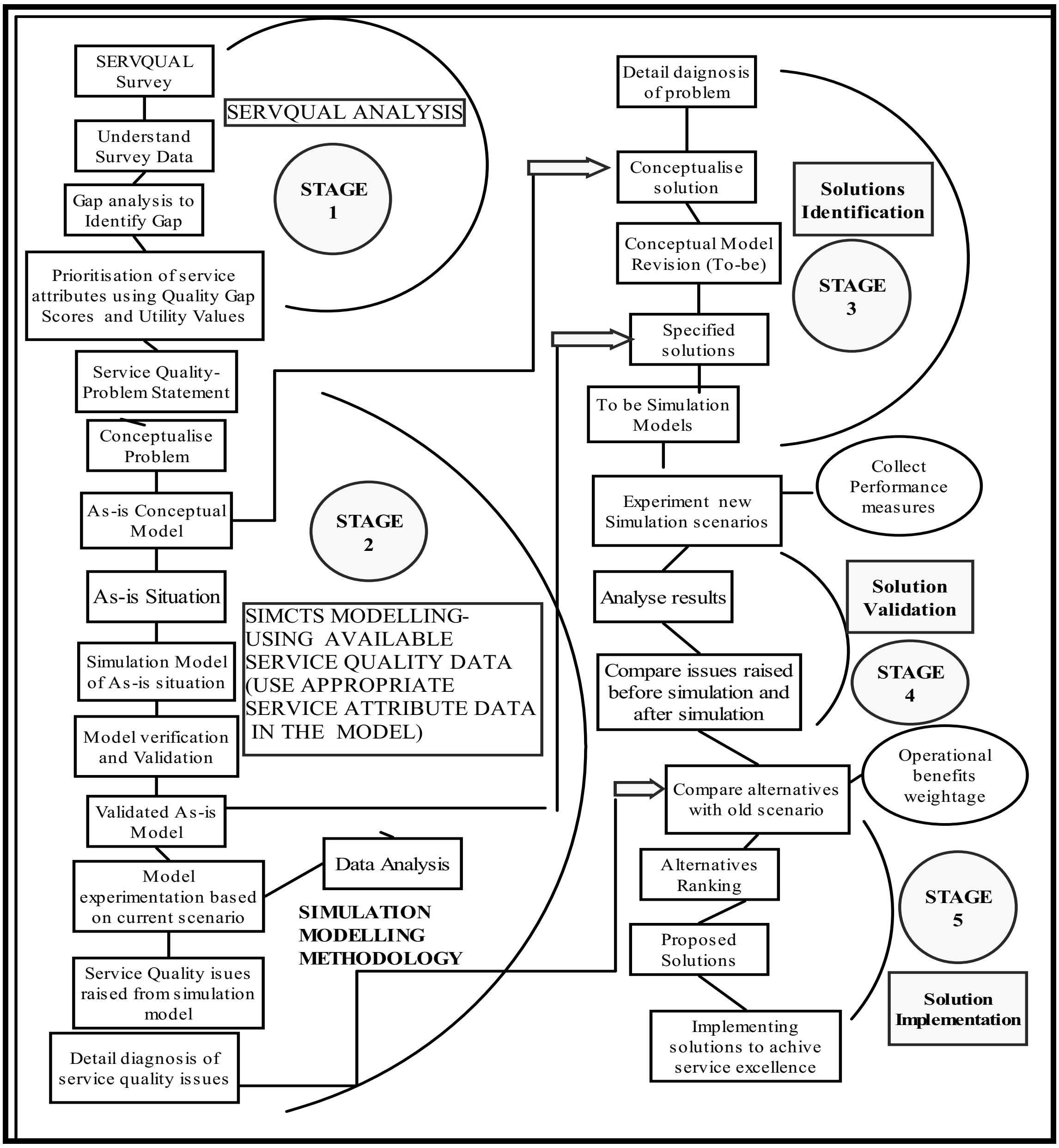


Figure 5.15: Various steps involved in SIMCTS framework [160]-[185]

In relation to aggregating model components black box modelling technique was used to reduce the level of detail. The complete service business model of ISP was developed as a series of interconnected sub-models each represented as black box.

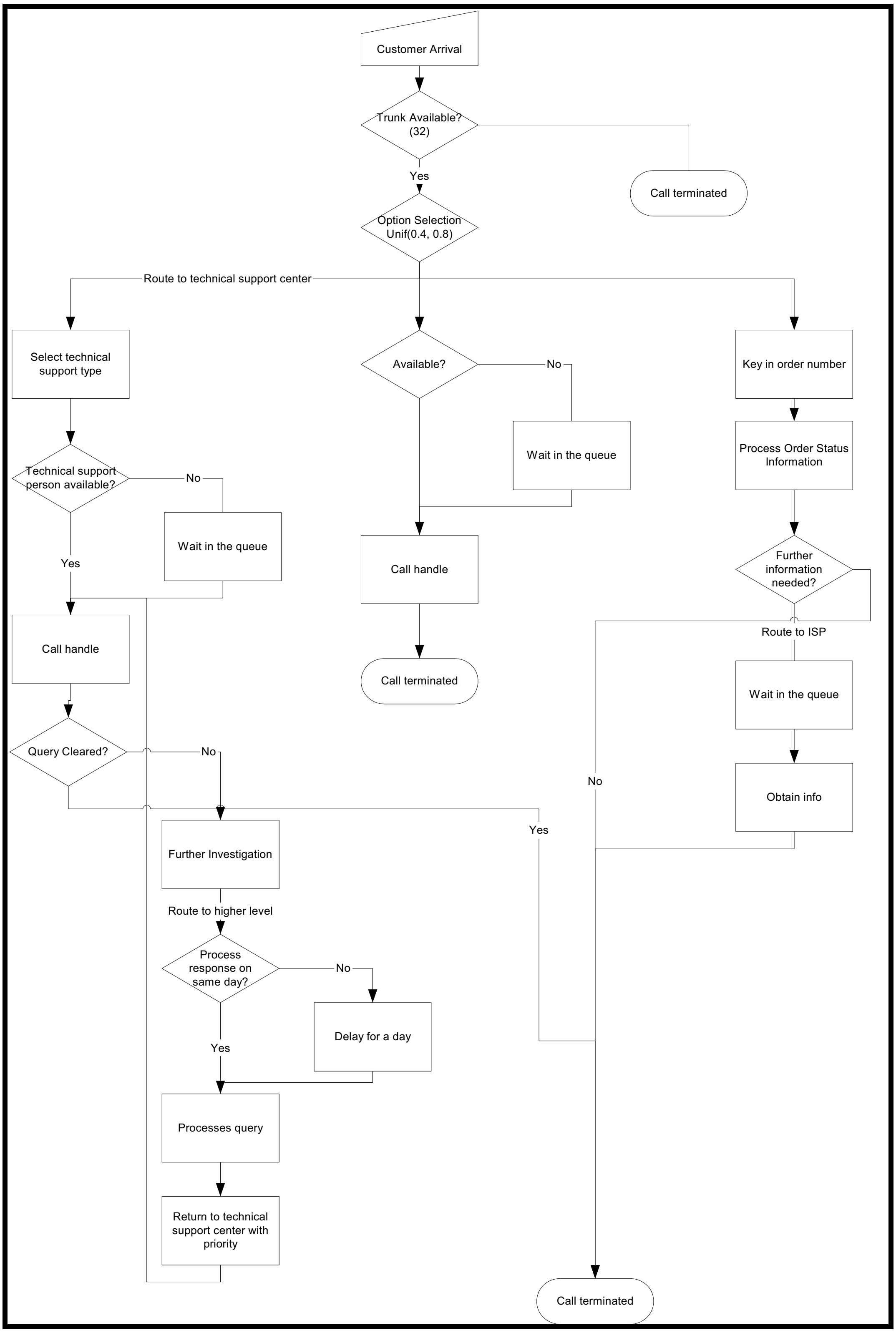


Figure 5.16: ISP service system flow logic [88][94][194]-[215]

The satisfaction variables can be collected by calculating the time entity enters the black box and time entity leaves the box. The time entity spends in the box is sampled from a distribution [212].

The % of customers who can be serviced everyday with current service design and to investigate the % of the customers who queue for less than 12 minutes for ISP service.

To achieve a 20% increase in customer service process based on changes to existing service design [scheduling, utilization, number of operators and trunks].

Careful consideration was given to input modelling process. Input modelling uncertainty and its impact on simulation model output results was understood. All service time in the model are independent of one another and of arrival process. The uncertainty is related to the call centre arrival rate of the poisson distribution, exponential distribution inter-arrival times. The service distributions and parameters used were obtained through combination of expert judgement and similar studies conducted in the past. It was interesting to note that varying service delay time did have huge impact on number of balked and renege customers (highly sensitive to input parameters). Sensitivity analysis was used to understand impact of input model uncertainty. It was however clear that sampled distributions will not exactly match the true distributions and may produce erroneous results. The sample data was analysed using the ARENA input analyser and expert fit software helped us to choose the best fit for the data and thus ensure that uncertainty is minimized (mean square error played a important role) [213].

## (viii) Input model uncertainty in call centres

The arrival process plays a very important role. Underestimating this in call centres leads to poor customer satisfaction as appropriate resource levels are not identified. Overestimating arrival rates increase the cost inspite of the fact that it provides good services

## (ix) Statistical Poisson Process:

In our call centre ISP model there are arrivals between 8 a.m and 6 p.m (typical call centres working hours in Australia). This corresponds to 20 half hour periods. The arrival rate in units of calls per minute are (7.5,7.7,6.36,2.1, 1.5, 5.66, 3.33, 4.66, 6.66, 0.83, 7, 4.4, 4.66, 4.1, 8.7, 2.33, 2.26, 1.43, 2.03, 9.83). The rate function is defined within the simulation model to generate arrival pattern. This process involves generating arrivals at peak rate and then use the current rate/peak rate to thin out arrivals. The main reason for using this thinning approach was due to the fact that the mean time between arrivals in our model was large. The rate function $\lambda(S)$ where "S" changes with time (S). Events occur one at a time, independent of each other and events occur during intervals [S1,S2] is poisson and are given by $\Lambda\ (S1,S2) = \int_{S1}^{S2} \lambda(S)$ . This is large over time intervals where $\lambda(S)$ is high and small where $\lambda(S)$ is low. We use the piecewise constant method and all changes occur over 30 minutes period. Here the $\lambda^*$ is the estimated rate function and generated events at peak rate function by calling the exponential inter-arrival time. With mean $1/\lambda^*$. To thin out the events we use $\lambda^{\Lambda}(S) / \lambda^*$ where $\lambda^{\Lambda}(S)$ is estimated rate function at time [88][94][97][184][211][215].

## (x) Terminating Simulation:

After inspecting the input data it is clear that they change over simulation run (customer arrivals change at simulation progresses). This clearly highlights that the model is terminating and produces transient output. The modelling approach involved a great deal of time to understand how to enter and store the data in the model. Once this was done the modelling constructs/modules available in ARENA simulation software were identified. A service system has many different service parameters. The call centre services require data about size of centre, number operators, schedule, inter-arrival times, service times and delay times. In case of modelling telecommunications product order, types of order, process times need to be available. Thus choosing appropriate data to model service system is crucial to success of the simulation project [88][94][97][184][200][212] . In the service simulation model occurrence of events changes the system state. The various events include customer arrival, service beginning and service completion. The beginning of service is an endogenous event that occurs within the simulated system. The arrival of customer is an exogenous event that occurs outside simulated system. In our model the system state variables are variables that are used to track the system variables. The system state variable remain constant over intervals of time and change value only at well defined points called event time in discrete simulation models. In the simulation model the customer entity moves through the model and is dynamic. The call centre operator is a static entity that serves other entities. Attributes that belong to particular entity are local values (time of arrival) [88][94]. Some of the key modules selected in ARENA platform for model building include Arrive, Depart, Sets, Assign, Resources, Server, Queue, Expressions, Chance, Choose, Reports, DSTAT, Count, Process, Delay, Seize, Release, Tally, Variable and Leave. For more information on these modules and their functionalities refer [88][94]. Figure 5.17 shows a snapshot of simulation model and series of sub models.

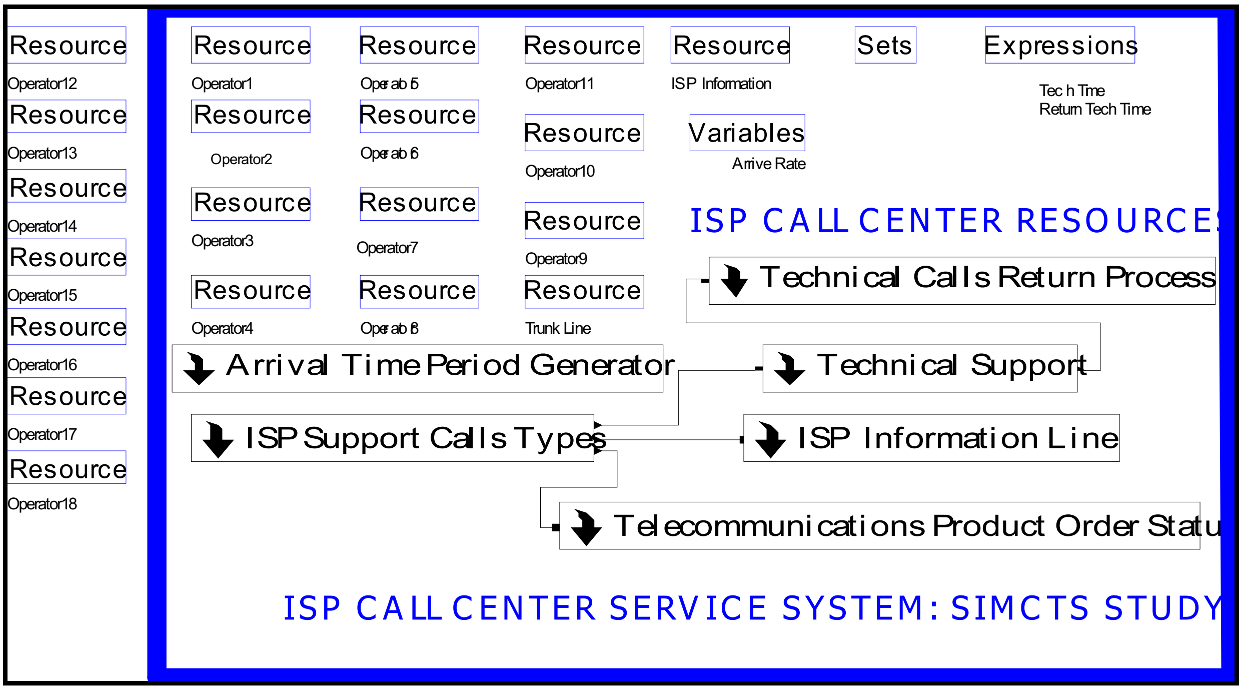


Figure 5.17: Simulation model of ISP call centre scenario [88][94][121]-[185]

A resource (ISP Operator) is an entity that provides service to dynamic entity. The dynamic entity requests for resource and permitted to capture it for duration and then releases the resource. ARENA has several resource states. They are idle, busy, inactive, failed and starved. Entity list is used internally to represent queues. Delay is an indefinite duration caused by combination of system condition. In [212] author indicates that service manager needs to know certain phenomena that occur in real system. Using simulation they can reconstruct the scene and determine answers by performing different "what-if" scenarios. In real system it is hard to accomplish this due to lack of full control. Simulation models can provide excellent training for call service representatives/operators. They can run the simulation model, provide decision inputs and learn to operate better[88][94][97][184][211][212] . The model developed serves only for the set of objectives mentioned.

## 5.8 Conclusion

In this chapter we have shown that service quality process is much more than just measuring and monitoring. Providers should anticipate and respond to customer service request. Quality improvements cannot be achieved solely by modernizing network equipment. A well engineered ISP network providing internet services to customers can still encounter problems in terms business profitability, customer loyalty and retention if users perceive poor service quality of carriers as they do not provide necessary help desk support needed from using the ISP services. We have shown through network scenario 3,4 and 5 that discrete event simulation that it is an effective methodology to design, to evaluate and to generate solutions for managing functional service quality. However, the lack of appropriate framework and building blocks in functional service quality domain affects the adoption of simulation as a methodology to measure and manage service quality. The proposed SIMCTS framework provides the necessary guidelines and steps in using simulation technique for managing service quality. Using the framework, we showed using the example, that key functional service quality metrics can be measured and different experiments were able to be executed. The main purpose of this case study is to show how the SIMCTS framework (using ARENA simulation package) can be used by small ISP organizations and their call centres to improve the processes involved in providing customer service and reduce the balking rates. This can potentially improve the customer satisfaction and lead to higher customer retention in a very competitive telecommunications service industry. The simulation study also helped to understand the and analyze the service operability performance, servability performance, service integrity performance and support service performance. The main highlight of the SIMCTS framework is that it incorporates the user-level service quality issues on top of the system-oriented service quality issues. In our opinion, this approach considerably increases the effectiveness in understanding and managing service quality data using simulation. The lessons learnt from such case studies/experiences in turn can prove to have a positive effect in improvising the customer satisfaction patterns. The way of controlling the SIMCTS framework using guidelines for management of key criteria, time, means and service quality factors will be something that we would like to carry out in the future. Based on the initial results obtained and the lessons learnt, the framework/ model will be continuously iterated for further development.  Overall, simulation approaches such as the SIMCTS has great potential to understand and foresee what is to happen in the future for telecommunication services. In the years to come as more and more evidence of success becomes available the popularity and the importance of SIMCTS like frameworks will be realized [111]-[212].

# Chapter 6: Results and Discussion of Simulation Models

In this chapter we discuss the results of the simulation model developed as a part of the simulation case studies and the service quality variable of interest. The discussion revolves around both technical and functional services scenarios that were modelled using the discrete event simulation methodology. The chapter also shows how the results help answer the research question, which basically investigates the application of modelling and simulation to understand and manage service quality data. The chapter also highlights the appropriateness and effectiveness of using a simulation framework such as SIMCTS to model ISP call centre operation involving call centre schedules, service representative training, understanding call centre variables such as customer balking and customer reneging. The results discussed for each of these case studies highlight not only the importance of using service quality data in simulation models and experiment different scenarios to optimize service performance, but also shows how discrete event simulation technology can be applied in a ISP business context, use the simulation results to make competitive marketing decision and come up with flexible service strategies based on specific customer services needs.

## 6.1 Scenario 1 (Chapter 4): Discussion and Verification of Simulation Results Using Queueing Theory Principles

The simulation model uses 5000 seconds. The model (Figure 4.1 in Chapter 4) illustrates the admission control process for users belonging to different service levels. This model uses simple averages to generate 166 entities for all 5 users (All 5 users use the same exponential distribution, 5000/30). All 5 users are routed to respective server for allocating network path based on processing. Of all the 5 users, User A entities arrive and they undergo queueing delay of 6 seconds (3+3=6, not the total delay as several queues have a utilization greater than one). The process time for these users is 30 seconds, that is it produces one entity every 30 seconds. Thus we can say that the service rate of these users is also on average 30 seconds. User B entities are different again, here the Network path B will produce one entity every 60 seconds. This would gradually increase the queue time and the queue would grow without bound. User C ,D and E entities still suffer a further delay due to the increased queue time faced by these users in Network path C, D and E. The processing time for these users are 40, 50 and 70 seconds respectively. All the entities belonging to User B,C, D and E entities will undergo a delay of 6 seconds and further delays due to network congestion (overloading). Thus the system does not reach steady state quite enough to process and allocate a network path for these users. Hence, the overloading process causes significant queueing delays in different network paths. The queue time in Network path A is considerably less for User A than for users of Network paths B,C, D and E. The simulation output clearly supports our theoretical analysis (Refer Table 6.1 and 6.2 for results). Thus the overloading process has significant impact on queue time according to different entity processing. To overcome this situation we have to place some restrictions on entity processing based on service types [83]-[87].

Level 1 users arrive and they are assigned a network station. They use a network management station. These are priority level 1 users. The simulation generates 100 level 1 users based on the defined arrival rates(5000/50). Of all the users who manage to use the network based on the network path routing, 94% would propagate through the queue experiencing an acceptable delay of less than 10 seconds and are then accepted and allocated with resources as required. The other 6% experience an additional delay of 30 seconds. Network path A_R (Network resource for Path A) is allocated for them that is reserved for higher priority class. The additional delay experienced by these users is due to fact that the entities belonging to the same level are subject to **rough traffic** that considerably increases delay for next incoming entities. This delay would considerably increase the queue time experienced by others users belonging to the same level and some packets are dropped. 94 packets are dropped in this specific case. This shows good agreement with simulation output that measured 96 packets in this category. Thus most of the users of this level are accepted [83]-[87].

Level 2 users get optimum level of service. The simulation model generates 125 users( 5000/40). The entities are subjected to the scanning condition **NR(NETWORK PATH A).gt.0.** Thus we could say the resource level of these users depends on current availability. Of all the users of this level 86% of them use resources below 50% (specified condition in the model). The processing time is considerably less, however they undergo a delay of 25 seconds.

The other 14% of entities undergo a delay of 25 seconds and also group delay experienced increases abruptly when some Level 1 users overuse the network, due to their priority status where entities of level 1 are "always allowed" to pass through unless a tie occurs. Thus we can conclude that the queue time experienced by these users in Network path B (NETWORK PATH B_R_Q Queue Time) is much higher than Level 1 users using Network Path A (NETWORK PATH A_R-Q). This causes entities to be dropped due to overflow in the pipeline queue and also due to lack of transporters. In this case it measured 108, this shows good agreement with simulation output that measured 110 in this category [83]-[87].

Level 3 users are the least priority users. The network path queue time experienced by these users is very high as they belong to **NETWORK PATH C_R_Q Queue Time**. Simulation model generates 55 users( 5000/90). Nearly 95% of these users undergo large delays. The process times taken for these users depend upon the current network resource availability. Level 1 and Level 2 users undergo some acceptable delays but still a majority of them are accepted as the probability of success for these users is very high due to the considerable amount of processing time and network resources allocated to them. The delay experienced by all entities of Level 3 is considerably higher than 55 seconds, however entities that strictly adhere to network conditions are allowed to pass through after acceptable time delays. Thus the preferential treatment of level 1 and level 2 users causes high delays. Level 3 users undergo starvation and only 5% (3) of them are accepted as the rest are rejected as the queue grows without bound and the buffer fills up thus flooding the network and all packets are rejected. The comparison between theoretical and simulation output resulted in simulation output measuring 3 in this category [83]-[87].

In general if we consider implementing Head-of-Line priority in the model then we can say that this is queueing discipline that is imposed on arriving users according to different service levels. This system is called fixed queueing priority. Utilization in this process would be considerably less than one and there occurs no overloading process and the system reaches steady state quite quickly to process and allocate network resources. The waiting time experienced by users who request for no more than two network resources in the sub-model would be considerably less than those who request more than two network resources. This ensures resource allocation based on user network resource requirements [83]-[89].

### 6.1.1 Arrival rate with different seed values impact on network path queue time

Arrival rates are varied for the different users and levels that use network paths A-E. From the graph (Figure 6.1) we can clearly observe that varying arriving rates the entities generated increases and decreases causing dramatic changes in queue time. Standard error of mean is calculated and we wish to display our results as estimates and corresponding standard errors. We use different arrival rates with six seed values and calculate 95% confidence interval assuming genuine random samples of population. The 95% confidence interval calculated based on assumption as gaussian distribution clearly states that queue time is not varying dramatically for path A compared to other paths. Path A is shared by User A and also by Level 1 users as they have more priority. Path B is shared by User B and Level 2 users. Paths C is shared by User C and Level 3 users.

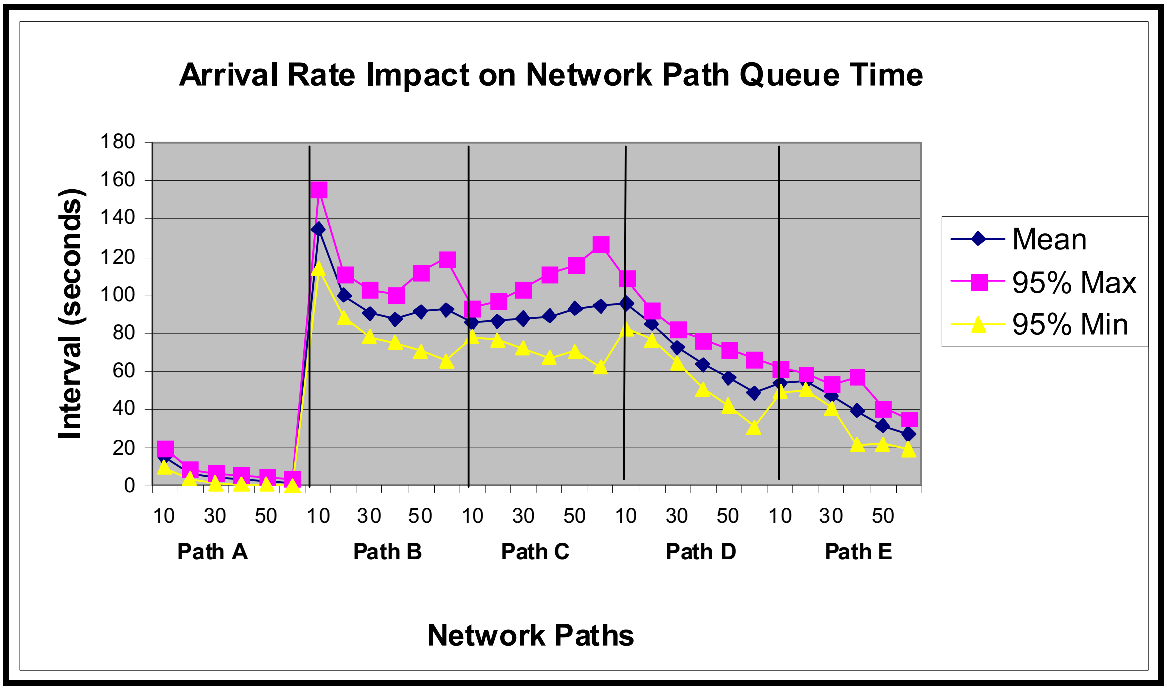


Figure 6.1: Graphs Showing the Impact of Arrival Rates with Different Seed Values on Network Path Queue Time

The number of entities generated will have an impact on the queue time as paths become busy and requires resources to be allocated to all users. However queue time also depends on priority level of users that admits more entities based on service levels and the network will have a traffic contract that would predict how many users from different levels can be accommodated at the same time (priority pricing approach). Through our confidence interval approach, we are quite sure of how often the true value of queue time for different network paths lies within the predicted range. Thus, through this process, we can control the flow of entities and restrict too many of them thus reducing network queue time and maximizing the network performance [150]. Discrepancies in simulation results occur due to Warm Up Period, Simulation Run Time and Number of Replications [83]-[87].

Table 6.1: Simulation output of Network services model

| **Identifier** | **Average (Seconds)** |
|---|---|
| NETWORK PATH A_R_Q | 2.2453 |
| NETWORK PATH B_R_Q | 39.345 |
| NETWORK PATH C_R_Q | 87.488 |
| NETWORK PATH D_R_Q | 92.535 |
| NETWORK PATH E_R_Q | 56.990 |
| # in NETWORK PATH A_R | .00135 |
| # in NETWORK PATH B_R | .02361 |
| # in NETWORK PATH C_R | .04356 |
| # in NETWORK PATH D_R | .05552 |
| # in NETWORK PATH E_R | .03419 |
| NETWORK PATH A_R BUSY | .01800 |
| NETWORK PATH B_R BUSY | .03600 |
| NETWORK PATH C_R BUSY | .05400 |
| NETWORK PATH D_R BUSY | .0000 |
| NETWORK PATH E_R BUSY | .04200 |

Table 6.2 : Count values for different service levels

| Identifier | Count | Limit |
|---|---|---|
| Network management users | 53 | Infinite |
| LEVEL1USERS | 96 | Infinite |
| LEVEL2USERS | 110 | Infinite |
| LEVEL3 USERS | 3 | Infinite |

## 6.2 Scenario 2 (Chapter 4) Verification and Validation of Simulation Model

Validation involves whether the model behaves with desired accuracy according to established modelling and simulation objectives (building right model). Verification has to be done for throughout the project and experimental analysis can be used for this. Objective established during modelling and simulation should be satisfied through simulation model developed. Model is looked at in detail and conditions specified for validation are provided. Problem formulated is modelled and is essential for model validation [163][170].

We used data validation technique and sensitivity analysis based on the following factors

- Simulation type (Discrete Event).
- Model type (Network based model).
- Problem modelled ( SLA network management).
- Modelling and simulation objectives (Effective simulation study in SLA management ).

Validation involves building the right model and verification involves building the model correctly. “Trace” option in ARENA was used to get intermediate results and compare them with theoretical output to check model values. Model was validated by making predictions and checking output against predictions (Sensitivity Analysis)[101]-[103].

### 6.2.1 Animation used to ensure model verification and validation

Animation is very important for better understanding of the model developed and to improve the model confidence. We have employed animation in the model to count the number of packets, monitor threshold conditions and any possible alarms generated out of it, visualize different packets generated by different users belonging to SLA levels and visualize entire network working process. In [107] simulation experts state that visualization provides high bandwidth communication that allows more information to be transferred in a very short time. This allows one to visualize the working process of very complex models and also validate the model design. Animation plays an important role in the model validation as it helped us to visualize the path entity takes and trace each of its activities in modules.

### 6.2.2 Terminating simulation analysis in the User SLA Process Plan Model

In terminating simulation model has a definite starting and specific stopping condition. This is suitable for places like factory (or) peak load analysis of networks. Instead of running the user model for specified length of run we wanted to experiment by placing a condition where the SLA level in user model no longer can accommodate more than specified number of users. This was done by specifying the maximum number of batches filed in “Arrive” module to range from 50-950 users. The simulation run field was left empty as automatically ARENA ends the simulation once specified users are accommodated. To track the number of users at SLA level we used the WIP (Work in Process) variable in

ARENA. This variable was defined in our **Arrive** module as users arrived in the model. Departing was done using the **Actions** module where variable WIP is assigned and decrement WIP. We used **Sequence** module where SLA process plans were defined and all user entities are routed to **Actions** module with station name **Decrement WIP**. Some detailed explanation about these modules in [106] was useful to perform this desired operation within our model.

Running the simulation model for specific set of replications and identifying that the replication used is desired set is a challenging task. Model was run for 10 replications and we computed the 95% confidence interval. Careful consideration was also given while choosing the replication by experimenting with different sets and observing any variation in output. SLA Levels (1-3), User 1 – User 3 queue time confidence interval was computed (Figure 6.2). From the graph it is clear that the queue time is not that much sensitive to higher batch size values used in the model. We observed wide variation in queue time between batch size 50-250 and then queue time had settled down. Thus confidence interval helped us in identifying how precise the estimate is (WIP average value is point estimate) [101]-[105].

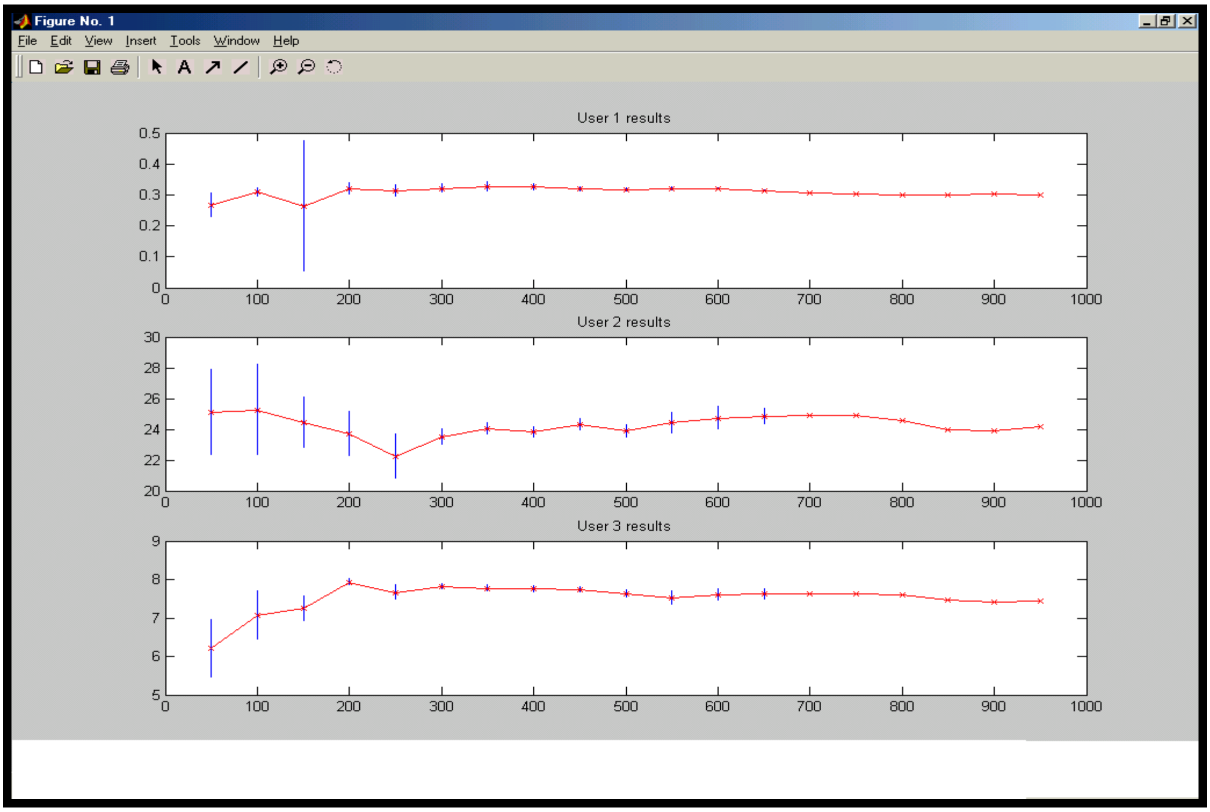


Figure 6.2: Confidence Interval Plot for User SLA Process Plan [111]-[140]

The service level management module uses 100000 seconds as simulation run time. The model is an open queueing network model. Poisson arrival at each queue and with exponential service times. We use independent service rate at each queue within the model. Users belonging to different SLA levels enter and leave the network. Five users arrive with exponential service times. The users are routed to server module for choosing the intended service required. The model uses a warm up period of 8000. This is to remove any initial bias in results and collect only statistics after the system has reached steady state. The output analyzer helped us to experiment with different warm up period run results. Once the entities undergo processing in servers they are sent to branch module where they have probabilistic split. When a user arrives at this module the module checks for first satisfied branch condition and sends the entity to the next module. We also employ deterministic rule of always and else to send a copy of entity to destination if fewer than maximum number of branches have been satisfied. The model generates 2830 entities based on various arrival rates. The entities choose the intended service with probabilistic branching and are sent to service type A with process time defined. Most of the entities at this fail to comply with rule due the nature of SLA policy that admits only 25% of entities based on optimal network service. This occurs only if the entities satisfy the first branch condition. Route from one queue to another is selected randomly with fixed routing time designated for all modules. They undergo routing delays between different stations. The entities generated in this cased is less than 4% due to poor resource utilization. This leads to only 86 of the entities departing the system that includes both the pass and failure inspected entities. The only difference is that all pass inspected entities are routed to server for SLA payment options [101]-[105].

Table 6.3: Queue length and server utilization [6]

Please see print copy for Table 6.3

From the above Table you can see that the utilization (100* resource busy/ resource available) ratio is high for user requirements A and user requirements B. This is due to the nature of the queue and process time of the user entities. The maximum number of queue is 3 for user requirement A and it becomes zero at the end of the run which indicated that queue is empty. In user requirement B 33 entities are in the maximum range and at end of the run still 9 entities are in the queue. The main reason for this due to the fact that SLA policy 1 involves more user processing states where users entities are duplicated and then inspected and are checked if their requirements could be satisfied with proposed SLA policy. During this process entities undergo variable delays and thus this causes increased queue time. This shows good agreement with simulation results. For other servers that process users based on their policies service type A user server quickly processes users because entities at this SLA level have no restrictions on usage limits. Policy 2 users have various resource constraints due to transfer limit to capacity of network link (high propagation delays encountered). Alarms are triggered based on different queue and resource usage conditions and user request processed accordingly. The results of the resource utilization data agree with our analysis. Thus through this resource statistics we can find the busy time and availability of a resource and calculate utilization. Based on the utilization ISP can estimate whether more users could possible be accommodated with available resources. Thus this simulation model helps to investigate some important scenarios such as for example [101]-[105]. In the alarm module we experimented with different processing time and arrival rates with defined threshold condition for the model and performed sensitivity analysis to check the model output for different input conditions [100].

Table 6.4: Arrival Rate: EXPO (50) Alarm threshold: More than 15 users, Simulation Time:100000 seconds

| **Process Time (EXPO)** | **Queue time** | **Count** | **Customer time in network** |
|---|---|---|---|
| 10 | 2.1965 | 2009 | 19.893 |
| 20 | 11.606 | 2022 | 19.893 |
| 30 | 47.646 | 2043 | 85.397 |
| 40 | 164.39 | 2055 | 212.24 |
| 50 | 1910.2 | 2015 | 1967.7 |
| 60 | 7674.4 | 1734 | 7736.6 |
| 70 | 13294 | 1445 | 13360 |
| 80 | 17510 | 1262 | 17581 |
| 90 | 22953 | 1118 | 23030 |
| 100 | 26328 | 994 | 26411 |

Table 6.5: Process Time: 20 Alarm threshold: More than 5 users, Simulation Time: 100000 seconds

| **Arrival Rate (EXPO)** | **Queue time** | **Count** | **Customer time in network** |
|---|---|---|---|
| 10 | 25359 | 4999 | 25382 |
| 20 | 1365.4 | 4967 | 1393.4 |
| 30 | 21.130 | 3379 | 49.130 |
| 40 | 10.508 | 2570 | 38.508 |
| 50 | 7.0344 | 2038 | 35.029 |
| 60 | 5.3075 | 1691 | 33.307 |
| 70 | 4.4682 | 1447 | 32.468 |
| 80 | 3.8103 | 1269 | 31.813 |
| 90 | 3.2514 | 1110 | 31.251 |
| 100 | 2.7854 | 995 | 30.785 |

Table 6.6: Arrival rate: EXPO (50) Alarm threshold: More than 15 users, Simulation Time:100000 seconds

| **Process Time** | **Queue time** | **Count** | **Customer time in network** |
|---|---|---|---|
| 10 | 1.3285 | 2039 | 19.329 |
| 20 | 7.0344 | 2038 | 35.029 |
| 30 | 24.175 | 2037 | 62.183 |
| 40 | 79.233 | 2037 | 127.26 |
| 50 | 1577.5 | 1967 | 1634.4 |
| 60 | 8265.8 | 1663 | 8327.7 |
| 70 | 13826 | 1428 | 13893 |
| 80 | 18112 | 1249 | 18184 |
| 90 | 21487 | 1111 | 21565 |
| 100 | 24201 | 999 | 24283 |

From the above results the quantitative validation of model is done based on sensitivity analysis by comparing simulation output with theoretical calculations done using queueing logic. The queue time is more sensitive to arrival rates, process time than threshold patterns. This is because the network operational load is highest at this SLA level which causes increased queue time and decreases total entity processed count value [100].

Network user inspection module was run for 100000 seconds. The users are checked for their service provision once they arrive in specified SLA groups and then are checked by the user processor. All users who arrive in the modelled M/M/1 server queue for server 1 and another M/M/1 server queue for server 2. Thus we have cascaded M/M/1 queues. The model was tested for different failure probability and process time. Visual basic form was used to allow the user to enter network inspection time and failure probability [100][101]. We used exponential service time distribution EXPO (100) and failure probability of 0.04. From the output results we observed that the model behaves as desired as the service provision 1 and service provision 2 server had processed all user by the end of simulation time (Table 6.4, 6.5 and 6.6).

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Please see print copy for Figure 6.3

Figure 6.3: Peak queues observed in Network SLA Model (Peaks observed between simulation run 25000-60000 Seconds) [113]

However we observed the user processor server was idle most of the time and this resulted in very high queue time and queue length for users. The main reason for this is due to the fact that the user processor had to process all entity within the specified time and this leads to lot of  entities unsuccessful. The entities that are processed are sent to corresponding depart module for collected statistics based on pass and failure inspection data. This helped us to identify how threshold user limitation would create congestion in networks and thus provide very poor end user service. The sensitivity analysis graph shown in Figure 6.3 helps us to visualize the peak intervals in the service provision 2 queue. We also experimented with the impact of simulation run time also on entity processing. This was done to observe changes in the model for input conditions over various period of model run. We observed the changes within 2000-50000 seconds, 50000-70000 seconds and 70000-100000 seconds. From our analysis we found that high queue time was observed in the run time between 20000-50000 seconds. This is due to too many entities generation and very high queueing delays. This leads to various queues with utilization greater than 1. The run time between 50000-70000 also experienced high delays initially but we noticed that the system had settled down after most of the users were sent to rework queue [101]-[105]. The results from the scenario 1 study can help service providers to define the traffic streams that need to be given more priority and the type of applications that require monitoring to check conformance with SLA. Simulation model developed in SLA scenario 2 can help ISPs to vary the simulator parameters such as number of customers with SLA's versus number of sources using TCP/IP default such as best effort, and then ascertain the best mix of different quality of service requirements in an internet.

## 6.3 Modelling the generation and Handling of Complaint Process and Complaint transfer to various sections in Service department (Chapter 5)

The model results showing the difference between the actual time and estimated (expected) waiting time for response to customer complaints as a function of satisfaction- Positive values indicate how much longer customer entity waited than expected shows how long a customer waited than expected. (Positive values indicate this) [88]. The arrival rates and service times for handling complaints might change from day to day and so it is very important to understand that numerical output performance measures are different for different days. We ran the model for 20 replications and this was done to know how much variability was associated with the results (Figure 6.4).

Please see print copy for Figure 6.4

Figure 6.4: A graph showing the difference between the actual time and estimated (expected) waiting time for response to customer complaints as a function of satisfaction [113]

Thus the model uses same input parameter and separate random number streams to generate inter-arrival time and service time for each replication. The capacity of resource can be changed over time and schedule operation available in ARENA can be used. All states of resources can be visualized *(Busy, Idle, Inactive and Failed)*. We used the schedule rule ***WAIT*** in ARENA to allow the arriving entities in the relevant section to wait until current entity in service release the resource. The complaints are loaded in to the system and middle level manager reviews them. The complaint slips are then organised and the problem is fixed. If the customer is notified within specified time set according to SLA the customer is satisfied. The relevant department is notified that the complaint has been fixed and complaint record is closed. Some of the main variables are animated and monitored during the simulation run [88][95].

### 6.3.1 Validation using Confidence interval and Sensitivity analysis for this Scenario

In the output analysis process of simulation model three important factors were considered. They are appropriate length of simulation, Interpretation of simulation results and analysis of the differences between the replications [84][55] (Figure 6.5 and 6.6). The confidence interval width depends on the level of confidence, number of replications and variation within performance measures collected. For validation purposes the "TRACE" and "STEP" command in ARENA was used. This command allows us to monitor a particular customer entity when it moves from one *SIMAN* block to other and determines if the logic is correct. In our model we set the trace condition to get the information about all the customer entities whenever the buffer before the service manager queue is full. The command used was [55].

```
> SET TRACE CONDITION NQ(Service Manager_Q).EQ.3
```

Because it is a steady state simulation it is important to find out appropriate number of replications and analyse difference between replications. We used the validation approach proposed in [20] in order to calculate the transient phase (warm-up period) and calculate number of replications. The model was run for 10 replications and ARENA output analyzer was used to generate the plot. From the plot the system steady state process was visualized. The model was run for 5000 minutes and system had reached steady state after 900 minutes. Thus the warm-up period will help us to remove any initial bias in the simulation results. Our initial approach was to achieve average customer waiting time to be 5% of sample mean with a desired confidence level of 95% [half-width less than (or) equal to 5% of the sample mean). The model was run for 25 replications and confidence interval (lumped results) were obtained using ARENA. After this 5% of sample mean was calculated and compared with the half-width of confidence interval. The above condition was not satisfied and it was necessary to determine the additional number of replications required [55][88].

Total number of additional replications is calculated using $(n^*) = n\ (h/h^*)^2$

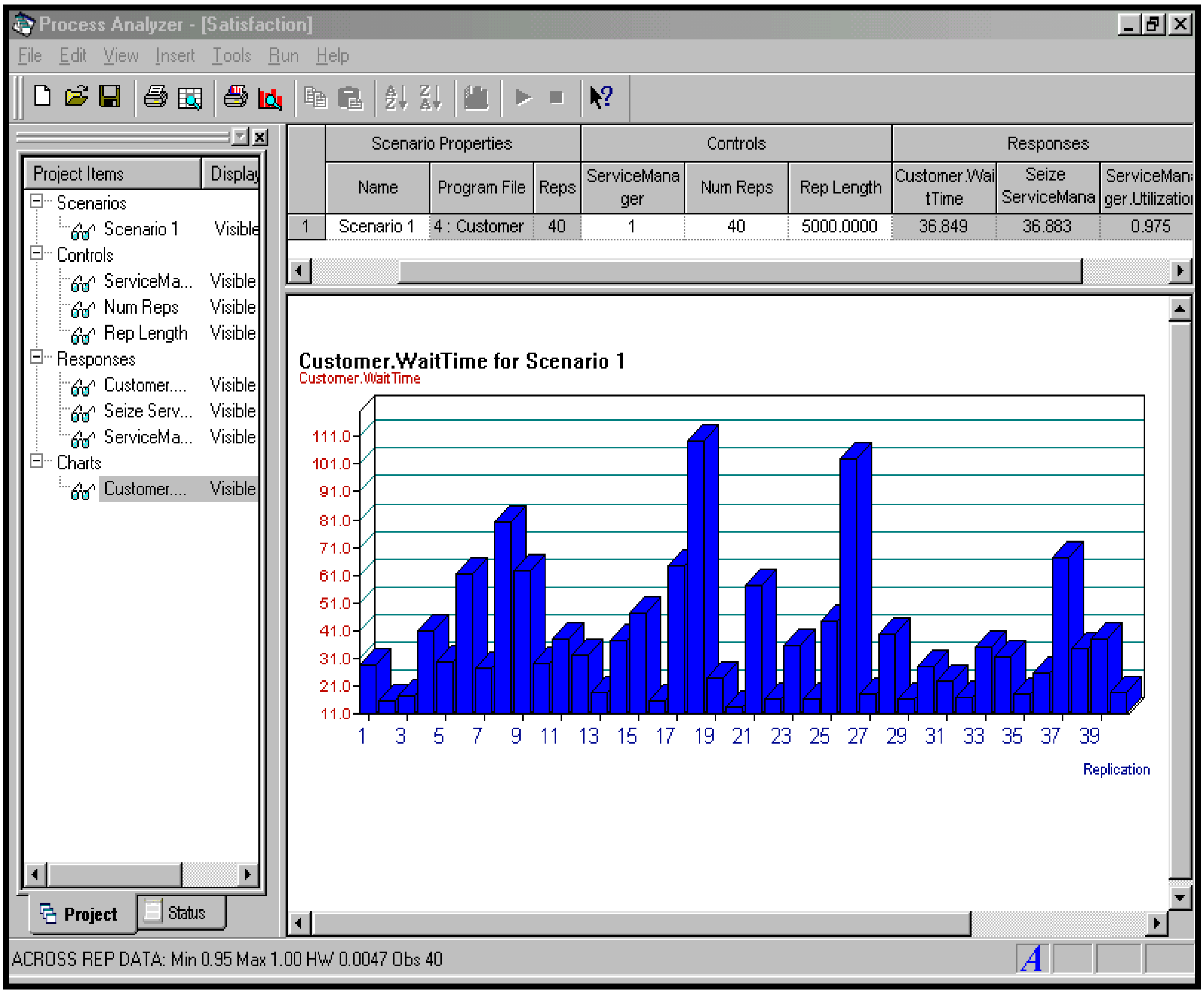


Figure 6.5: A sensitivity plot analysing simulation output across 40 replication [88][113]

Where '*n*' denotes initial number of replications, '*h*' is the half-width of initial confidence interval and *h** is desired half-width. From this the additional number of replications was found to be 15. In order to create independent replications of simulation (avoiding identical results) from those already performed *SEEDS* element in ARENA was used. 6 different seeds values were used and model was run. This helped to validate the model and increase the model confidence. Thus, 40 replications are necessary to obtain customer waiting time that is less than 5% of sample mean at 95% confidence level. Sensitivity analysis (making predictions and checking output against predictions) was done for waiting time across 40 replications (Refer Figure 6.5) [55][88]

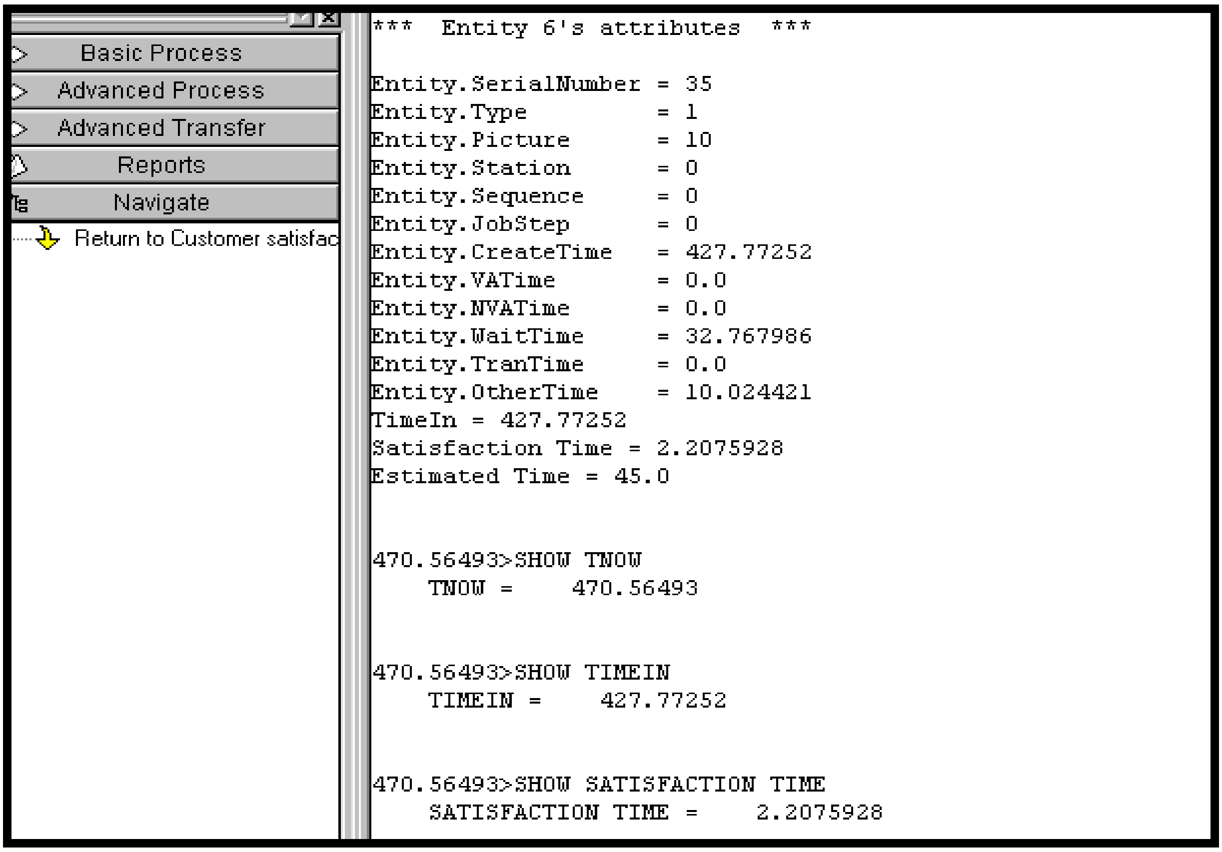


Figure 6.6: Simulation validation by “STEP” and “DSTATS” feature in ARENA and SIMAN editor [88][113]

Some of the important results collected from the model includes the total number of complaints received during the reporting period, number of complaints enquiry operators and service managers available and busy and the total number of enquiries submitted and recorded based on different complaints level (Figure 6.6).

## 6.4 A Call Centre Balking Model to Model SIMCTS Service Quality Attributes (Chapter 5)

When the inter-arrival time increased the server was less busy. In situations where the high arrival rates were noticed the server was busy most of the time. We were thus able to investigate the break point utilization where the utilization reached 100% [215] .The model parameters are defined below for the above case (Figure 6.7 and 6.8).

Please see print copy for Figure 6.7

Figure 6. 7: Model Parameters for Customer Balking and Reneging Model [113]

Please see print copy for Figure 6.8

Figure 6.8: Impact of service delay time on customer balking, reneging and serviced customers [113]

ISPs are changing their customer care operations to the internet. There is a huge investment in human resource and computing resources on call centres. All ISPs employ service experts for understanding operational service processes. This person can also be a service manager. Key scenarios covered in the model include a stage where service manager should handle traffic from internet to call centre. This has become a integrated part of real time service platform. Simulation model developed demonstrates how technology can enhance call centre service operations. Existing system is modelled and flow of entities and their relationship of activities within call centre system was understood and exercised in the model [88][94]. The ISP call centre receives email enquiries . The service enquiries received are logged and is handled by service manager. The simulation model helps to investigate the mean time it takes to process email enquiries coupled with telephone enquiries. This is a steady state process as input do not change during simulation run. The model parameters are defined below for this case (Figure 6.9).

Please see print copy for Figure 6.9

Figure 6.9: Model Parameters for Customer Balking and Reneging Model [113]

Customer arrival /emails, calls(input); Service type request (delay); different processing times with call centre operator intervention (resources). Service activity mix is where different customer request for different service type. The ISP provide the mix of all service types and associate a process time. An expert opinion was obtained to gain estimate of time to perform particular service activity. TRIA () distributions was chosen to approximate process time (Figure 6.9). It was interesting to note that varying service delay time did have huge impact on number of balked and renege customers (highly sensitive to input parameters). Sensitivity analysis was used to understand impact of input model uncertainty. Delay service time parameters were varied and output results were sensitive. This helped us to collect more data and then improve the estimation of accuracy of input parameters [181].

We ran the independent replications of simulation model (ARENA automatically uses non-overlapping streams of random numbers). Simulation is started with same initial conditions for each replication. In the **server queue** in balking model, any call that is unable to find a resource is balked. This is an important aspect of overflow routing. The main performance measure of interest is the effect of changes in model service delay time on number of balked, reneged and serviced customers. From the graph in Figure 6.10 it is clear that as the service delay time increases then more customers balk from the system. The number of renege customer also increases. Thus there is an overall impact on service quality as the serviced customers number decreases. The ISP manager should thus manage the email service process delays as well as the telephone service delays to improve overall service quality [215] (Figure 6.10).

Please see print copy for Figure 6.10

Figure 6.10: Consolidation of service reviews using the balked customers statistics and email enquiries reviews using service delay factor variation and specifying service manager process delays [113]

Following the SIMCTS framework, we verified the model by checking whether the model has been correctly coded and correctly transferred from the model data collected (and conceptualized) to the simulation model. During this stage, (distributions of the) input variables have been determined, the model structure has been defined and calculation rules have been setup to calculate the output variables.

SIMCTS framework also requires solution validation. For that, we checked if the model is correct as compared to the reality. In other words, we checked if the model represents reality. This is required to ensure that during the search for solutions a correct comparison can be made with the model in order to evaluate the improvements. There are three forms of validation: replicate validation, structural validation and expert validation. Replicate validation compares the values of an output variable in reality with the values for the same output variable calculated by the simulation model. In structural validation, the simulation model is usually made to calculate different alternatives. This not only requires that the simulation model adequately reflect reality, but also that the simulation model properly responds to changes in the input variables. Here we followed the last validation procedure, i.e. expert validation. In this case, experts assess qualitatively the output and structure of the simulation model. This technique is very useful in situation where there are no measurement data or because it is too expensive or too time-consuming to collect detailed measurement data. During the verification and validation of the model, animation can be an important factor. An animation quickly provides an understanding of the working of the program and is thus a very useful tool for the modeller to use during the verification phase of SIMCTS. During the validation, animation can be used during the expert tests. A proper animation to a simulation model will make the model easier to understand for experts.

## 6.5 ISP Call Centre Service System: Simulation Strategies and Methodologies in Customer Satisfaction (Chapter 5)

In our case study the simulation experimentation was not performed to obtain concrete solutions to ISP service systems, but instead help develop a very good understanding of the real world. Implementing the results of simulation study is very important. There are several ways of implementing the simulation results. In this case study we look at alternative staff schedule impact on the determinants of customer satisfaction and identify the best schedule. New ISPs can implement such models and their effectiveness can be continuously monitored. Thus apart from learning the service processes and their interaction ISPs can also make very confident business decisions. Service managers of ISP thus need to understand the effect of help desk and trouble ticketing features and their direct impact on customer service. This will increase their responsiveness attitude, as simulation will help them to understand the effect of one customer satisfaction variable on another. Model was run for multiple replications of day long scenarios [88][94] [215].

The simulation model has 32 trunk lines and 17 operators. The call centre has several links to its branches within city. This particular centre operates with 11 technical support calls operators. The changes in schedule occur very frequently based on the availability of staff. There is also an automatic call routing strategy used to re-direct customers to operators located in other centres. Automatic Call Distributor (ACD) is a telephone answering method to handle very high volume of incoming calls. It distributes them to agents in various ISP call centre branches equally using standard telephone lines. This is again based on the availability of the operators in that centre. The authors were particularly interested to see the relationship between the number of trunk lines and number of operators. Most small ISP call centre do not operate 24 hours and also do not increase the operators unless there is a absolute necessity. After conducting the simulation scenarios we believe that the the relation between the trunk lines and number of operators depend upon the subscriber base, frequency of calls, nature of enquiry, cost of providing service and waiting time threshold. Managing these factor helps ISP to synchronize service operations[88][94][97][184][211][212] .

**Proposed Changes:**
**Schedule A:**

There are 35 operators in all inter-connected centres and 30 are busy entire 8 hours( Each operator works for 8 hours). Table below shows the call centre utilization levels.

Please see print copy for Figure 6.11

Figure 6.11: Technical support services proposed schedule changes and related utilizations [113]

**Schedule B**: There are 30 operators in inter-connected call centres working first 4 hours and 20 operators working next 4 hours. 25 are busy the first 4 hours and 18 last 4 hours.

**Schedule C:** There are 30 operators in inter-connected call centres for first 4 hours and 25 for last 4 hours. 20 of the operators were busy for all 8 hours. Figure 6.11 looks at utlisation statistics reported from simulation for above 3 schedules

The following scenarios were explored for technical support centre. The scenarios explored reflect the technical support services operations. However there is a still a direct impact of these scenarios in ISP information line where 6 operators are dedicated for this operation, Figure 6.11.

**Call Centre Scenario 1:** Impact of trunk lines on number of abandoned calls without changing the number of operators. From the graph (Figure 6.12) we observe that the increasing the trunk lines increases the % of balked calls. This is because more customers are able to get to the call centre network but only few are serviced by operators and rest balk from the system.

The model helps ISP managers to set service levels and the standard % for abandoned calls and thus plan for number of operators and trunk lines required. Several key statistics such as line time, trunk line utilization were also collected and analyzed to derive meaningful conclusions of the model. Rather than assigning a higher priority to return calls over incoming calls, it is better to dedicate a few trunk lines for this purpose. Understanding the relation between number of calls, average time, available time of operator, utilization rate at which ISP call centre is running helps to decide the number of operators.

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Please see print copy for Figure 6.12

Figure 6.12: Impact of trunk lines on number of abandoned calls with current operator levels [113]

**Call Centre Scenario 2**:All the technical support operators are available continuously with the schedule 1@480, 0@180 (each operator works for 8 hours (480 mins) and in total there are 660 minutes of call centre operations). 1 represents an individual operator, 0 represents the unavailability of operator, 32 trunk lines.

**Call Centre Scenario 3**:***Operator 1-Operator 5*** 1@480, 0@180, ***Operator 6***: 0@150, 1@180, 0@30, 1@300, ***Operator 7***: 0@30,1@210, 0@150, 1@270 , ***Operator 8***: 1@180, 1@480, ***Operator9-Operator 11***: 1@480, 0@180 , 32 trunk lines.

Comparing these two scenarios it quite clear from graph (Figure 6.13) that making all the operators available during the specified time period reduces the % of balked calls. Even though the number of balked calls is reasonably high, still it is not as high as Schedule 3. It is important for ISP managers to review these aspects prior to increasing the number of trunk lines and number of operators. Additional scenarios were conducted by making schedule changes and the % of balked calls were recorded and analyzed to come up with feasible schedule.

Please see print copy for Figure 6.13

Figure 6.13: Optimizing the ISP schedules to set service standards [113]

As-is Category scenario:[Technical support types]

(i) Category Type 1 calls: operator1-operator 5 technical support. (ii)Category Type 2 calls: operator 6-operator 10 technical support (iii)Category Type 3 calls: Operator 8,11,5,2,3,9,1 technical support. Alternative schedules used for scenarios listed below involving additional operators: *Op1*: 1@300, 0@180, 1@180, *Op2-Op5*: 1@300, 0@180, 1@180, *Op6*: 0@150, 1@180, 0@30, 1@300, *Op7*: 0@30, 1@210, 0@150, 1@270, Op8: 0@180, 1@480 *Op9-Op11*: 1@300, 0@180, 1@180, *Op12*: 0@30, 1@210, 0@150, 1@270, *Op13*: 1@300, 0@180, 1@180, *Op14*: 0@180, 1@480, *Op15*: 1@300, 0@180, 1@180, *Op16*: 1@300, 0@180, 1@180, *Op17*: 0@30, 1@210, 0@150, 1@270*,* *Op18*: 1@300, 0@180, 1@180,]

Alternative Scenario 1: All 11operators are cross trained to handle various categories of technical support call types (categorty type 1, category type 2. category type 3) trunk lines=32, Alternative Scenario 2: Four additional resources were added and all 15 operators cross trained to handle 3 category types of calls trunk lines=32, Alternative Scenario 3: 15 technical support operators cross trained to handle all category types calls and trunk lines =95., Alternative Scenario 4: 18 technical support operators cross trained to handle all category types calls and trunk lines =95, Alternative Scenario 5: 8 technical support operators cross trained to handle all category types calls and trunk lines =32, Alternative Scenario 6: 8 technical support operators cross trained to handle all category types calls and trunk lines =95.

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Please see print copy for Figure 6.14

Figure 6.14: Alternative schedule scenarios and their % service levels [113]

From the scenarios explored, we can clearly see from Figure 6.14 that including 8 cross trained operators with 32 trunk lines and 95 trunk lines where all operators can handle 3 category types, there is around 15% decrease in balked rates for 32 lines (overall balk rate is reasonably high). There is a operational benefit in terms of cross trained agents, but still the number of operators trained, number available and total trunk decide the magnitude of the lost calls. It was interesting to see that having 11 operators cross trained with 32 trunk lines did decrease the % of balked calls. Any significant increase in trunk lines should be balanced with the number of operators cross-trained and the schedule [215].

The simulation results help ISP manager to understand and establish a Telephone Service Factor (TSF) standard. This standard defines the % of calls answered within an acceptable time. It is important to take in to consideration the average time to answer, speed of answer and balk call average waiting time. A comparison between average time to answer and balk call average time helps managers to set wait time period acceptable to customers. The simulation results thus helps to improve telephone service factor and reduce the %-abandoned calls by answering them on time. The results indicate that some calls were lost due to unavailability of trunk lines and majority of calls were lost due to unavailability of operators. Trunk line utilization, line time utilization, and operator utilization statistics helped us to derive this conclusion [1].

Verification is process to ensure that model behaves as intended based on assumptions. Validation is making sure model closely behaves as the real system. The verification method we used was allowing a single entity to enter call centre model and trace that entity to make sure model logic is correct. "Step" feature in ARENA helps to control model execution. Animation speed factor was adjusted to monitor individual entity flow. Model was run under extreme conditions and no abrupt behavior was observed. This helped to check if the summary data is correct [88][94]. To increase our model confidence, it was essential to compare the real system and our simulation model. Simulation analyst who had detail knowledge of actual ISP system was asked to view the model. This person's expectations and intuition helped us a lot to improve the model and make number of changes (in fact several modules were deleted and the authors had to build some more sub - models). It was necessary to fine tune model to adjust some of model parameters. The analyst chose specific scenarios we ran in the model and compared a few important customer service levels parameters using the output averages. The author would like to state here that the comparison was done in order to make sure the model reflected the real system. The study undertaken was not to propose any concrete solutions to ISP. The response from the simulation analyst was that model was indeed close to a typical real system (distribution of data indeed played a important role) [88][94][215].

## 6.6 Conclusion

To answer the main research questions “*What is it that the use of discrete event simulation techniques can contribute to the understanding and managing of the functional service quality data for different ISP service operations?”* we conducted a number of simulation studies. We have investigated what effects the SLA (service level agreements) will have on customer expectation and customer satisfaction, and the need to understand and manage SLA’s and to come up with effective SLA’s by analyzing different “what-if” questions. To forecast or predict planned changes and their effects on current network management operations and study if they would have a positive or negative impact on the current level of customer expectations before and after implementing the SLAs.

After evaluating the current literature on service quality in an ISP context, key factors that affect ISP business performance were identified. This includes some technical specifications. The scenario conducted on “Simulation of Policy Based Networks through Differentiated Service Levels” highlights the need for small ISPs to have effective network policies and provide differentiated services. The case study highlights the importance of simulation to provide flexible service provisioning based on specific customer service needs. The scenario conducted on “Modelling and Simulation of Alarm Based Network Management for Effective SLA Monitoring and Management” emphasized the need for small ISPs to meet the objectives specified in SLA (Service Level Agreements) and meet the marketing promises made. These network scenarios look at technical specifications that affect customer satisfaction and the importance of managing these technical elements (Chapter 4). The scenarios helped us to achieve objective 1 and research question 1.

We also investigated the impact of simulation studies on different network scenarios to establish current (or) improved levels of customer satisfaction and highlight the need for improvement of the functional service quality elements to handle increasing customer demands and expectations. The importance of managing key service quality dimensions that have a direct impact on customer satisfaction. After evaluating the current literature on service quality in an ISP context key factors that affect ISP business performance were identified. Functional elements that affect ISP business performance were identified based on the reports published by TIO (Telecommunications Industry Ombudsman), ACMA (Australian Communications and Media Authority) and IIA (Internet Industry Association of Australia). A network scenario was conducted on modelling dimensions of complaint satisfaction (Chapter 5). The actual time and estimated time in processing customer complaints were modelled using the discrete event simulation technique and was found to be an important indicator of customer satisfaction. The scenarios helped us to objective 2 and research question 2 [113]-[140].

The scenarios covered in Chapter 5 highlight the benefits that can be achieved by using simulation tools and techniques in modelling key functional service quality elements in ISP context and come up with a generic simulation framework for the proposal, evaluation and decision support of customer satisfaction in telecommunication services. This framework is a simple simulation study framework suitable for an internal study of planned business changes and their impact on current customer expectations and satisfaction levels and serves as a knowledge base of past, present and predicted customer expectations (possible to use within an organization). Three main scenarios (Scenario 4 and 5 in Chapter 5) emphasized the importance of having a consistent simulation framework like SIMCTS in modelling service quality attributes involved in ISP business operations . The case studies involved modelling ISP call centre operations and also the importance of understanding the customer waiting time tolerance zone by modelling customer balking and customer reneging. Steps involved in the SIMCTS case study, modelling SIMCTS elements, simulation modelling and analysis mapping with SIMCTS, SIMCTS testing and validation are discussed in detail in these scenarios. The scenarios helped us to achieve objective 3 and research question 3.

From our research we conclude that both the technical quality of the service and functional quality dimension of the service process influence the customer satisfaction and ISP service quality. After analysing the results and testing the hypothesis we found that discrete event simulation is an effective approach to understand and manage functional service quality data for different ISP service operations.

# Chapter 7: Conclusion and Future Work

With an increasing usage of telecommunication services it is important to raise awareness of the various telecommunication issues. High speed Internet access is increasing and constitutes a growing component of Internet market. The telecommunications industry has changed considerably over the last 5 years (2002-2006). New providers have entered the market; there were mergers between sone ISPs and others ceased to operate. Thus Internet Service Providers should be prepared to support new technology based network services that influence the transformation of the telecommunications industry. From our research we conclude that the technical quality of the service and functional quality dimension of the service process both influence the customer satisfaction and ISP service quality. ISP customers may feel that they get the same technical quality as before, but the manner in which functional service is provided has deteriorated. Chapter 1 introduced the research domain and the problem domains and uses the statistics published by Australian Bureau of Statistics (ABS, 2005) [2] to act as a baseline for this research.

Chapter 2 covered a detailed literature review on customer satisfaction and service quality in the ISP context. The literature integrates simulation techniques and their effectiveness in exploring different network scenarios in network management area.

ISPs who serve their customers on a regional basis should be aware of the bandwidth and reliability the customers expect from them. It is also important for the service providers to understand the changes in customer requirements over time and when ISPs expand their services they have to ensure that the customers are capable of paying extra for the bandwidth and reliability. Service guarantee through an SLA can convey to customers the service level and benefits they can expect from using a service, and from an employees' view convey the results they are expected to produce for their customers. It also helps providers recognize and re-design the service process for service failures.

We showed in Chapter 3 the effectiveness of using the discrete event simulation methodology to model network scenarios involving technical and functional attributes. This chapter also discusses the simulation software ARENA that is used for this research project. Justification of this software for this project has also been covered to highlight the suitability of this software to model both technical elements and functional elements in networking area. In the Internet service provisioning process there are many relatively new services offered. Many consumers are still learning to judge the service they receive. This depends on the context of many different situations. ISP technical support is very important for the newcomers to Internet and those who have limited technical skills. There is no easy technique to objectively measure the quality of technical support on offer, as this widely depends on individual ISP and quality of staff manning the help line. Good customer service builds a relation, strengthens customer loyalty and discourages them from switching providers for price. In the current situation customer service departments will be asked to serve more customers on a broader scope of issues and problems and as cost effective as possible. For marketing service quality and achieving it, service guarantee is a powerful tool. Service guarantee also affects the performance of providers in several ways. The scenario 2 modelled in Chapter 4 answers research question 1 and sub question 1.1. SLA management was covered in Chapter 4 in scenario 2 that was modelled. Network scenario 1 in Chapter 4 involved flexible service provisioning using differentiate service scheme. This scenario answers sub question 1.2 and 1.3 as it identifies the key network service parameters like network queue time, resource allocation, queueing policies, network traffic and their impact on overall customer satisfaction.

Many small ISPs operate in a very highly competitive market with slim profit. There is a difficulty to sustain in the business in countries where telecommunications liberalization occurred after the explosion in Internet use. Service managers need to make sure that all selected customer satisfaction variables that help customers to make decisions are relevant, comprehensible, quantifiable, measurable, comparable, revealing and available.

## Major Contributions

The main contribution of this research is the development of SIMCTS framework that addresses both user level and system oriented service quality issues. The research work highlighted the fact that service quality process is much more than just measuring and monitoring. Providers should anticipate and respond to customer service request. Quality improvements cannot be achieved solely by modernizing network equipments. Chapter 5 covered 3 main functional scenarios that were modelled using the developed SIMCTS framework. The scenario 3 involved modelling complaint service attributes and the scenario 4 and 5 involved modelling determinants of customer satisfaction in ISP call centre operation. They include customer balking, customer reneging, customer queue time, telephone service factor and technical assistance. The study also identified the benefits that can be achieved by cross training operators who are able to handle different call types based on the nature of the complaint and severity level of the complaint. The simulation is designed to provide a real world edge that is missing in traditional service quality studies/model such as SERVQUAL. This technique helps small ISPs to understand their operations, service strategy and have a balanced approach that emphasizes importance of service quality, marketing and human resources management. The developed SIMCTS framework provides the necessary guidelines and steps in using simulation technique for managing service quality. Using the framework, we showed using the example, that key functional service quality metrics can be measured and different experiments were able to be executed. The main purpose of the case studies conducted were to show how the SIMCTS framework (using the ARENA simulation package) can be used by small ISP organizations and their call centres to improve the processes involved in providing customer service and reduce the balking rates. This can potentially improve the customer satisfaction and lead to higher customer retention in a very competitive telecommunications service industry.

ISPs need to provide excellent functional service in situations where technical support is required. These include key service quality dimensions such as tangibles, reliability, responsiveness, assurance and empathy. Particularly issues like Internet access problems, connectivity problems, password problems, search engine problems, technical related problems emphasizes that responsiveness nature of service providers to customers is very important. This will minimize customer exodus and reduce the churn rate. Chapter 6 highlights the results and discussion of simulation scenarios conducted as part of this research study. After analyzing the results and testing the hypothesis we found that discrete event simulation can be used to understand and manage service quality data for different ISP service operations. The future work will involve investigation of other possible ISP service scenario that can be modelled using SIMCTS and also using the SERVQUAL data in the simulation model which is obtained by conducting SERVQUAL surveys (customer expectations and customer perception, ISP expectations and ISP perception).

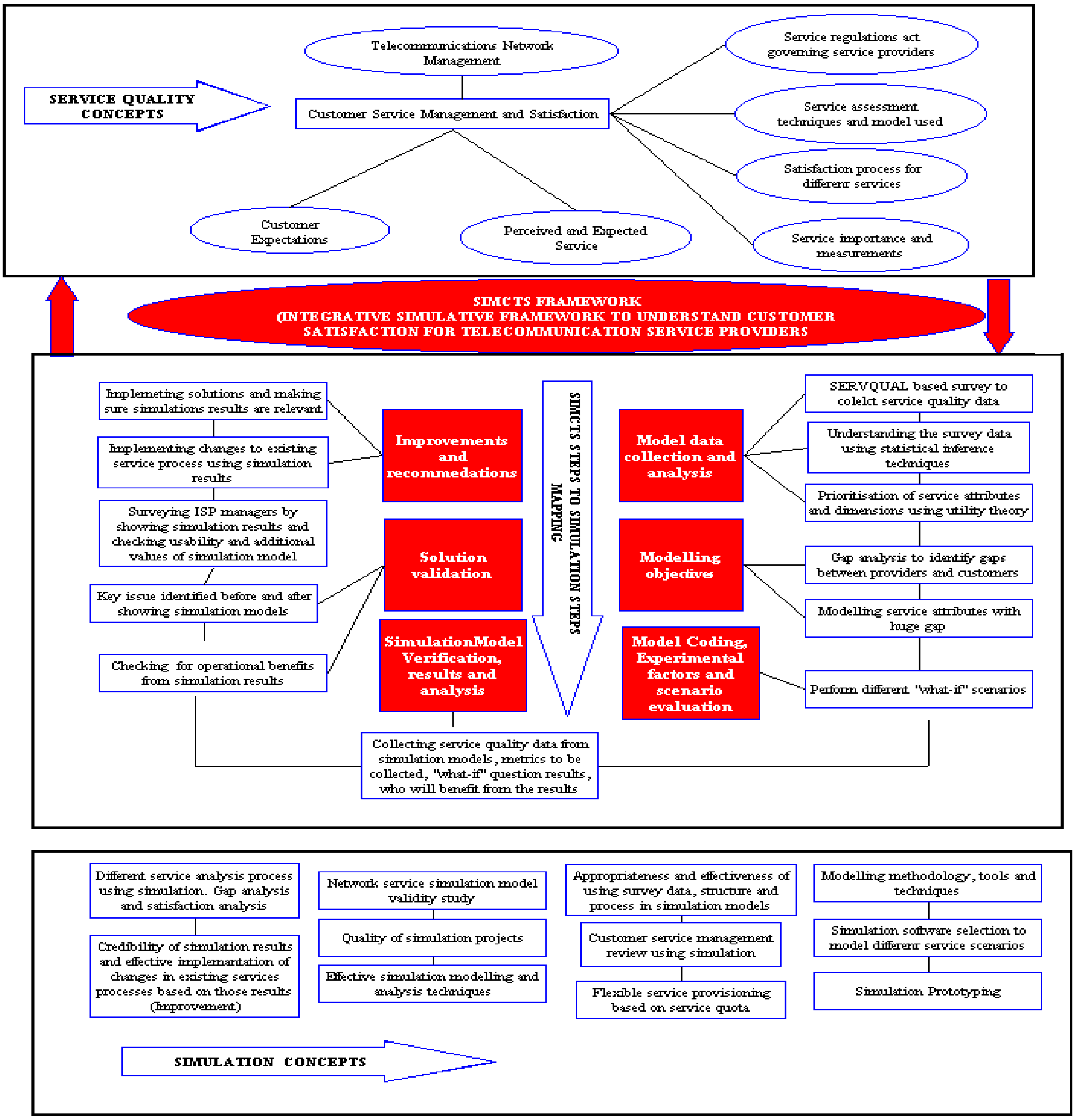


Figure 7.1: SIMCTS Building blocks elements to be tested as part of future work [111]-[185].

SERVQUAL dimensions can be prioritized at both attribute level and the dimension level using the utility theory proposed by [212]. After performing the gap analysis the service attribute that belongs to an associated dimensions and one that has huge gap can be modelled and various alternative scenarios can be explored using simulation. Service quality issues identified before and after the use of simulation can help us to understand the benefits simulation can bring to improve ISP service performance. SIMCTS models can also be run and shown to ISP managers and ISP managers can be surveyed to understand how simulation frameworks like SIMCTS can help them in customer training and also come up with optimal business model. The building block of the SIMCTS Framework is a part of future work is shown above.

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