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THE USE OF SIMULATION FOR EVALUATING BRANCHLESS BANKING SERVICING OPPORTUNITIES VIA CELL PHONES

(A CASE STUDY ON PALESTINE ISLAMIC BANK)

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ABSTRACT

Research Title:

THE USE OF SIMULATION FOR EVALUATING BRANCHLESS BANKING SERVICING OPPORTUNITIES VIA CELL PHONES

(A CASE STUDY ON PALESTINE ISLAMIC BANK)

Mobile Financial Services (MFS) are new phenomena in the world of Mobile Commerce which helps customers to interact with a bank via a mobile device and makes banking virtually anywhere on a real-time basis a reality. This study investigates the impact of adopting MFS applications on minimizing service channels costs, improving the performance of servicing levels, and providing new sources of revenue for Palestine Islamic Bank (PIB) in Khanyounis.

In this study, two types of models to analyze and evaluate the impact of adopting banking servicing opportunities via cell phones are presented. The first is a simulation model used for shedding some light on which input parameters (factors) are most important and how they affect the responses of interest. The second depends on the outputs of simulation for finding the optimum combinations of input parameters by following Response Surface Methodology (RSM) as an optimization technique and assuming that certain level of customers representing the early adopters are will to used MFS. Arena 7.01 simulation software is used for developing and running the simulation experiment and Design Experts 7.1 statistical package is used for constructing RSM plots and optimizing the input parameters.

This work demonstrated that MFS can help financial institutions and banks in Palestine to improve customers' service, reduce total service costs for costly branch offices by migrating transactions away from the bank, in addition for providing the possibility of generating revenues. The study emphasized that Palestinian banks must learn from successful stories around the world, taking into consideration the need to find new methods for payments and money withdrawals as to overcome the difficulties appeared in Gaza Strip area for the supply of Israeli Shekels, US Dollars and Jordanian Dinars used for day-to-day transactions which caused many difficulties for both customers and banks.

ملخص الرسالة

عنوان الرسالة:

استخدام المحاكاة لتقييم فرص تقديم خدمات بنكية من خلال الهواتف الخلوية

(دراسة حالة على البنك الإسلامي الفلسطيني)

تعد التعاملات المالية من خلال المحمول ظاهرة جديدة في مجال التجارة الخلوية على مستوى العالم، اذ تخول الزبائن من التعامل مع البنك عن طريق استخدام جهاز المحمول بحيث يصبح إتمام التعامل المصرفي من أي مكان وفي أي وقت حقيقة. إن هذه الدراسة قد سعت الى تحليل وتقييم مدى تأثير الخدمات المالية المقدمة من خلال الهاتف المحمول على إمكانية خفض تكلفة تقديم هذه الخدمات وتقليل زمن الإنتظار للمتعاملين مع البنك الإسلامي الفلسطيني (فرع خانيونس) من خلال قنوات الخدمة التقليدية.

لقد تم تطوير نوعين من النماذج لتحليل وتقييم فرص تقديم خدمات بنكية من خلال الهواتف الخلوية حيث اعتمد النموذج الأول على تطوير نموذج محاكاة يهتم بتسليط الضوء على المدخلات (العوامل) المؤثرة على مؤشرات الاستجابة محل الاهتمام في الدراسة. بينما اعتمد النموذج الثاني على مخرجات تجربة المحاكاة من أجل إيجاد الوضع الأمثل للمدخلات باستخدام طريقة مسطح الاستجابة Response Surface Methodology (RSM) على افتراض أن نسبة معينة من الزبائن تمثل المستخدمين الأوائل سوف تستخدم الخدمات المالية من خلال المحمول. لقد تم استخدام برنامج المحاكاة Arena 7.01 لتطوير وإدارة تجربة المحاكاة، وحزمة التحليل الإحصائي Design Experts 7.1 من أجل بناء الرسوم البيانية لمسطحات الاستجابة وإيجاد الوضع الأمثل للمدخلات.

هذه الدراسة أظهرت أن خدمات المحمول المالية يمكن أن تساعد البنوك والمؤسسات المالية في فلسطين في تحسين مستوى الخدمات المالية المقدمة إلى المستفيدين مع تقليل التكاليف المرتبطة بقنوات الخدمة التقليدية وذلك بتخفيف الضغط الحاصل عليها ونقل أغلب المعاملات لتتم من خلال الهاتف المحمول اضافة لامكانية تحصيل أرباح اضافية من خدمات المحمول المالية. ولقد شددت الدراسة على ضرورة استفادة البنوك الفلسطينية من التجارب الناجحة في العالم آخذين بعين الاعتبار محاولة إيجاد طرق بديلة لحل المشاكل المالية الناتجة عن نقص السيولة النقدية في منطقة قطاع غزة، والتي تسببت بمعاناة كبيرة للبنوك التجارية والمتعاملين معها على حد سواء.

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Special thanks to those noble people who helped me during model verification and validation stage. Also I would like to thank my job colleagues in Hulul, Paltel and Jawwal companies for their intellectual encouragement and support.

Special gratitude must be expressed to my parents for their continuous support, understanding, and their unshakable faith in me.

Finally, the deepest appreciation is expressed to my wife, for her silent sacrifice and endless support throughout this long journey as a graduate student.

DEDICATION

TO MY DEAR PARENTS . . .

WITH LOVE AND APPRECIATION

TO THE FUTURE OF PALESTINE . . .
MY CHILDREN . . .

EBAA & AMROU

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ABBREVIATIONS

1G	The first generation of mobile telephony systems
2G	The second generation of mobile telephony systems
2.5G	It extends 2G of mobile telephony systems
3G	Third generation technology
3.5G	It extends 3G of mobile telephony systems
4G	Future forth generation mobile technology
AIA	Arena Input Analyzer
ANOVA	Analysis of Variance
ATMs	Automated Teller Machines
BPS	Bit Per Second
CCD	Central Composite Design
DOE	Design of Experiment
DX	Design Experts software
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HTTP	Hyper Text Transfer Protocol
ICT	Information and Communications Technology
IS/IT	Information System/Information Technology
IT	Information Technology
ITU	International Telecommunications Union
JAWWAL	Palestine Cellular Communications Company (JAWWAL)
KPI	Key Performance Indicators
LAN	Local Area Network
MMS	Multimedia Messaging Service
MFI	Mobile Financial Information
MFS	Mobile Financial Services
M-ATM	Mobile Automated Teller Machine

ABBREVIATIONS (Continued)

MTIT	Ministry of Telecommunications and Information Technology
NS Arrival	Non-Stationary Arrival
QoS	Quality of Service
PALTEL	Palestinian Telecommunications Company
PDA	Personal Digital Assistant
PCBS	Palestinian Central Bureau of Statistics
PIB	Palestine Islamic Bank
PIN	Personal Identification Number
PNA	Palestine National Authority
PT	Permanent Teller
SMS	Short Message Service
TAN	Transaction Number
T_Customer	Teller area customer
TT	Temporary Teller
WAN	Wide Area Network
WAP	Wireless Application Protocol
WBG	West Bank and Gaza Strip
WiMAX	Wireless Metropolitan Area Networks
WPT	Wataniya Palestine Telecom Company
WSC	Winter Simulation Conference

GLOSSARY OF TERMS

1G	The first Generation of mobile phones was voice oriented analogue mobile and cordless telephones which were not suitable for modern mobile commerce services.
2G	The second generation of mobile telephony systems uses digital encoding. 2G networks support high bit rate voice, limited data communications and different levels of encryption. 2G networks include GSM, and CDMA. 2G networks can support SMS applications.
2.5G	2.5G extends 2G systems, adding features such as packet-switched connection and enhanced data rates. 2.5G networks include EDGE and GPRS. These networks support WAP, MMS, SMS mobile games, and search and directory.
3G	The third generation of mobile systems provides high-speed data transmissions of **144 Kbps** and higher. 3G will support multimedia applications such as full-motion video, video conferencing and Internet access.
4G	Forth Generation of GSM networks is the future scenario of mobile networks that will replace 3G. It will provide unique capabilities to mobile users.
Analog Technology	Transmission of a cellular call via radio waves. This was the first cellular means of transmitting cellular phone calls.
Brick-and-Mortar	A "brick and mortar business" is a term used mainly on the Internet to differentiate between companies that are based solely online, and those that have a real-world counterpart. A brick and mortar business has a commercial address "made of brick and mortar" where customers can transact face-to-face. The company might also have an online presence.

GLOSSARY OF TERMS (Continued)

Browser	A browser is a software application that locates and displays web pages. It initiates requests to a web server and displays the information that the server returns.
Cellular Operator	Represents the telecommunication company which provides mobile services.
Coding	DOE term. Coding changes factor levels from their natural units (such as time or temperature) to a -1 to 1 scale. This provides greater accuracy during computations and allows b-coefficients to be ranked by their magnitude for screening.
dotMOBI Domain (.mobi)	Is the initiative set up by Vodafone, Nokia and Microsoft in March 2004 to popularize use of the internet via mobile devices, in acknowledgment that the industry needed to radically improve end-users' experience with the mobile internet.
EDGE	Enhanced Data Rates for GSM Evolution EDGE allows higher data transmission speeds based on the GSM standard. This system is sometimes referred to as "2.5G", to denote a halfway house between the GPRS-enhanced GSM technology and UMTS. Thanks to improved coding, data rates of up to **48,000** bits per channel are possible with EDGE. The acronym E-GPRS, also frequently used, stands for "Enhanced GPRS" = enhancement of the GPRS standard. When EDGE and GPRS are combined, data rates of up to 384 kilobits per second are possible.
E-mail	Short for electronic mail it refers to messages or information that are sent via the Internet
GPRS	GPRS is a radio technology for GSM networks that adds packet-switching protocols. As a 2.5G technology, GPRS enables high-speed wireless Internet and other data communications. GPRS networks can deliver SMS, MMS, email, games and WAP applications.

GLOSSARY OF TERMS (Continued)

GSM	Abbreviation for Global System for Mobile Communications. The uniform GSM standard ensures perfect compatibility between networks and mobile phones in any location. For example, a user in Switzerland can use his mobile phone to call or receive calls from Germany or Spain. The abbreviation originally stood for "Group Special Mobile", which was the name of the study group that developed a European standard for mobile networks in 1982. Today, this network is the result of their work - the standard for digital mobile telephony (now used all over the world).
ICT	Information and Communications Technology is a term used for the applications of modern communications and computing technologies to the creation, management and use of information.
Interaction	DOE term. An interaction is a joint effect of factors. For instance, time and temperature interact when baking a cake. Both must be set together to get good results. Another common example is drug interaction, where two medicines taken together produce an effect that neither could produce by itself.
Main effect	DOE term. The main effect for a factor is the effect on a response due to that factor only.
MMS	Multimedia Messaging is based on the same principle as conventional SMS. Compared with the SMS, which is restricted to a maximum of **160** text characters and cannot exceed **160** bytes, up to **100** kilobytes of different types of data, such as text, short tunes, pictures, photos or brief video sequences, can be transmitted with MMS.

GLOSSARY OF TERMS (Continued)

PDA	A **Personal Digital Assistant (PDA)** is a handheld computer, but has become much more versatile over the years. PDAs are also known as **small computers** or **palmtop computers**. PDAs have many uses: calculation, use as a clock and calendar, accessing the Internet, sending and receiving E-mails, video recording, typewriting and word processing, use as an address book, making and writing on spreadsheets, scanning bar codes, use as a radio or stereo, playing computer games, recording survey responses, and Global Positioning System (GPS). Newer PDAs also have both color screens and audio capabilities, enabling them to be used as mobile phones (smart phones), web browsers, or portable media players. Many PDAs can access the Internet, intranets or extranets via Wi-Fi, or Wireless Wide-Area Networks (WWANs). Many PDAs employ touch screen technology.
Regression	DOE term. Regression is a mathematical technique used to fit data to a mathematical model.
Server	A computer that makes services, as access to data files, programs, and peripheral devices, available to workstations on a network.
Service provider (Carrier)	A company that provides telephone (or another communications) service.
SIM	Subscriber Identity Module. It is an electronic chip contains subscription data and inserted in the mobile handset.
Sweet Sport	DOE term. The Sweet Spot is the experimental trial that meets all of your response goals simultaneously.
Transformation	DOE term. A transformation is a mathematical operation performed on responses to make their standard deviation estimates consistent.

CHAPTER ONE

INTRODUCTION

This chapter consists of the following sections:

CHAPTER ONE

INTRODUCTION

1.1. RESEARCH BACKGROUND

One of the most remarkable technology stories of the past decade has been the spread of mobile phones across the developing world. In fact, mobile devices have become an integral part of everyday life. Mobile telecommunication services worldwide have experienced a rapid growth. Total number of subscribers will exceed**2.8** billion by the end of **2008** (GSA, 2008).

The advent of various emerging mobile telecommunication technologies is going to create new growth momentum across the mobile communications market in a few years. The way the world views mobile communications is expected to change in the coming years. All the power of the World Wide Web is expected to be available, at high speeds, for those who are on the go. High-speed web connections, always-on systems, and a concentration on data rather than voice are the major changes that are anticipated (Bertrand et al., 2001).

These developments will be achieved with 3G protocols. The first generation (1G) protocols included analog cell phones. Second generation (2G) protocols included digital systems used by several mobile devices. (3G) allowed users to enjoy the broadband experience with mobility, while the forth generation (4G) is the next generation of wireless networks that will replace 3G networks sometimes in the near future, Fig. (1.1) shows generations of mobile telecommunication standards.

Recently, in **September 2006**, new 2G/3G license was granted by Palestinian National Authority for second operator, Wataniya Palestine Telecom (WPT), to build and operate GSM 2G/3G network in West Bank and Gaza Strip. (Ingham, 2007). It is expected that WPT will launch its commercial services in **2009**. Palestine Cellular Telecommunications Company (JAWWAL) was the first operator in the Palestinian territories and currently operating GSM/2.5G network and started its commercial launch in **August 1999**.

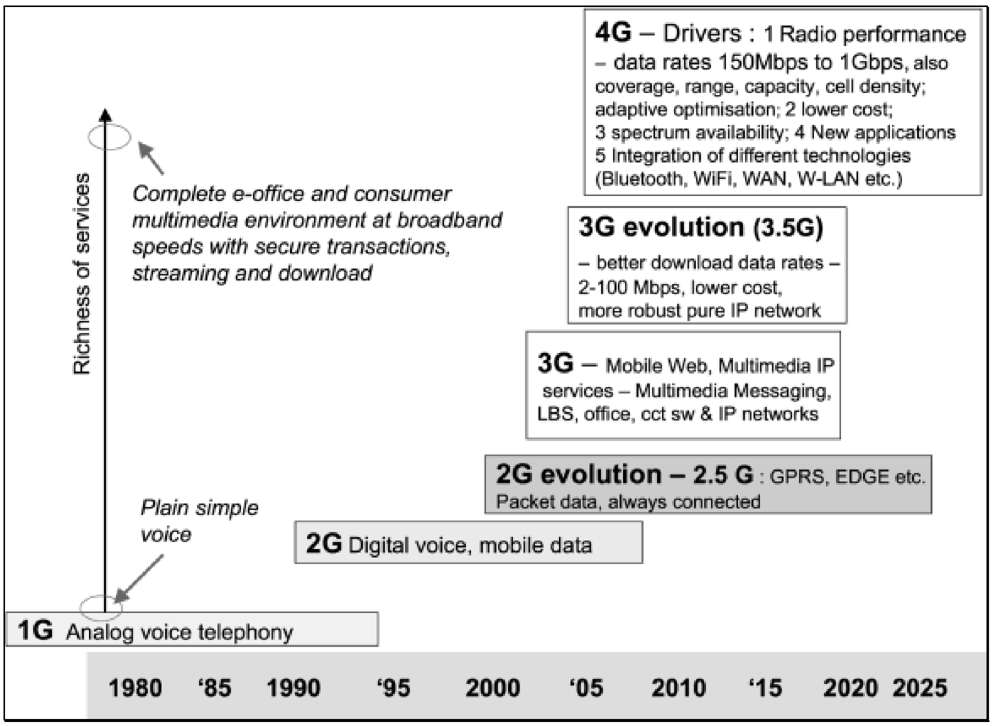


Figure 1.1: Generations of mobile telecommunication standards
Source: (Forg, 2004)

The rapid spread of mobile phones means that the number of mobile users already exceeds the number of Personal Computers (PCs) world wide as shown in Fig. (1.2). It is expected that by **2010** half of the world's population will have access to the internet through a mobile device (Dev-Mobi, 2007). Figure (1.3) shows a statistical abstract about mobile phones growth compared to PCs in Palestine during the period from year 2000 to year 2005 .

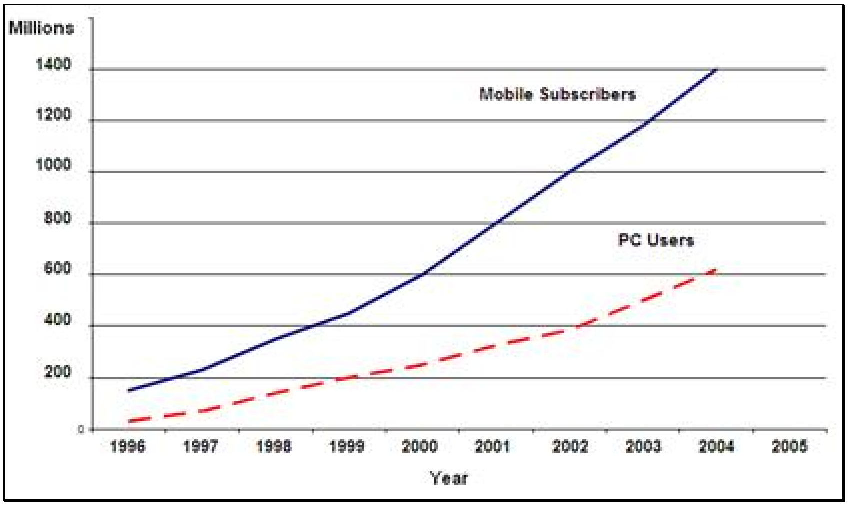


Figure 1.2: Mobile phone subscribers' growth rate compared to PC users world wide
Source: (Merwe, 2003)

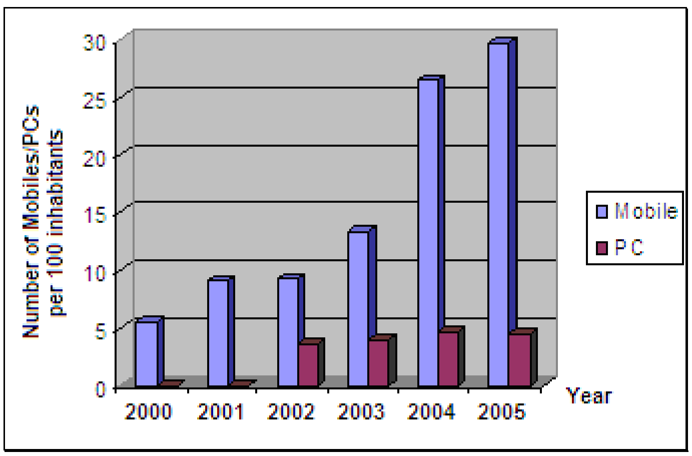


Figure 1.3: Number of mobile devices growth vs. PCs per 100 inhabitants in Palestine
Source: Reproduced from (ESCWA, 2006)

This leads us to conclude that mobile phones will be the cornerstone of Mobile Commerce (M-Commerce) by offering a communications channel for initiating and executing on-line financial transactions. This channel may not only reduce the cost of financial transactions for provider and customer, but also allow new entrants to the financial sector, and new relationships to be formed for distributing services. These changes hold the prospect of accelerating access to financial services on the back of the mobile infrastructure (Porteous, 2006).

Mobile Financial Services (MFS) are new phenomena in the world of M-Commerce which helps customers to interact with a bank via a mobile device and makes banking virtually anywhere on a real-time basis a reality. MFS can be divided into two sub-categories: *Mobile Payment (M-Payment)* and *Mobile Banking (M-Banking)* (Georgi and Pinkl, 2005). M-Banking is usually defined as carrying out banking business with the help of mobile devices such as mobile phones (Georgi and Pinkl, 2005). M-Payment services could be described as services, which use mobile devices to initiate and confirm payments (Tiwari and Buse, 2006). The advantage for the customers lies in the fact that they do not need to carry cash. Therefore, MFS can be seen as a promising M-Commerce application.

There are several successful stories for implementing M-Banking and M-Payments services around the world in *banking* and *telecommunication* industries. In South Africa for example, *WIZZIT Bank*, a division of the South African Bank of Athens offers the usual banking services — deposit, withdrawal, payments, and airtime purchases — through a variety of access points including cell phones, Automated Teller Machines, post offices and bank branches. So, it combines *branchless* and *branch-based* banking, and its link with the post office constitutes a public-private partnership. It has reached poor people that earlier could not dream of opening bank accounts (Anklesaria, 2007). WIZZIT bank account can be used by anybody, any time, and anywhere. It is a **24/7** bank in the pocket. For example, if the customer has a WIZZIT account, he can use a cell phone to send money to a friend or pay an account. All what customer need is the other party's account details and bank branch number. Even better, if they are WIZZIT account holders, it is enough to know their cell phone number. So there will be no need to stand in queues and carry cash around (Richardson, 2006).

In the Philippines, *Globe Telecom Company* has been offering *branchless* banking since **2000**. Its *G-Cash* service enables customers to use cell phones to operate e-accounts. The customer can deposit cash into the e-account or withdraw it, using the retail agents of Globe Telecom, who are spread across the country. Customers can use G-Cash to pay bills, repay loans, or purchase goods at shops (it's effectively a debit card). In the

Philippines, **1.3 million** people now have e-accounts with Global Telecom (Anklesaria, 2007).

Palestine needs to learn from these models especially that bank branches in Gaza Strip area are suffering from Israeli siege. Sharp drop in imports and exports, and limitations on the supply of currencies used in Palestine (mainly Israeli Shekels, US Dollars and Jordanian Dinars) used for day-to-day transactions besides the irregularity of salaries dates which caused banked customers to increase the demand on banking facilities during salary withdrawal dates. As a result, the main goal of this research is concerned with evaluating the impact of mobile emerging technologies on optimizing bank branch operations. Therefore, a case study on a branch office for a Palestinian bank in Gaza is analyzed in terms of the demand for the current service channels, cost for delivering services to customers via tellers and ATM channels, and the possibility to improve servicing levels as a result of adopting Mobile Financial Services (MFS).

1.2. RESEARCH PROBLEM

The main question that will be addressed in this study is: What will be the impact of implementing mobile financial services on Tellers and ATM service channels for Palestine Islamic Bank (Khanyounis Branch) in terms of total service costs and customers waiting time for each service channel?

1.3. RESEARCH OBJECTIVES

The main objective of this research aimed to evaluate banking servicing opportunities via cell phones as an opportunity for branchless operations that may reduce the cost of the delivered services, improve customer satisfaction, and develop new sources for revenue.

This main objective can be sub-divided into the following specific tasks in order to be achieved:

A. To discuss mobile emerging technologies and its implications for business. In addition, this study set the differences and similarities between Electronic Business (E-Business) and Mobile Business (M-Business) applications.

B. To highlight banking servicing opportunities via cell phones and the potential benefits of adopting MFS applications (M-Banking and M-Payments) as a promising M-Commerce application for banks and customers in Palestine.

C. To highlight possible factors that may affect the usage of MFS in Palestine.

D. To build a simulation model for a bank branch as to study the impact of adopting MFS as an opportunity to:

I. Reduce cost of distributing services;

II. Reduce customers waiting time; and

III. Provide a new source of revenue.

E. To construct Meta-Models (Regression Models) for the simulation experiment that approximate the relationships between different combinations of possible opportunities and its responses with statistical models (typically regression models).

1.4. RESEARCH IMPORTANCE

Branch offices historically have been one of a bank's major costs as well as its main contact point with retail customers. This makes branches a logical target for efforts to cut costs and increase productivity. The movement to increase productivity and cut costs in branches led to the development of new channels for servicing opportunities, these opportunities offered the potential for reducing average transaction costs and less need for brick-and-mortar branch offices and tellers (BCC, 2002). At the same time, these innovations improved customer convenience and service.

In the recent past, banks have actively provided and developed electronic retail banking delivery systems to provide customers with self-service options that eliminate the need to visit a branch physically. Self service options like Automated Teller Machines, telebanking, internet banking have been successfully deployed by banks to reduce the branch costs, increase customer satisfaction, retain customers and to discover new revenue opportunities. A new self-service option known as MFS has recently emerged resulting from the fusion of financial services and mobile technology (Philip, 2006).

If implemented proficiently, MFS can help banks in Palestine to improve customer acquisition and customer retention, reduce total service costs for costly branch offices by migrating simple transactions away from branches. Figure (1.4) shows that the numbers of branches in Palestine were increasing rapidly during the past decade with comparison to number of banks which means additional costs for distributing banking services. Good utilization of cell phones distribution channel may provide the opportunity for cutting bank branch offices costs.

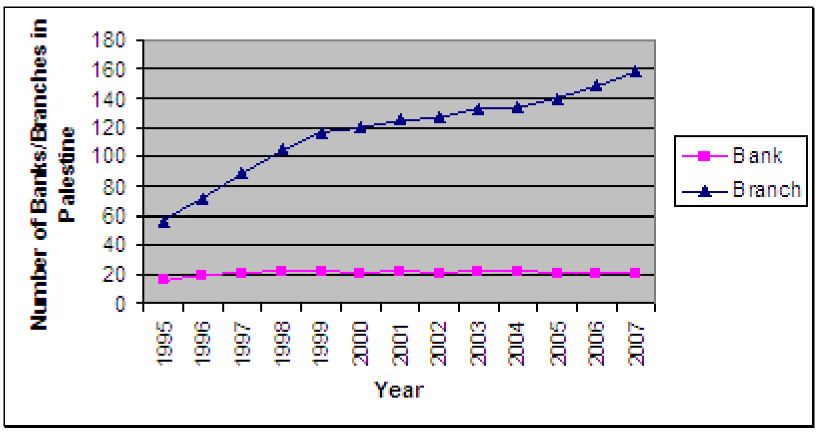


Figure 1.4: The development of banks and its branches in Palestine
Source: Reproduced from (El-Kourd (2007)

In today's environment, customers are hard pressed for time with daily deadlines, appointments and meetings. In such a situation, M-Banking and M-Payments enable them to carry out their financial transactions '*anytime*, *anywhere*' through mobile phone.

This study focused on studying the impact of adopting MFS applications on minimizing the cost of tellers and ATM service channels, improving the performance of servicing levels, and providing new sources for revenue, taking into consideration the need to find new methods for payments and money withdrawals as to overcome the difficulties appeared in Gaza Strip area and resulted from the limitations on the supply of Israeli

Shekels, US Dollars and Jordanian Dinars used for day-to-day transactions which caused many difficulties for both customers and banks.

The researcher hope that this study will provide a strong and reliable method for evaluating MFS investments and servicing opportunities based on a quantitative approach as to simplify the decision making process and provide new methodology for banks in Palestine for evaluating IT investments. Given that **46%** of the banks in Palestine do not have quantified measures to ensure that they have achieved their strategic goals and **26.32%** do not have formal IT investment evaluation instructions (El-Kourd, 2007).

1.5. RESEARCH METHODOLGY AND DESIGN

1.5.1. Research Methodology

To answer the main question of this research, a case study based on a computer simulation approach is followed to evaluate the impact of branchless banking servicing opportunities via cell phones on optimizing bank branch operations. PIB branch in Khanyounis is selected upon PIB request. The traditional service channels (Tellers and ATM) are analyzed and evaluated using simulation approach and Response Surface Methodology as an optimization technique. Some of the variables that were examined include: customer waiting time, variability in customer arrivals, and cost for distributing services.

Furthermore, a discussion about mobile financial technologies and their implications for business was included based on bibliographical research from various literature resources.

1.5.2. Sources of Data

Inter-arrival and service rates collected through direct observation and historical records. In addition, data on the number of daily customer transactions through ATM and tellers channels, and performance of the system are collected for validation purposes. Secondary data sources supported theoretical background of this study.

1.5.3. Software Package Tools

Arena software package version (7.01) used in fitting and analyzing the collected data, and building the simulation model. In addition, other packages like Change Point Analyzer (CPA) version (2.3) used to determine the change of pattern in a sequence of data for different arrival rates, and Design Expert (DX) version (7.1) software for analyzing simulation experiment outputs statistically, constructing response surface plots, and building a meta-models.

1.5.4. Research Phases

This research consisted of *four* major phases to achieve its objectives. The first phase handled problem formulation and objectives of the overall project plan. In addition to some literature review about mobile financial services and its implications for business based on bibliographical research from various literature resources.

The second phase included data collection and computer model design in addition to model verification and validation. The third phase focused on experimental design, production runs and analysis meanwhile the final phase handled research documentation, conclusions, and recommendations.

1.6. LITERATURE REVIEW

The literature review of this study was structured from previous MFS and simulation studies in addition to some literature on Palestinian banking sector for two reasons. First, this structure will provide a broad, yet rich context and history for the proposed research problem from all aspects related to the purposes of this study, and second, it attempts to illustrate why examining this research problem is a necessary research endeavor.

1.6.1. MFS Studies

The study of Tiwari (2006) titled "*The mobile commerce prospects: A strategic analysis of opportunities in the banking sector*", was based on objective and statistical approach and aimed to analyze the opportunities of using mobile banking services in Germany. The researcher distributed two questionnaires, one for banking customers and the other for banks as to study the potential of M-Banking in Germany. The study found that M-Banking seems to possess the potential to become one of the widely spread and accepted applications in the field of M-Commerce in Germany. In addition, the study concluded that technological innovations in the field of telecommunication will increase the need for mobility.

The study of Philip (2006) titled "*Mobile Banking in Kuwait and Customers' perceptions regarding usage of Mobile Banking Services*", was also based on objective and statistical approach and aimed to study and analyze different perceptions of customers for using Mobile Banking services. The study found that the primary reasons customers use M-Banking are: convenience, accessing banking services 'anywhere, anytime', alerts to banks promotions on new products/services and control of account movements. The most important reason was the ability to access banking services 'anywhere, anytime' followed by convenience. The study concluded that M-Banking service providers should understand the personal needs of their clients in order to provide value added services. In addition, the researcher provided a set of recommendations that can be of great help to the managements of Kuwaiti banks in designing and implementing effective policies and programs for successfully distributing bank services through mobile banking.

The paper of Matilla (2002) titled "*Factors Affecting the Adoption of Mobile Banking Services*", was based on objective and statistical approach. The paper focused on defining the factors influencing mobile banking adoption as a result of distributing questionnaires on a target sample derived from banking customers. The study aimed at forming a model describing consumer behavior patterns for using banking services via wireless delivery channel. A quantitative survey sheds more light on this researched issue. The data was collected in Finland during **May-July 2002** and includes **1253** survey responses. Based on the findings of the survey and the reviewed literature, a model of the factors influencing adoption of mobile banking services was formed.

The working paper of Tiwari et al. (2006) titled “*Mobile Banking as Business Strategy: Impact of Mobile Technologies on Customer Behavior and its Implications for Banks*”, was based on objective and descriptive approach. The paper aimed to study impact of mobile technologies on consumers' behavior as a business strategy for banks in Germany. The paper concluded that M-Banking has gained non-negligible relevance for banks today. The paper explained as well that M-Banking presents an opportunity for banks to retain their existing, technology-savvy customer base by offering value-added, innovative services. It might even help attracting new customers. Further, M-Banking presents a chance to generate additional revenues.

The study of Borbon (2003) titled “*The effects of technology in retail banking*”, explained that mobile communication device of the near future will likely be some sort of Phone/PDA combination. Therefore it is important to allow for more customization in online banking websites in order to make it convenient to browse with the small screen of such devices, so that they can easily show relevant information to a particular user. The author indicated that mobile communication devices have good potential in the banking industry; nevertheless, banks should be extremely careful in their mobile services deployment as a failure in these channels would produce a strong negative effect in the customers’ mind and that could be hard to overcome even if technology improves.

The study of Cervera (2002) titled “*Analysis of Java to Mobile Edition (J2ME) for developing Mobile Payment Systems*”, aimed to describe the factors that affect the introduction of a successful M-Payment system, and use these factors to examine whether the J2ME technology is suitable for building such successful M-Payment systems. J2ME is tested, compared with other client technologies, and strengths and weaknesses of J2ME in relation to M-Payments are described. The conclusions were that J2ME for M-Payments depends undeniably on compatibility with the mobile phones and the release of the Mobile Information Device Profile (MIDP version 2.0). J2ME is suitable for successful M-Payments, but depends on the manufacturer's willingness to implement specific J2ME Application Program Interfaces (API) and facilities in a consistent way. The phones must support push of URLs to ensure smooth download of the payment application and the wireless API to ensure push and pull of data for easy payment initiating if J2ME shall be a part of a successful M-Payment system.

1.6.2. Simulation Studies

The study of Hammond and Mahesh (1995) titled "*A simulation and analysis of bank teller manning*", aimed to provide a computer laboratory models for testing new policies and presents an application study to find cost effective bank teller management policies for providing high quality service levels at reasonable costs in a modern banking system. Two models were developed as to help senior management examining new policies. The first was a spreadsheet model to calculate desired teller manning levels from mathematical queuing models, and the second was a simulation model for testing new management policies by writing **FORTRAN** code subroutines.

The paper of Chandra and Conner (2006) titled "*Determining bank teller scheduling using simulation with changing arrival rates*", used simulation as to investigate scheduling of bank tellers at a branch office in Indonesia. The model accounts for real system behavior including changing arrival rates throughout the day, customer balking, and teller breaks. A change point analysis conducted and revealed two types of arrival rate patterns for this system. The researcher compared scheduling rules and the corresponding service levels when demand varies. A schedule is suggested that, on average, limits customer waiting time to less than eight minutes and customer balking to less than **9** customers per day. The suggested schedule incurs the minimum weekly cost and is robust to changes in system costs.

The paper of Slepicka and Spohrer (1981) titled "*Application of simulation to the banking industry*", used simulation as a tool to evaluate how the addition of an On-Line Teller Terminal System (OLTTS) will affect customer service in a bank. The paper analyzed the present performance of the bank tellers before running the simulation model. The study concluded that the installation of an OLTTS will lower teller transaction time, raising the tellers' productivity. It has also been shown; using computer simulation that this increase in productivity would lead to better customer service.

1.6.3. Palestinian Banking Sector Studies

The study of Abu Jaber (2007) titled "*Readiness of the Palestinian Banking Sector in Adopting the Electronic Banking System*", was based on objective and statistical approach. The researcher distributed questionnaire for banks to study the readiness of the banking sector in Gaza Strip to adopt E-Banking application. The findings of this research indicated that there are different success and obstacle factors which influence the adoption of E-Banking. The researcher concluded that banks, customers, and monetary authority legislations play an important role in the success of the adoption.

The study of El-Kourd (2007) titled "*Information Technology Investments Evaluation Practices in the Banking Sector in Palestine*", was also based on objective and statistical approach. The researcher distributed questionnaire for IT managers of the twenty one banks operate in Gaza strip and West bank to study how banks evaluate their IT investments. The study found that **46%** of the banks in Palestine do not have quantified measures to ensure that they have achieved their strategic goals and **26.32%** do not have formal IT investment evaluation instructions. One of the main recommendations of this study was to keep developing and searching for more comprehensive methods for evaluating IT investments.

The main difference of this study from the previously mentioned studies is that it is concerned with evaluating the impact of MFS on the cost of distributing services via tellers and ATM channel. In addition, customer service performance indicators are investigated to obtain the best staffing levels in the case of adopting MFS. Also this study tried to find the possibilities of how we can minimize crowds in banks during salaries days. Therefore, a case study on a branch office for a Palestinian bank in Gaza was analyzed based on a simulation experiment approach and through constructing response surface plots and meta-models to achieve study objectives.

CHAPTER TWO

MOBILE FINANCIAL SERVICES OVERVIEW

This chapter consists of the following sections:

CHAPTER TWO

MOBILE FINANCIAL SERVICES OVERVIEW

2.1. INTRODUCTION

This chapter provides an overview of technological standards that have either contributed to the development of Mobile Financial Services (MFS) or that can be expected to shape its future in banking sector. Banking servicing opportunities via cell phones and its potential benefits as a promising MFS application for customers and banks in Palestine will be discussed in addition to the factors that may affect the usage of this trend. In this section we further differentiate between the terms "Electronic" and "Mobile", so as to clarify the respective concepts by showing their similarities and highlighting their differences as to avoid misunderstanding for the most important terms related to these technology aspects.

2.2. CONCEPTUAL BACKGROUND

In order to clarify Mobile Financial Services (MFS) term, it is necessary to understand the conceptual background of other related terms e.g. Electronic Business (E-Business) and Mobile Business (M-Business), Electronic Commerce (E-Commerce) and Mobile Commerce (M-Commerce). It is therefore useful to establish working definitions for the terms "Commerce" and "Business", "Mobile" and "Electronic" as they seem to have transcended their dictionary meanings and acquired new significance during the past decade (Tiwari et al., 2007) as a result of the rapid development for using technology in the world of finance and banks.

2.2.1. Difference between "Commerce" and "Business" terms

The InvestOpedia dictionary describes "Commerce" as "The buying and selling of goods, especially on a large scale. Commerce is done between businesses, individuals, countries and so on" (Commerce, n.d.). The term "Commerce", in this research, refers to the exchange of buying or selling of goods, or services, and involving transportation from place to place. The term "Business" was defined within the same dictionary as "Any commercial, industrial or professional activity undertaken by an individual or a group" (Business, n.d.). In this research, the term "Business" refers to all activities undertaken by a firm in order to produce and sell goods and services. These activities are, thus, not exclusively of "commercial" nature, but also include other processes such as procurement, production, Customer Relationship Management (CRM) and Human Resources Management (HRM) (Tiwari et al., 2007).

Therefore, "Commerce" is just a component or activity of a "Business", and logically, "E-Commerce" is simply a subset of "E-Business", and hence "M-Commerce" is accordingly a subset of "M-Business".

2.2.2. Difference between "Electronic" and "Mobile" aspects

The adjective "Electronic", used within the specific contexts of "E-Business" or "E-Commerce", signifies an "*anytime access*" to business processes. The access to computer networks is in this case stationary. The services are therefore not completely independent of the current geographic location of the user (Hohenberg and Rufera, 2004). The adjective "Mobile", used within the specific contexts of "M-Business" or "M-Commerce", signifies an "*anytime and anywhere access*" to business processes. The access takes place using mobile communication networks, making these services independent of the geographic location of the user (Hohenberg and Rufera, 2004).

In many cases the words "Wireless" and "Mobile" are used interchangeably to denote mobile applications. However, the adjective "Wireless" denotes basically the way how the transmission of data is performed. Wireless means that data is delivered to an end user across airwaves. The adjective “Mobile” refers to applications, which are designed for users on the move, i.e. for applications that support the user independent of his location. This means that a wireless application does not have to be a mobile application as well (Stanoevska-Slabeva, 2003). For example, VISA Company launched a new credit card service that enables cardholders to make ‘contactless’ or ‘wireless’ payments using a standard credit or debit card. Users simply ‘wave’ their card in front of a special card-reader to process the payment. These new credit cards can not be used remotely; users must be standing in front of card-reader. In some other cases, it might be possible to process a payment by mobile phone though internet or SMS without any need to be physically at the point of sale, this type of payments we call it‘remote’ or ‘mobile’ payments. In other words, wireless application is simply an alternative to wired communications.

2.2.3. Defining M-Business and M-Commerce

M-Business and M-Commerce terms can be defined in analogy to E-Business and E-Commerce terms as illustrated in Fig. (2.1). The prevailing definition for E-Business according to United Nations Conference on Trade and Development is “Electronic Business processes that include Customer Acquisition and Retention, E-Commerce, Order Fulfillment and Tracking, Inbound and Outbound Logistics, Inventory Control, Finance-, Budget- and Account Management, Human Resource Management, Product Service and Support, Research and Development as well as Knowledge Management” (UNCTAD, 2004). Therefore E-Business is the integration of systems, processes, and value chains using Internet-based and related technologies and concepts. E-Commerce is a part of E-Business and is limited to transactions carried over computer-mediated channels that comprise the transfer of ownership or the entitlement to use tangible or intangible assets according to E-Commerce definition project (Statistics- Canada, 1999). In simple words, E-Commerce is commerce using computers through Internet.

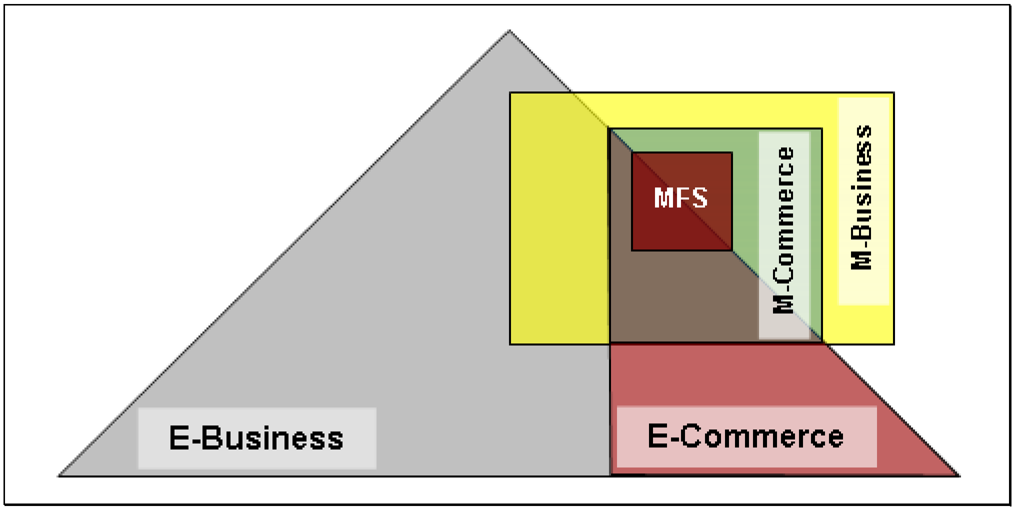


Figure 2.1: A holistic perspective of M-Business and M-Commerce
Source: (Tiwari et al., 2007)

As an analogy to the above definition for E-Business, M-Business can be defined as a collection of mobile technologies and applications used to support processes, value chains using mobile telecommunication networks. M-Commerceis a subset of M-Business and can be defined as "Any transaction, involving the transfer of ownership or rights to use goods and services, which is initiated and/or completed by using mobile access to computer-mediated networks with the help of an electronic device" (Tiwari and Buse, 2006).

Some people conceive M-Commerce as an extension of E-Commerce to mobile phones. Some others think it is another new channel. In general, M-Commerce refers to any transaction with a monetary value that is conducted via a mobile telecommunications network (Hsieh, 2007) and (Tiwari and Buse, 2006). M-Commerce technology is entirely different from E-Commerce where processing is accomplished through the internet via a browser and being connected through wired/wireless Internet connection (Aungst and Wilson, 2005) and by the use of personal computers. M-Commerce uses mobile telecommunications network for accessing the internet as to purchase goods and/or services, through sending and receiving SMS/MMS messages (Hsieh, 2007) or accessing internet through WAP service using hand-held wireless devices which is a unique feature that does not exist through E-Commerce applications.

The previous conceptual background discussion leads to the following conclusions that can be derived from Fig. (2.1):

1. E-Business and M-Business offer many similar services in both commercial and non-commercial areas.
2. E-Business offers additional services, not feasible with M-Business.
3. M-Business, too, offers unique services, not feasible with conventional E-Business.
4. E-Commerce is an integral subset of E-Business.
5. M-Commerce is an integral subset of M-Business.
6. E-Commerce and M-Commerce offer many similar services
7. E-Commerce offers additional services, not feasible with M-Commerce.
8. M-Commerce, too, offers unique context-sensitive, location-based services, not feasible with E-Commerce.

2.3. MOBILE TELECOMMUNICATION STANDARDARDS

This section provides an overview of the technological standards that have either contributed to the development of M-Commerce or that can be expected to shape its future.

Several technologies are used in mobile telecommunication industry. Analog Cellular System and Analog Mobile Phone System (AMPS) are considered as **First Generation (1G)** cellular service. Digital Advanced Mobile Phone System (D-AMPS), Time Division Multiple Access (TDMA), Global System for Mobile Communication (GSM), and Code Division Multiple Access (CDMA) are all the **Second Generation (2G**) mobile technologies. In the 1990s, International Telecommunication Union (ITU) forecasted the future trend of mobile communication and decided to set up one standard for the world telecommunication. It dedicated 1.9GHz~2.5GHz bandwidth for the new mobile telecommunication technology and required the industry to develop new technology for high speed data rate up to 2Mbps. This new mobile telecommunication technology is called the **Third Generation (3G)** (Hwang Yi, 2001).

A **Fourth Generation (4G)** of mobile communication systems, likely to appear after the successful deployment of the current 3G systems, is frequently debated these days. 4G systems will offer short- to moderate-range communications with very high data rates (>100 Mbps) (Bria et al., 2001). Table (2.1) summarizes data speeds and possible applications for different mobile generations.

Table (2.1) Data speed and possible application according to mobile generation

Generation	Attribute/Data Rate	Typical Application
1G	Analog	Voice only
2G	Digital/9.6Kbps	Voice, SMS
2.5G	Digital/57.6Kbps ~ 384Kbps	SMS, MMS, Internet
3G	Digital/384Kbps ~ 2Mbps	Video, Internet, Multimedia
3.5G	Digital/2Mbps ~100Mbps	Better download rates for Video, Internet, Multimedia
4G	Digital/expected to reach 100Mbps ~ 1Gbps	Integration with WiMAX and QoS, Satellite telecommunications

Source: Modified from (Hwang Yi, 2001)

M-Commerce services are likely to be delivered using existing second-generation (2G) and enhanced 2G (2.5G) technologies and networks. This could result in the majority of transactions being reliant on SMS and text-based information between consumers and businesses. Following the introduction of 3G services by a second operator in 2008, Palestine's mobile market is likely to see explosive growth over the next three years. Palestinian operators will seek to distinguish themselves from the competition by introducing new services, which could also have an accelerating effect on the already fast growing Internet and broadband market.

2.4. M-COMMERCE IN BANKING SECTOR

2.4.1 Scope of Mobile Financial Services

M-Commerce is potentially important for a wide range of industries, including telecommunication, IT, finance, retail and the media, as well as for end-users (Paul-Budde, 2008). With the effort for gaining competitive advantage, new forms of distribution channels are invaluable outlets for financial institutions since they provide the opportunity for cutting costs without diminishing the existing service levels. As customers are demanding greater convenience and accessibility, many banks are eyeing cost-effective alternative service delivery systems (Philip, 2006). Finance-related services that are offered by employing mobile telecommunication technologies are generally referred to as "Mobile Financial Services" (MFS). MFS can be divided into two sub-categories: *Mobile Payment (M-Payment)* and *Mobile Banking (M-Banking)* (Georgi and Pinkl, 2005). MFS, helps customers to interact with a bank account via a mobile device and makes banking virtually anywhere on a real-time basis a reality. For banks, branchless banking through retail agents is used to reduce the cost of delivering financial services, relieve crowds in bank branches, and establish a presence in new areas (CGAP, 2006) and this is exactly the real benefit behind adopting MFS.

M-Banking is usually defined as carrying out banking business with the help of mobile devices such as mobile phones or PDAs (Georgi and Pinkl, 2005). M-Payment services could be described as services, which use mobile devices to initiate and confirm payments. Each subscriber gets an individual PIN to authenticate himself via WAP or SMS, in order to make payments for his purchases (Tiwari and Buse, 2006). The advantage for the subscriber lies in the fact that he does not need to carry cash with him. Therefore, MFS can be seen as a promising M-Commerce application.

2.4.2 MFS Provider Participation Models

From the point of view of service provider participation, four models can be used for offering MFS (Faber, 2003):

1) Bank-Oriented Initiatives: Banks adapt their financial services distribution channels, e.g., M-Banking;

2) Telecom-Oriented Initiatives: Telecoms exploit their advantage base, established financial relationships with customers for billing and prepaid services and provide payment products and services than their own, e.g., Jawwal Company launched *Hat w Khod* service for transferring credit from mobile to mobile as to support those who are far away and can not purchase prepaid cards to charge their mobiles with new credit (Jawwal, n.d.);

3) Balanced/Mixed Initiatives: Banks and telecoms cooperate M-Payment services; and

4) Independent Initiatives: Payment service providers launch are relatively independent of banks and telecoms. This can be seen on Visa, MasterCard, PayPal, etc. initiative for establishing M-Payment applications.

2.4.3. MFS Applications and Technologies

The software technology inside a mobile phone terminal has to support a wide range of functionality in connecting cell phones to data services, multimedia messages consisting of text, pictures and audio, and downloadable Java applications (Nokia, 2002). Figure (2.2) shows the main software building blocks of mobile terminal platform architecture.

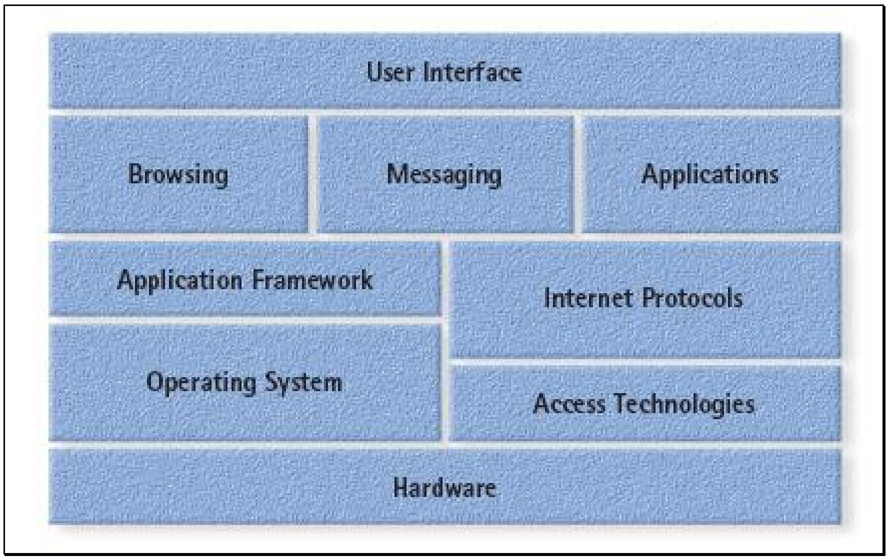


Figure 2.2: The software building blocks of a mobile terminal platform architecture
Source: (Nokia, 2002)

As shown in Fig. (2.2) MFS applications depend on three different types of technologies (Tiwari and Buse, 2006):

1) Browser-based applications: Generate the user interface on the server and transport it subsequently to the mobile device. This interface is then presented to the user graphically with the help of a browser. Primary examples of browser-based MFS applications are services based on WAP and HTTP protocols (Tiwari and Buse, 2006). WAP phone enables accessing financial data in a mobile environment, an advantage the PC can never truly emulate. While much has been said about the positive side of WAP based banking, consumers also need to be aware of the application's constraints in order to assess the application as a whole. WAP sites are effectively menus and scrollable lists used as pointers to information required. The main constraints lie with the restrictive displays used. The WAP phones only display text format. In comparison to the PC, the storage capacity for WAP is little or none and can only handle small quantities of data at a time (Philip, 2006).

In addition to the above-mentioned WAP services that are especially designed for mobile phones, it is also possible to make use of the standard, web-based Online Banking services via certain (computer-like) mobile devices such as PDAs (Tiwari and Buse, 2006). This form of M-Banking is attractive for banks as the infrastructure costs in terms of additional investment are not very high. For customers too this form is an attractive proposition, for they are usually anyway familiar with the web-based banking services. The main disadvantage of web-based M-Banking is that it is accessible only via a certain type of mobile devices, i.e. PDA or 3G cell phones. But since PDAs have a much lower penetration than mobile phones, only a relatively small number of bank customers can make use of this facility. From another hand, 3G technology is expected to push 3G cell phones to higher level of penetration. Another disadvantage relates to the fact that the user has to prepare and carry out the transaction in the online mode, which definitely means increasing the utilization costs at the customer side.

2) Messaging-based applications: In messaging-based applications the communication between the bank and the customer is carried out via text messages (SMS). These messages may be triggered automatically by the bank whenever certain predefined events occur, for instance whenever a transaction is performed on the account. Alternatively, the messages may be sent by the bank as a response/confirmation to customer requests. A customer message may contain either an instruction, e.g. to carry out a transaction, or an information request for the account status (Dilg, 2004).

The obvious advantage of SMS for both operators and end users is the ease of use. Banks can not only respond to customer's queries related to banking needs but also send out promotional messages and announcements related to the bank's new products and services, a feature of relationship based services. However, due to the high sensitive character of the transmitted information, (Pouttschi and Schurig, 2004) points that encryption of the data is missing during the on the air transmission between the service center and the mobile phone. As a result, banks offer only pure information services like requesting account balance via SMS. Therefore, the ability to conduct transaction based services is not largely possible. This disadvantage is what differentiates SMS from WAP Banking application. On the other hand, due to the secure nature of the WAP platform both information and transaction based services are possible (Philip, 2006). This problem can be easily solved by cell phone manufacturers and software development companies through applying special encryption software for securing SMS messages. This will allow for the simultaneous exchange of all types of data, including confidential and mission critical information with customers. Table (2.2) in the next page shows that only two banks in Palestine offer internet and SMS based banking services. There are no advanced M-Banking and M-Payments services available till now in Palestine. Palestinian banks are facing big challenges to compete with foreign banks that are having a good opportunity to launch internet and MFS in Palestine (Appendix-A presents an overview about banking sector in Palestine).

The term "MMS Banking" refers to banking services via Multimedia Messaging Service (MMS). This system works in analogy to SMS Banking. The only difference lies in the extended scope and enhanced quality of push services for Mobile Financial Information (MFI), particularly for stock market charts and product information and offers (Tiwari and Buse, 2006).

3) Client-based applications: Client-based applications are those which require software to be installed on the mobile device. Transactions can be prepared offline (e.g. entry of necessary details). Once all necessary data have been keyed in, a connection to the server is established and the data transmitted. (Tiwari and Buse, 2006). It is conceivable that the possibility of entering data offline triggers a positive psychological effect for a customer as he does not feel the psychological pressure to be particularly fast during data-entry in order to save costs. This reduces the probability of typing errors getting transmitted thereby helping Mobile Banking win greater acceptability (Tiwari and Buse, 2006).

Table (2.2) Current status of banking sector in Palestine

No	Bank Name	Nationality	Electronic Banking	Mobile Banking	Number of Branches
1	Jerusalem Bank for Development & Investment	Palestinian	No	No	9
2	Palestine International Bank	Palestinian	No	No	4
3	Bank of Palestine	Palestinian	Yes	Yes, SMS for account information only	29
4	Palestine Investment Bank	Palestinian	No	No	7
5	Palestine Islamic Bank	Palestinian	No	No	13
6	Al-Aqsa Islamic Bank	Palestinian	No	No	2
7	Arab Palestinian Bank for Investments	Palestinian	No	No	1
8	Palestine Commercial Bank	Palestinian	No	No	5
9	Arab Islamic Bank	Palestinian	No	No	9
10	Palestinian Banking Corporation	Palestinian	No	No	2
11	The Housing Bank for Trades & Finance	Jordanian	Yes (*)	Yes (*)	10
12	Arab Bank	Jordanian	Yes	Yes, SMS for account information only	23
13	Cairo Amman Bank	Jordanian	No	No	16
14	Union Bank for Savings and Investment	Jordanian	Yes (*)	Yes (*), SMS for account information only	1
15	Jordan Ahli Bank	Jordanian	Yes (*)	Yes (*), SMS for account information only	5
16	Bank of Jordan	Jordanian	Yes (*)	Yes (*), SMS & WAP for account information only	8
17	Jordan Kuwaiti Bank	Jordanian	Yes (*)	Yes (*), SMS for account information and transfer between accounts	2
18	Jordan Commercial Bank	Jordanian	No	Yes (*), SMS for account information only	3
19	Egyptian Arab Land Bank	Egyptian	No	No	7
20	The Pricipal Bank of Development and Agricultural Credit	Egyptian	No	No	1
21	HSBC Bank Middle East	Foreign	No	No	1

(*) Service not available in Palestine now.
Source: Prepared and assembled by researcher

2.4.4. Classification of MFS

MFS can be classified in two ways. Depending on the originator of a service session, these services can be classified as'Push/Pull' nature. **'Push'** is when the bank for example sends out information based upon an agreed set of rules while**'Pull'** is when the customer explicitly requests a service or information from the bank. Another way of categorizing the MFS is by the nature of the service **Transaction based** and **Information based** (Philip, 2006). Request of the last three transactions is information based and a request for a fund's transfer to some other account is transaction based service. Transaction based services are also differentiated from information based services in the sense that they require additional security across the channel from the mobile phone to the banks data servers (Frost&Sullivan, 2003).

In addition to transaction and information based services, there are also**Relationship based** services which are focused around personalized service portfolios that allow users to pre-configure preferences for receiving targeted promotions by banks (Frost&Sullivan, 2003). Table (2.3) shows possible applications for MFS and its classification according to the above discussion.

Table (2.3) Classification of mobile financial services

	Push Based	**Pull Based**
Transaction Based	--	- Fund Transfer. - Bill Payment. - Other financial services like share trading.
Information Based	- Credit/Debit Alerts. - Minimum Balance Alerts. - Bill Payment Alerts.	- Account Balance Enquiry. - Account Statement Enquiry. - Cheque Status Enquiry. - Cheque Book Requests. - Recent Transaction History.
Relationship Based	- Receive Promotions.	- Enable/Disable Services.

Source: Adapted from (Frost&Sullivan, 2003); (Philip, 2006)

2.5. UTILITY OF MFS FOR BANKS

2.5.1. MFS as Distribution Channel

The term 'distribution channel' signifies a medium of delivery that a bank employs to deliver services for customers (Tiwari and Buse, 2006). Branchless banking represents a new distribution channel that allows banks and financial institutions offer financial services outside traditional bank premises. Some models of branchless banking (for example, Internet Banking and ATMs) can be seen as modest extensions of conventional branch-based banking. Other models (such as MFS) offer a distinct alternative to conventional branch-based banking in that customers conduct financial transactions at a whole range of retail agents instead of at bank branches or through bank employees (CGAP, 2006). MFS can be used to substantially increase the financial services outreach to the *unbanked* communities. Unbanked is defined as having no relationship with a bank. The unbanked have no deposit accounts and generally use only alternative ways for managing their financial needs (Diebold, 2006).

If implemented proficiently, MFS can help financial institutions and banks in Palestine to improve customer acquisition and customer retention, reduce total service costs for costly branch offices by migrating simple transactions away from branches. Figure (1.4) in chapter one shows that the numbers of branches in Palestine were increasing rapidly during the past decade with comparison to number of banks which means additional costs. Good utilization of cell phones distribution channel may provide the opportunity for cutting bank transaction costs. Transactions to be executed via cell phone may cost ($0.08/transaction) meanwhile traditional branch and teller distribution channel will cost ($1.0/transaction) on average, Fig. (2.3).

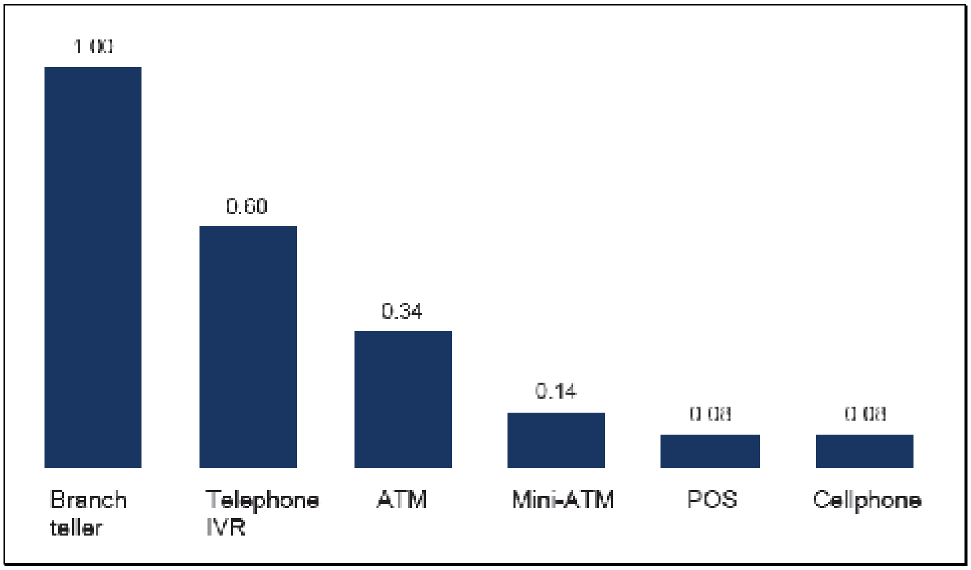


Figure 2.3: Costs (USD) per transaction, per distribution channel
Source: (Genesis Analytics, 2006)

2.5.2. MFS as Source of Revenue

Innovative mobility-centric services can be offered on a premium basis. This would not only help attract new customers but may even generate additional revenues from the existing customer-base (Tiwari and Buse, 2006). Due to the convenience of the mobile channel, customers have the opportunity to conduct transactions more frequently and banks can gain increased revenue from transaction fees (Philip, 2006).

When transactions are carried out through mobile, banks in Palestine will gain valuable marketing information and utilize it to develop sophisticated, personalized marketing campaigns and increase cross selling success rates (Philip, 2006).

2.5.3. MFS as Business Model

Branchless banking through cell phones has the potential to extend financial services to the unbanked communities. In many developing countries, particularly in rural areas, access to financial services is costly and very limited. This translates to a large percentage of the population operating on a cash basis only and outside of the formal banking system.

The proliferation of mobile services worldwide has created a unique opportunity to provide social and financial services over the mobile network (World-Bank, 2007).

There are several examples of efforts to turn a profit by serving millions of previously unbanked customers in low-income communities. M-PESA is one such M-Banking service, offered by Safaricom Ltd. in Kenya. M-PESA allows users to deposit, withdraw, and transfer money to within and outside of the M-PESA network. G-Cash, offered by Globe Telecom in the Philippines, offers comprehensive financial services. WIZZIT Bank in South Africa targets the base of the pyramid with financial services and recruits new customers by hiring low-income university students to run demonstrations in slums and rural villages (Katz and Escalante, 2007).

Banks and customers in Palestine faced a condition which is alike to those who might be resident at rural areas and do not have enough cash for daily operations or might have limited access to banking facilities. MFS would not only give banks and banked customers the opportunity to overcome the difficulties resulted from the above situation but may even attract unbanked customers and poor communities who will be able to use M-Payment and M-Banking applications for daily transactions.

2.6. FACTORS AFFECTING THE ADOPTION OF NEW INNOVATIONS

This section tries to reveal some of the complexities of technology adoption that can be applicable to MFS. The aim is to gain some insight into the possible determinants of success or failure in MFS adoption among consumers in Palestine. First, the diffusion of innovations theory will be explained, and then some literature about factors affecting the successful adoption of E-Banking technology in Palestine will be revised.

2.6.1. Diffusion of Innovations Theory

Rogers (2003) formulated the diffusion of innovations theory to explain the adoption rates of various types of innovations. The theory views that there are four main elements in the diffusion process of new ideas are: (1) an *innovation* (2) that is *communicated* through certain *channels* (3) *over time* (4) among the members of a *social system*. (Rogers, 2003). Figure (2.4) shows the diffusion process of new ideas over time. Each time we have a new idea or innovation; there will be different adopter distributions tend to follow an S-shaped curve over time. Earlier adopters play a major role as change agents to support the diffusion process through their successful adoption story.

Diffusion of innovations theory determines five innovation characteristics that affect the adoption of new ideas (Rogers, 2003):

1) Relative advantage: is “the degree to which an innovation is perceived as better than the idea it supersedes”. Relative advantage has been measured in terms of economic benefits, social prestige, status, convenience, and satisfaction.

2) Complexity: relates to “the degree to which an innovation is perceived as difficult to understand and use”. Perceived complexity has a negative effect on the adoption.

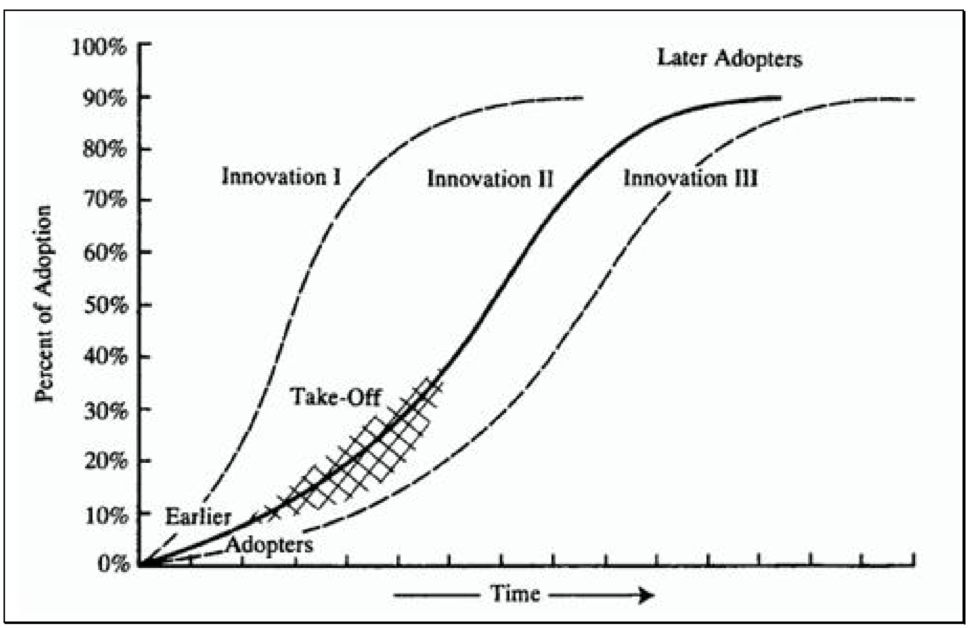


Figure 2.4: The process of diffusion of new innovations
Source: (Rogers, 2003)

3) Compatibility: indicates the "degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters". An idea that is incompatible with the values and norms of a social system will not be adopted as rapidly as an innovation that is compatible.

4) Trialability: signifies "the degree to which the innovation may be experimented with on a limited basis". A possibility to try an innovation before adoption will reduce the uncertainty and increase the likelihood of the adoption.

5) Observability: is "the degree to which the results of an innovation are visible and communicable to others". The easier it is for individuals to see and discuss the results of an innovation, the more likely they are to adopt it.

2.6.2. Factors Affecting the Adoption of E-Banking in Palestine

Abu Jaber (2007) examined the different factors that may affect the adoption of E-Banking technology in Palestine. Abu Jaber found that there are six important factors to enhance the adoption process by banks and customers:

1) Usefulness of the service to the bank and customers;
2) Security availability of the service;
3) Convenience of the service;
4) Advertisements used to convince customers about the new service;
5) Ease of use for the new service; and
6) Cost of introducing the service by banks as well as the cost of using it by customers.

Comparing these factors to Rogers's theory of Diffusion of Innovation leads to conclude that all these factors were addressed under the five characteristics of innovation that affect the adoption of new ideas. Table (2.4) reflects this comparison.

Table (2.4) Comparing factors affecting the adoption of E-Banking service in Palestine with innovation characteristics for diffusion of innovation theory

Innovation Characteristics		**Abu Jaber findings**
Relative advantage	The degree to which an innovation is perceived as better than the idea it supersedes	- Usefulness of the service to the bank and customers - Convenience of the service
Complexity	The degree to which an innovation is perceived as difficult to understand and use	- Ease of use for the new service
Compatibility	An idea that is compatible with the values and norms of a social system will be adopted rapidly	(Was not discussed in this study)
Trialability	A possibility to try an innovation before adoption will reduce the uncertainty and increase the likelihood of the adoption	- Advertisements used to convince customers about the new service
Observability	The easier it is for individuals to see and discuss the results of an innovation, the more likely they are to adopt it	- Security availability to the service - Cost of introducing the service by banks as well as the cost of using it by customers

2.7. CONCLUSION

MFS is offering several benefits and added value to banks and customers alike. Mobile operators value M-Commerce applications much. Because through M-Commerce the network created by the operators can be benefited to the maximum limit. Banks in Palestine must be aware of this race especially that some of the foreign banks in Palestine already established partnership relations with mobile operators to offer MFS outside Palestine. Moreover customers' perception of MFS as a new innovation will affect the rate of adoption. Many innovations require a lengthy period of many years from the time when they become available to the time when they are widely adopted. Therefore, a common problem for many banks is how to speed up the rate of diffusion of MFS. The challenge for banking sector in Palestine is not to get unbanked to the bank, but to get the bank to the unbanked.

CHAPTER THREE

SIMULATION MODELING

This chapter consists of the following sections:

CHAPTER THREE

SIMULATION MODELING

3.1. INTRODUCTION

Simulation modeling is fast becoming an important aid in achieving higher levels of efficiency and productivity. Historically, the most frequent uses of simulation modeling have been directed to the improvement of manufacturing operations. More recently, simulation has come into its own as a powerful tool for improvement of operations within the services sector (Zottolo et al., 2007). The primary objectives of this chapter are to develop an understanding of the role and limitations of simulation as a system analysis and decision support tool; highlight the main advantages of simulation modeling against disadvantages, explore the different applications of simulation with a brief description about using simulation in the service sector, and finally review commercial simulation modeling packages.

3.2. SIMULATION CONCEPTS

3.2.1. Definition of Simulation

Simulation is one of the most powerful tools available to decision-makers responsible for the design and operation of complex processes and systems. It makes possible the study, analysis and evaluation of situations that would not be otherwise possible. In an increasingly competitive world, simulation has become an indispensable problem solving methodology for engineers, designers and managers (Shannon, 1998).

Simulation can be defined as "the imitation of the operation of a real-world process or system over time" (Banks, 2000). The process of interest is usually called a system. When building a simulation model of a real-life system under investigation, one does not simulate the whole system. Rather, one simulates those sub-systems which are related to the problems at hand. This involves *modeling* parts of the system at various levels of detail. This can be graphically depicted using Beard's managerial pyramid as shown in Fig. (3.1) (Perros, 2007).

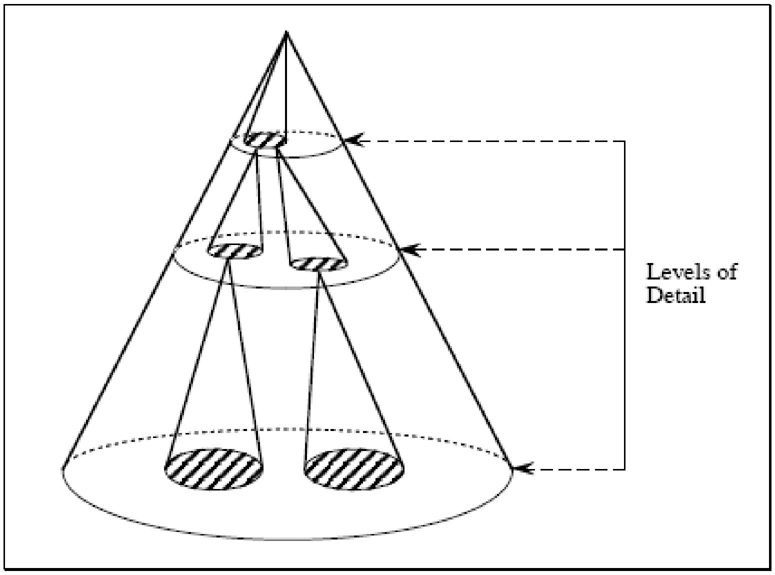


Figure 3.1: Beard's managerial pyramid
Source: (Perros, 2007)

3.2.2. Simulation Modeling

In order to study the system, we make a set of *assumptions* about it. These assumptions constitute a model. Assumptions are expressed in mathematical or logical relationship. If the model is simple enough, it may be solved by mathematical methods such as calculus, algebra or probability theory. However, many real world problems are too complex. Models of these systems are almost impossible to solve analytically. In a simulation, we use a computer to evaluate a model numerically and data are gathered in order to estimate the desired characteristics of the model (Hartmann, 2005).

A simulation model is a representation that incorporates time and the changes that occur over time. Simulation models can be classified by many ways, but one useful way is along these dimensions (Kelton et al., 2004):

(1) Continuous vs. Discrete: It is convenient to distinguish between *continuous* and *discrete* simulations. In a continuous simulation the underlying space-time structure as well as the set of possible states of the system is assumed to be continuous (Hartmann, 2005), thus the state of the system can change continuously over time; an example would be the level of water flows in a tank. In discrete simulations, changes can occur only at separated points in time (Kelton et al., 2004) such as customer arrivals to a bank.

(2) Static vs. Dynamic: Simulation models can be classified as *static* or *dynamic*. A static simulation model is a representation of a system at a particular point in time (Kelton et al., 2004). Static simulation is usually referred as a *Monte Carlo* simulation. A dynamic simulation model is a representation of a system as it evolves over time (Kelton et al., 2004).

(3) Deterministic vs. Stochastic: A deterministic simulation model is one that contains no random inputs; a stochastic simulation model contains one or more random input variables like a bank with randomly arriving customers requiring varying service times (Kelton et al., 2004). A model can have both deterministic and random inputs in different components. It is often a must to allow for random inputs in order to make the model a valid representation of reality. Random inputs can be generated through specifying probability distributions from which observations are sampled (Kelton et al., 2004).

3.3. ADVANTAGES AND DISADVANTAGES OF SIMULATION MODELING

Simulation has a number of advantages that allow the identification of problems, bottlenecks and design shortfalls before building or modifying a system. It allows comparison of many alternative designs (Carson II, 2005) and let us experiment with new and unfamiliar situations as to answer "what if" questions (Shannon, 1998). Evaluation and comparisons can take place before committing resources and investment to a project. Simulation allows study of the dynamics of a system, how it changes over time and how subsystems and components interact (Carson II, 2005).

On the other hand, often simulations are time consuming, data is not available or costly to obtain, and the time available before decisions must be made is not sufficient for a reliable study (Carson II, 2005). Simulation modeling is an art that requires specialized training and therefore high skills of the modelers (Shannon, 1998). If two models of the same system are constructed by two competent individuals, they may have similarities, but it is highly unlikely that they will be the same. Despite its tremendous benefits, simulation is not a perfect technology. It is a decision support tool that may help in simplifying the decision making process. As such, simulation output must be carefully analyzed. Most simulation models have random inputs such as equipment reliability, variable demand or loss, which cause the simulation output to be random too (Kelton et al., 2004). Therefore, running a simulation once is like performing a random physical experiment once and the results will probably be different each time. So it is highly recommended to run simulation models many times before concluding results.

3.4. APPLICATIONS OF SIMULATION MODELING

Simulation modeling is used in a multitude of applications. Many researchers attempted to classify and categorize the simulation applications. The researchers found 22 applications shared among the simulation packages(Abu-Taieh and El-Sheikh, 2005). The use of simulation modeling for some applications is more popular than others as shown in Fig. (3.2). Simulation modeling is often used for modeling and designing many applications including hospitals, military operations, traffic, airports, services industries, computer systems, telecommunication networks and manufacturing systems like factories, flexible manufacturing systems, assembly lines, warehouses, and supply chains (Herrmann et al., 2000).

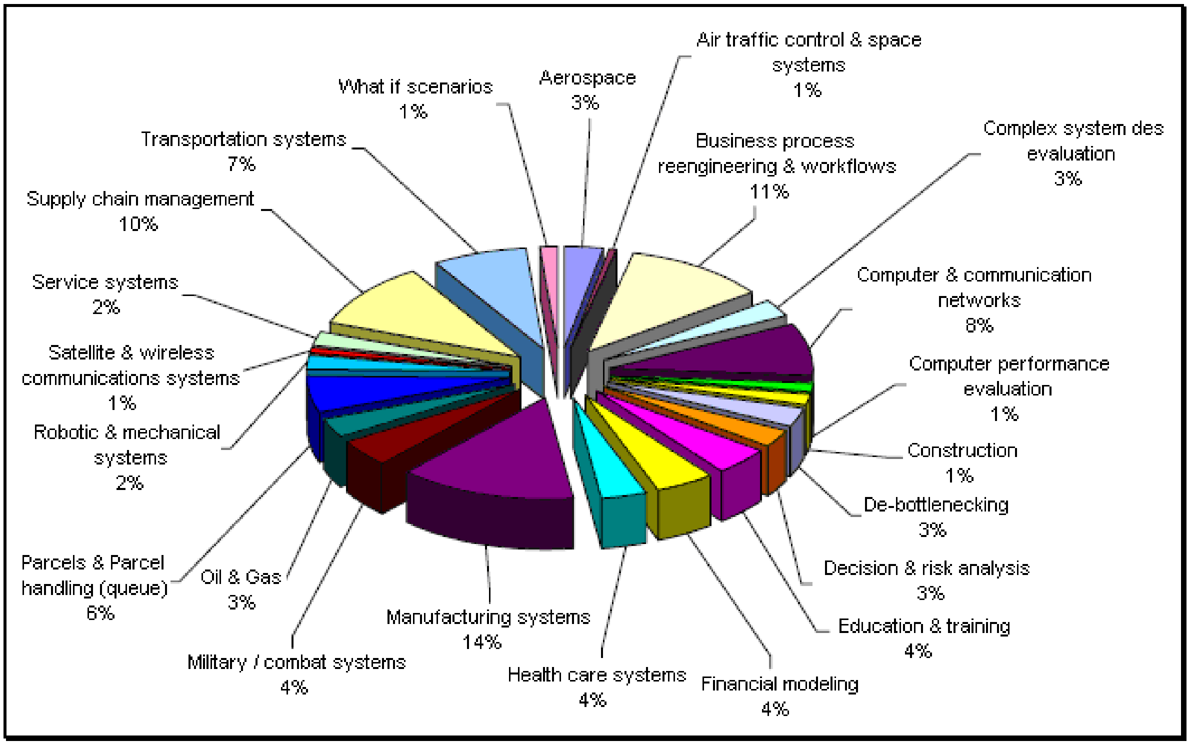


Figure 3.2: Popularity of simulation applications
Source: (Abu-Taieh and El-Sheikh, 2005)

3.4.1. The Use of Simulation Modeling in the Service Industry

Service industry has been developing rapidly and receiving more attention in the recent years by system modelers. Customer satisfaction is a growing concern in service industry settings such as banks, hospitals, and call centers. High variability in demand is prevalent in the service industry, and customers still expect to be served promptly when they arrive (Chandra and Conner, 2006). Therefore, there is a need for efficient staff utilization with minimal possible cost, taking into account varying demand levels for the day of the week, or even for the time of the day.

Improving customer satisfaction and service levels usually requires extra investments. To decide whether or not to invest, it is important to know the effect of the investment on the waiting time, and service cost. Usually managers and decision makers seek to balance between the service and waiting time cost to offer the best service with minimal cost

(Chase, 2007). Figure (3.3) shows the relation between these costs and how to obtain the minimum aggregate cost and optimal capacity.

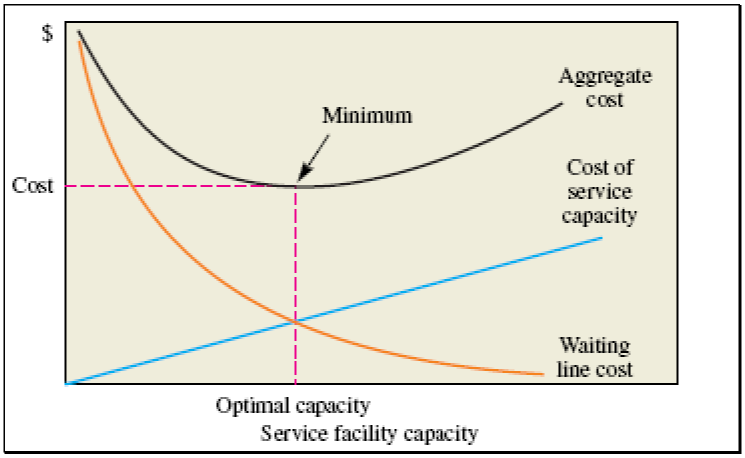


Figure 3.3: Waiting line versus service capacity level trade-off
Source: (Chase, 2007)

The service system is characterized by the number of waiting lines, the number of servers, the arrangement of the servers, the arrival and service patterns, and the service priority rules (Reid and Sanders, 2005). Figure (3.4) shows single and multiple lines and servers structures.

Some waiting line and service problems that seem simple on first impression turn out to be extremely difficult or maybe impossible to solve.Waiting lines that occur in series and parallel (such as in assembly lines and job shops) usually cannot be solved mathematically (Carson II, 2005). Therefore, simulation modeling is necessary to explore and analyze alternative designs to obtain the optimal solution.

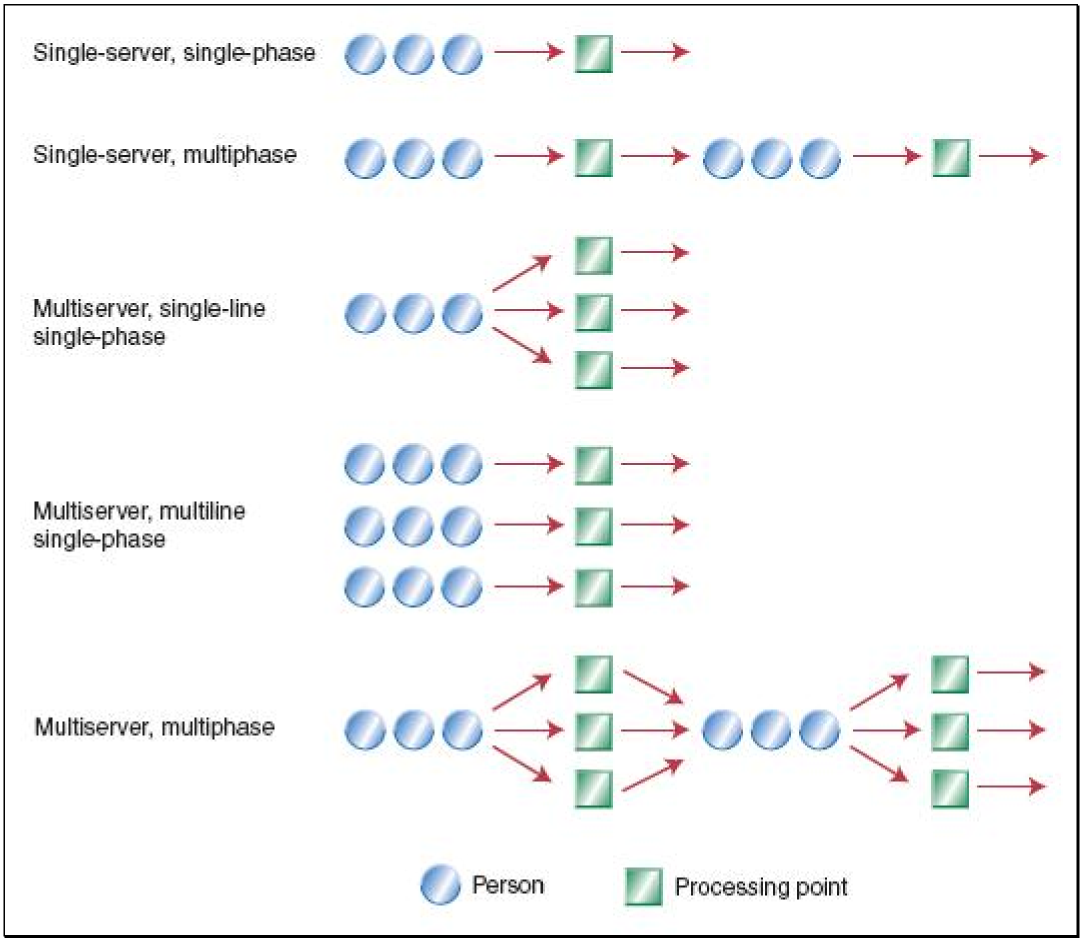


Figure 3.4: Examples of waiting line systems
Source: (Reid and Sanders, 2005)

3.5. SIMULATION MODELING SOFTWARE

Commercial simulation modeling packages enable modelers to develop simulation models and also provide facilities to carry out simulation optimization as to help modelers optimize performance parameters that are of critical importance in the design of the systems under study. Most simulation modeling packages provide statistical reports (mean, minimum value, maximum value) to simplify analysis for performance measures (e.g., wait times, inventory on hand, utilization … etc.). There are many different simulation modeling packages in the market and each has its strengths and weaknesses. The best packages allow the user to combine easy-to-use constructs with more flexibility (Miller and Pegden, 2000). Some of the most popular simulation modeling packages include Arena, AutoMod, ProModel, Simul8, and Witness. Figure (3.5) shows that most of the papers during WSC 2007 were referring to Arena simulation package.

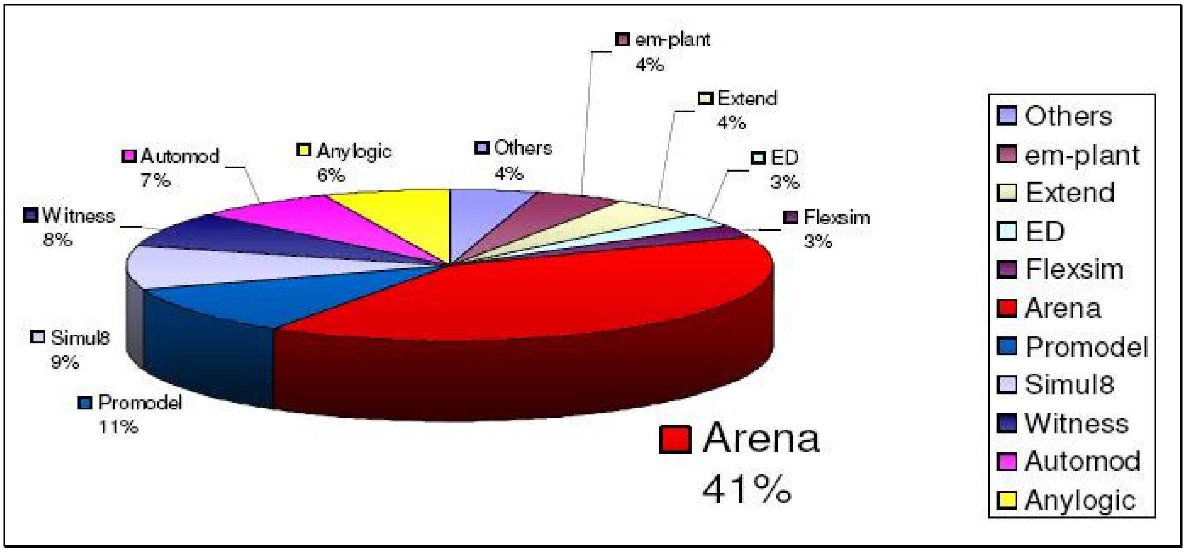


Figure 3.5: WSC 2007 Papers Referring to Simulation Software
Source: (Rockwell-Automation, 2007)

3.5.1. Arena Simulation Modeling Package

Arena, the simulation package which is used in this study, has been developed based on the principle of *flow-oriented simulation*. The idea behind flow-oriented simulation is that you can represent a real situation as a series of delays and processes through which entities flow. This way of modeling corresponds with the way in which people often represent a system intuitively as shown in Fig. (3.6). If you ask someone how he thinks a certain process works, often this person will draw a diagram using blocks and arrows to indicate the activities that are carried out and the sequence in which they are performed (Verbraeck et al., 2002). Figure (3.7) shows a model representation for system developed by Arena Simulation package.

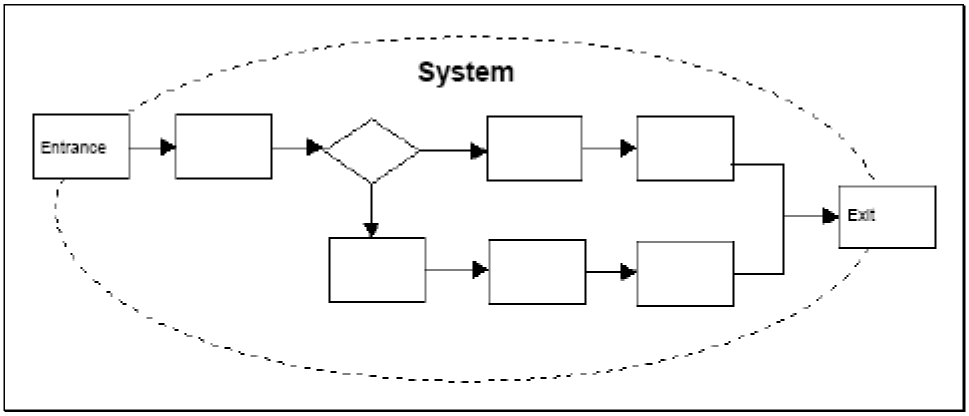


Figure 3.6: Flow model with system borders
Source: (Verbraeck et al., 2002)

Arena is a simulation software developed by Rockwell Automation. It uses the SIMAN simulation language. And it is currently in version 12.0. Arena is extensively used to simulate a company's process or system to analyze its current performance as well as possible changes that could be made. By accurately simulating a process or system, a company can see the outcomes of changes without implementing them in real-time, thus saving valuable time and resources.

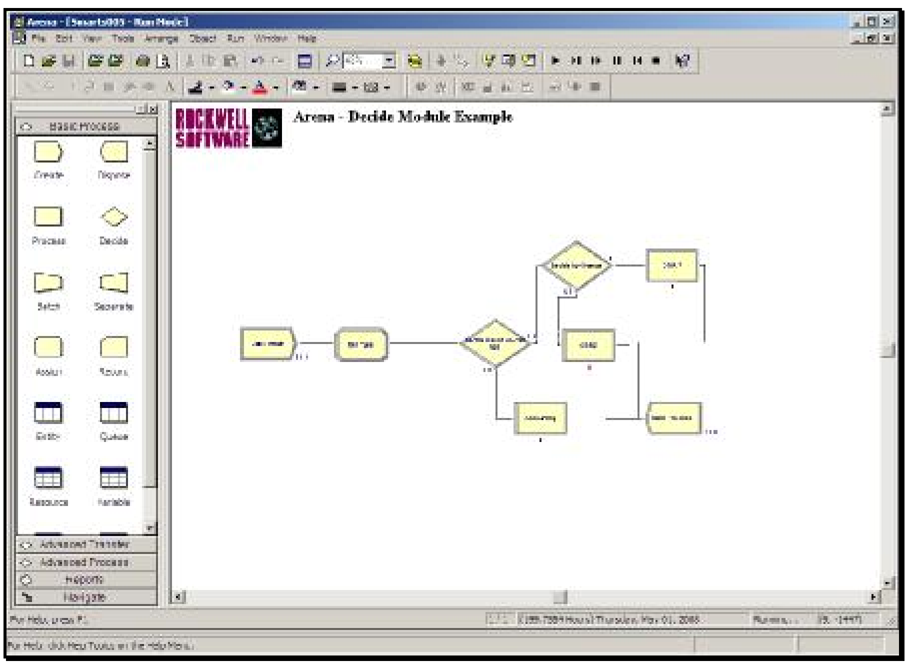


Figure 3.7: Sample model running in Arena 7.01 Basic Edition

In Arena, the user builds an experiment model by placing *modules* (boxes of different shapes, see Appendix-B) that represent processes or logic. Connector lines are used to join these modules together and specify the flow of *entities*. While modules have specific actions relative to entities, flow, and timing, the precise representation of each module and entity relative to real-life objects is subject to the modeler. Statistical data, such as waiting time and resource utilization, can be recorded and outputted to reports as to simplify analysis.

3.6. SIMULATION OPTIMIZATION

The optimization of simulation models deals with the situation in which the analyst would like to find which of the model input parameters lead to optimal performance. Within this context, a simulation model can be thought of as a mechanism that turns input parameters into output performance measures (Kelton and Barton, 2003):

$$\begin{aligned} Output_1 &= f_1\,(Input_1, Input_2, \ldots Input_n) \\ Output_2 &= f_2\,(Input_1, Input_2, \ldots Input_n) \\ Output_n &= f_n\,(Input_1, Input_2, \ldots Input_n) \end{aligned} \qquad (3.1)$$

Where the functions $f_1, f_2, \ldots f_n$ (n>0) represent the simulation model itself.

Viewing a simulation model as a function has motivated a family of approaches to optimize simulations based on *Response Surface Methodology* and *Meta-Models* (April et al., 2006). A response surface is plot that numerically characterizes the function that the simulation model represents and is built by recording the responses obtained from running the simulation model over a list of specified values for the input parameters (or input factors). Figure (3.8) shows sample response surface plots constructed by Design Experts software (Statease, n.d.).

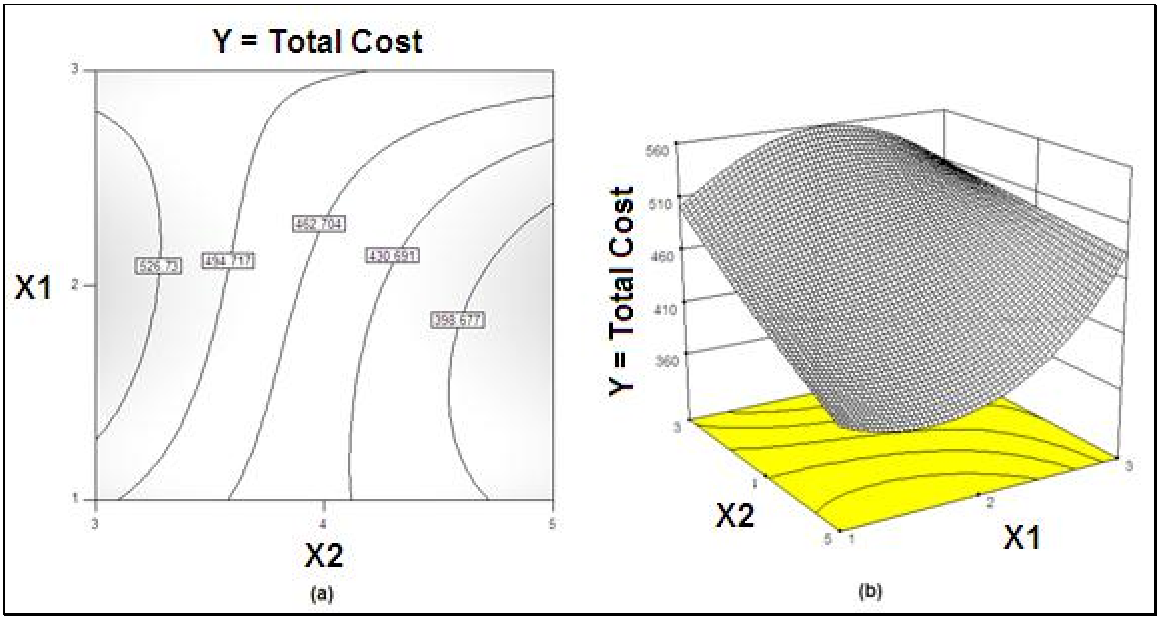


Figure 3.8: (a) Contour plot for the response of total cost. (b) 3D response surface plot for the same response

A Meta-Model is an algebraic model of the simulation. It approximates the response surface and therefore optimizers use it instead of the simulation model to estimate performance (April et al., 2006). Standard linear regression has been and continues to be one of the most popular techniques used to build meta-models in simulation (April et al., 2006). The meta-model could be regarded as a proxy for the full simulation models response surface; all we would need is a pocket calculator or spreadsheet to evaluate any combination of interest (Law, 2006). For example, if there are two factors (*X*1 and *X*2) that are thought to affect an output response *Y*, we might approximate this relationship by the regression model (Kelton et al., 2003):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2 + \beta_4 X_1^2 + \beta_5 X_2^2 + \varepsilon \qquad (3.2)$$

Where the β_j coefficients are unknown and must be estimated somehow, and ε is a random error term representing whatever inaccuracy such a model might have in approximating the actual simulation-model response *Y*. It is important to remember that meta-models are just an *approximation* to the actual simulation model that will approximate the relationships between the factors and the responses with statistical models (regression models). The use of meta-models can help to find the combination of input factor values that *optimizes* (i.e., minimizes or maximizes, as appreciate under some constraints) main and important responses.

Alternatively, every commercial simulation software package nowadays contains an optimization module that performs some sort of search for optimal values of input parameters rather than just performs pure statistical estimation.

The choice of the procedure to employ in simulation optimization depends on the analyst and the problem to be solved.

3.7. CONCLUSION

When planning a new system or making significant changes to an existing one, simulation modeling is a key tool for predicting and validating system performance. Simulation modeling is not a perfect technology. It is a decision support tool that aids in decision making process and it is not a decision-maker. Simulation software tools like Arena are used to describe and analyze the behavior of a system, answer questions about proposed changes to the system, and help designing new systems.

CHAPTER FOUR

RESEARCH METHODOLOGY AND DESIGN

This chapter consists of the following sections:

CHAPTER FOUR

RESEARCH METHODOLOGY AND DESIGN

4.1. INTRODUCTION

The main purpose of this chapter is to explicate the research methodology with sufficient details for the case study being analyzed including problem formulation, data collection and manipulation, model conceptualization and transfer, verification and validation of the simulation model, in addition to the design of the experiment and the alternatives or opportunities that are to be simulated in order to build a meta-model as to facilitate the analysis of the outputs and achieve the objectives of this study.

4.2. CASE STUDY DESCRIPTION

PIB in Khanyounis is a small branch office of a national scale bank in Palestine. Services provided by this branch office include: savings, account deposits and withdrawals, transfer of funds, foreign currency exchange, and ATM services. The process of interest within this branch office is the service delivered to customers via tellers and ATM channels.

There are five counters in the tellers' area which can physically be opened as shown in Figure (4.1), but current practice at the bank is to open two counters permanently, with the additional counters being opened only during rush days and peak hours as needed. The additional counters served by temporary tellers called from the administrative employees.

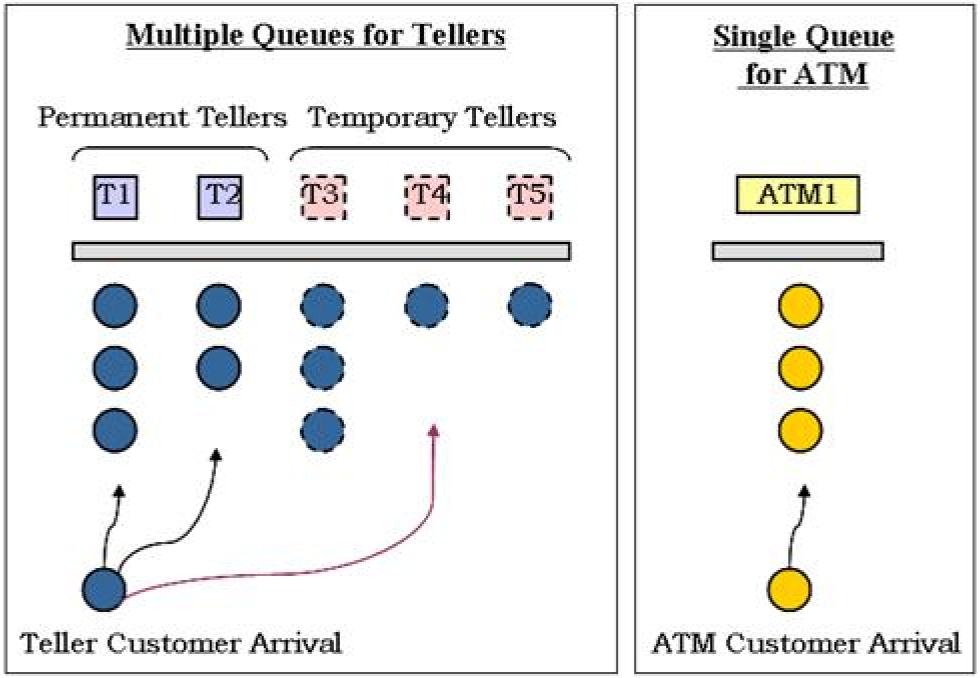


Figure 4.1: Tellers and ATM services subsystems

The bank opens Sunday through Thursday from **8:30AM** to **2:30PM**. ATM services delivered to ATM customers through a machine located outside the building and operated around the clock. The building is large enough that the assumption of an infinite capacity for the waiting customers is reasonable. At **2:30PM**, the bank closes but the customers in the bank at that time will be served. Customers arrive to the tellers' area and wait in *multiple* queues; meanwhile ATM customers wait in a *single* queue until being served.

4.3. RESEARCH METHODOLOGY

This study consisted of *four* major phases as shown in Fig. (4.2). The *first phase* handled problem formulation and objectives of the overall project plan. The *second phase* focused on collecting the data for the simulation experiment, simulation model conceptualization and translation, in addition to verification and validation. The *third phase* handled experimental design and run for the simulation experiment. The outputs of the simulation experiment at this phase were used to construct regression models and RSM plots for the responses of interest. The regression models were used as a proxy for the full simulation model's responses as to enable decision makers to evaluate any combination of interest through a pocket calculator or spreadsheet only without the need for a simulation analyst. RSM used as an optimization technique for the main factors of interest. And finally the *fourth phase* covered the conclusions and recommendations for the study.

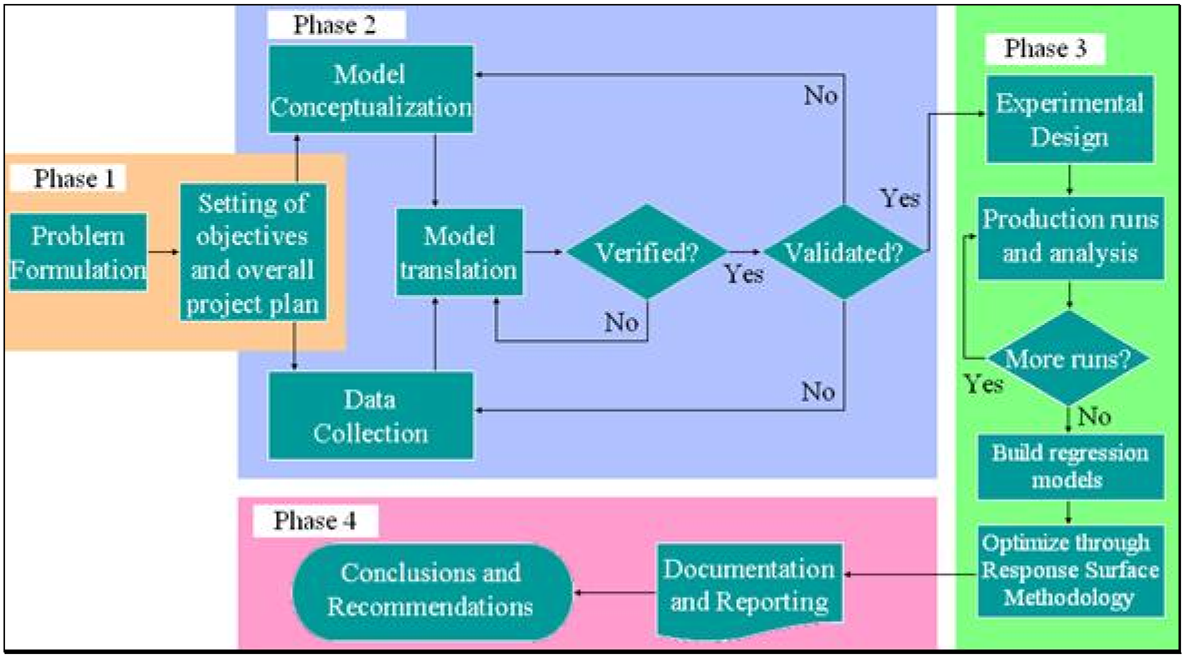


Figure 4.2: Phases and steps for research methodology

4.4. PROBLEM FORMULATION AND STUDY OBJECTIVES PHASE

4.4.1. Problem Formulation

PIB (Khanyounis branch) - like any other working bank in Palestine - currently facing growing challenges to serve more customers with limited teller and ATM resources. Service quality and its delivery cost are of a major concern for the management especially during salary withdrawal days (rush days). Governmental employees and bank customers wait on average for **50 minutes** in long queues to be served from tellers and **25 minutes** to be served from ATM during rush days. During normal days customers usually wait for **18 minutes** to be served by tellers. There is no time-efficient way to improve customer service other than increasing the number of tellers and ATMs or open new branch offices which for sure will add more costs to banking operations usually any bank is seeking to minimize as it will directly affect revenues.

4.4.2. Simulation Study Objective

The main goal of the simulation study is to examine new opportunities for distributing banking services via MFS. It will explore and evaluate the impact of MFS on improving customer satisfaction; reducing service costs for service channels, and moreover, exploring new sources for revenue generation. The outputs of the simulation experiment will be used later for building regression models response surface plots for the responses.

4.5. SIMULATION MODEL DESIGN PHASE

4.5.1. Data Collection and Input Data Analysis

The data collection stage gathers observations about system characteristics over time. The data used for the simulation model were collected during **January**, **February**, and **March 2008**. It consists of the total number of daily customer arrivals for the tellers and ATM service distribution channels during months of **January** and **February 2008**, the rates of customers arrival during day hours to the bank, average rates of service time for tellers and ATM resources, average waiting time for customers, average queuing lines length, cost for operating one teller and one ATM resource, average transaction cost for the transactions executed via tellers and ATM service channels. The data were collected from historical records, statistics, and supported with daily observations from the field (See Appendix-C for more info about data collection forms).

The total number of daily customer arrivals was found to be changing from day to day. It was very hard to have a data sample that represent all days of the month; therefore, *Change-Point Analysis-CPA*(See Appendix-D for more information about CPA) was used to detect arrival patterns per day of month. Chandra and Conner (2006) used this technique to develop a simulation model with segmented arrival rates per day hours as to analyze a real queuing system for a bank in Indonesia. Hawkins formulated the single mean change-point model as follows (Chandra and Conner, 2006):

$$X_i = \begin{cases} N(\mu_1, \sigma) & \text{if } i \leq \tau \\ N(\mu_2, \sigma) & \text{if } i > \tau \end{cases} \quad \text{.......} \quad (4.1)$$

Where τ is the change-point between the two segments of data.

The change-point is detected by sequentially computing the t-statistic to compare the mean of 'left' ($i \le \tau$) and 'right' ($i > \tau$) segments:

$$T_{jn} = \sqrt{\frac{j(n-j)}{n}} \, \frac{\overline{X}_{jn} - \overline{X}^{*}_{jn}}{\hat{s}_{jn}} \quad \text{.. (4.2)}$$

Where j: putative change-point, $1 \le j \le n$-1

n: possible range of observations, n = 3, 4, …

$\overline{X}_{jn}$: average of the 'left' segment

$\overline{X}^{*}_{jn}$: average of the 'right' segment

$\hat{s}_{jn}$: pooled standard deviation of the two segments

As to simplify the process of detecting change-points, a *Change-Point Analyzer* was used (Variation, n.d.). The results revealed two patterns for customer arrivals per month, one for ***Normal Days*** and a different segment for ***Rush Days*** which represent salary withdrawal days. Figure (4.3) shows the two patterns for customers' daily visits to the tellers' area (lobby area) of the bank during the months of **January** and **February 2008**. This means that it is important to have a sample from these two segments to be able for studying and evaluating the previously described problem accurately. Figure (4.4) indicates that ATM distribution channel is also having two segments of customers' arrivals that represent normal and rush days as well.

4.5.1.1. Arrival Rates

The arrival process was modeled using customers' arrival statistics collected for customers visiting tellers' area and ATM service distribution channels. Customers' arrival statistics shows that the inter-arrival times fluctuate throughout the day hours, therefore it follows a *Non-Stationary Arrival*, (i.e., the arrival rate of customers is a function of time). Table (4.1) and table (4.2) shows the observed average arrivals for the tellers area and ATM service distribution channels. The non-stationary arrival is very useful and often provides an accurate way to reflect time-varying arrival patterns. The exponential distribution which is often used for modeling inter-arrival time (Kelton et al., 2004) was selected to model the customer arrivals.

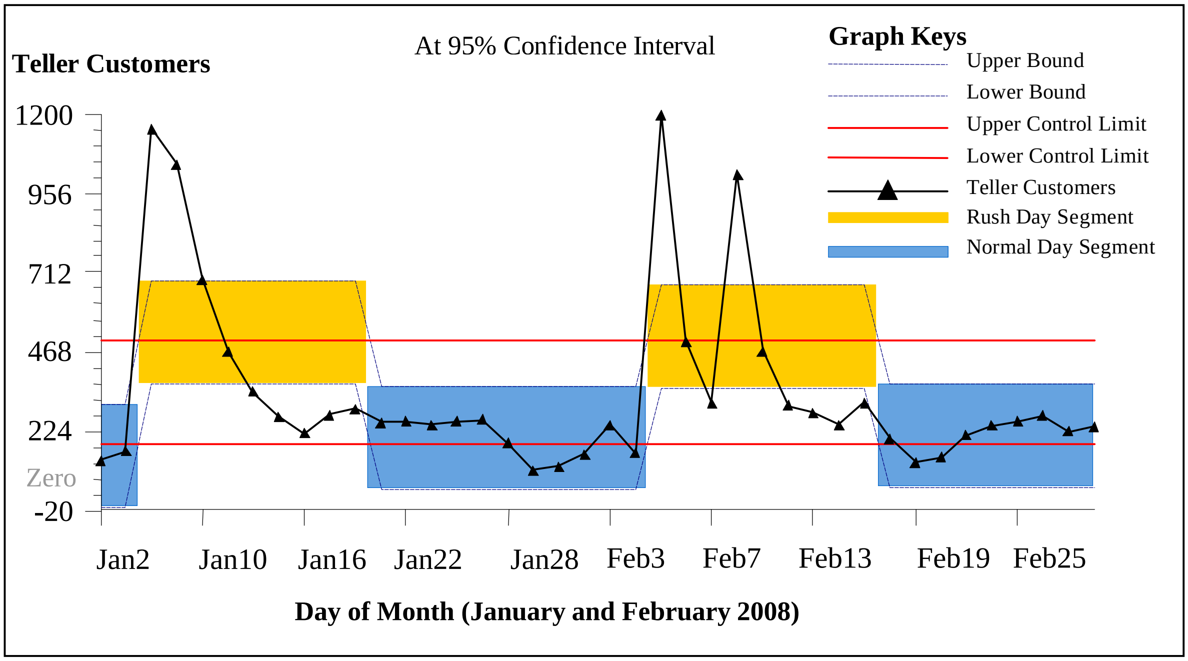


Figure 4.3: Change-point analysis revealed two distinct segments for the number of customers visiting tellers' service distribution channel per month

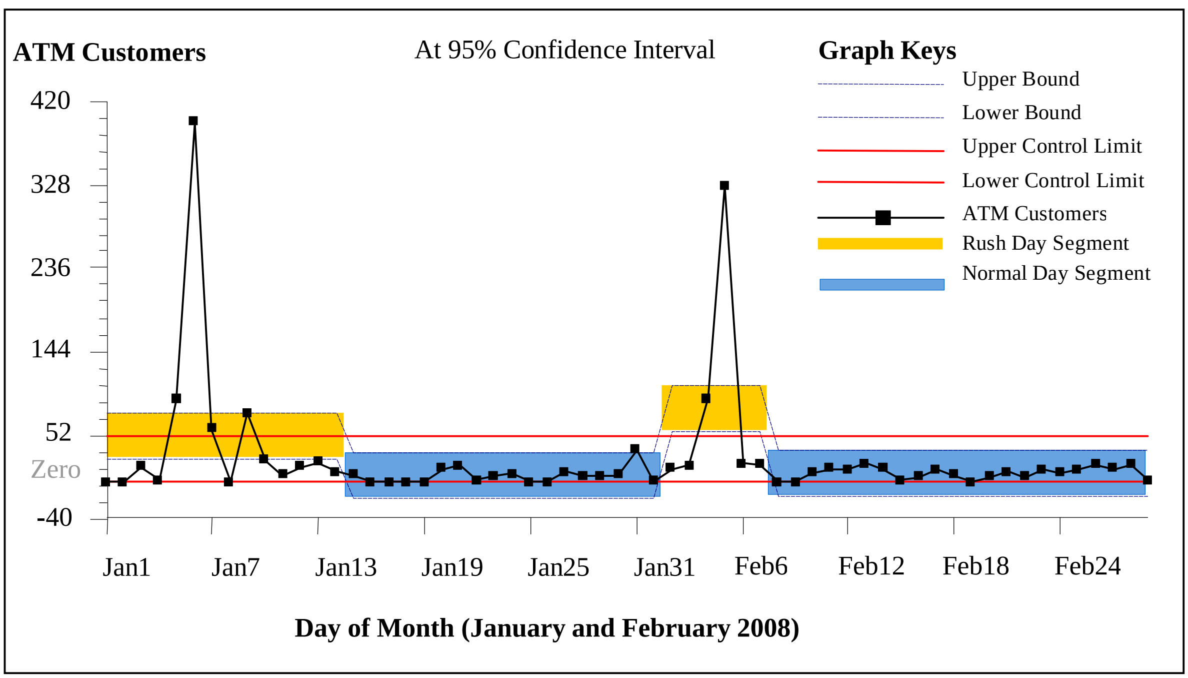


Figure 4.4: Change-point analysis revealed two distinct segments for the number of customers visiting ATM service distribution channel per month

Table 4.1: Observed average arrivals for tellers area

Time Period (*)	Observed Average Arrivals (Tellers Area)	
	Normal Day (3 Days Sample)	Rush Day (2 Days Sample)
08:00-09:00	25	114
09:00-10:00	68.67	254.5
10:00-11:00	67.67	287.5
11:00-12:00	88.33	388.5
12:00-13:00	73.33	293.5

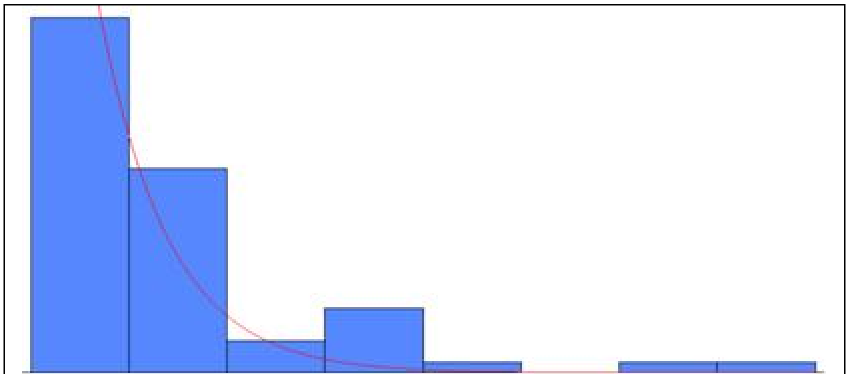
Table 4.2: Observed average arrivals for ATM area

Time Period (*)	Observed Average Arrivals (ATM Area) (**)	
	Normal Day (3 Days Sample)	Rush Day (2 Days Sample)
08:00-09:00	0.33	26
09:00-10:00	0	31
10:00-11:00	0.33	49.5
11:00-12:00	1.67	52.5
12:00-13:00	2	54.5
13:00-14:00	1.67	35.5
14:00-15:00	0.67	15
15:00-16:00	1	13
16:00-17:00	0.33	12.5
17:00-18:00	0	14
18:00-19:00	0.67	12
19:00-20:00	1	11.5

(*) Although the bank official working hours were from **8:30AM** to **2:30PM**, data collection process was limited to the period between **8:30AM** and **1:00PM** because of the high variability of closing times because of the electricity outage and fuel shortage crisis for operating the power generators in Gaza strip area during the data collection phase. ATM machine data collection process was limited to this constraint as well, it was having variable opening and closing hours during data collection period. In addition, it was not possible to have a data sample for the **24** operating hours as it will require huge efforts for data collection. As a result, the data collection process for ATM channel was limited to the period between **8:00AM** and **8:00PM**.

(**) The total number of customers using ATM service distribution channel was considered to be limited and not growing in an appropriate way due to the scarcity of the required material to produce new ATM cards as a result of the applied siege on Gaza Strip area during data collection period.

Arena Input Analyzer (AIA) was used in fitting input raw data for each time period of customers' arrivals. The AIA automatically creates a histogram from the sampled data, and provides a summery of sample statistics as shown in Fig. (4.5). The minimum square error with largest goodness of fit test p-value is desirable (p-values greater than or equal **0.05** was considered to be a good fit) (Kelton et al., 2004). The exponential arrival expressions for customers visiting tellers and ATM service distribution channels is shown in tables (4.3) and (4.4) respectively. (See Appendix-E for more information regarding probability distributions used in this study).



Distribution Summary

Distribution: Exponential **Expression: -0.001 + EXPO(0.95)** Square Error: 0.011696 Chi Square Test Number of intervals = 4 Degrees of freedom = 2 Test Statistic = 4.14 **Corresponding p-value = 0.138** Kolmogorov-Smirnov Test Test Statistic = 0.269 Corresponding p-value < 0.01	Data Summary Number of Data Points = 64 Min Data Value = 0 Max Data Value = 5 Sample Mean = 0.938 Sample Std Dev = 0.906 Histogram Summary Histogram Range = -0.001 to 5 Number of Intervals = 8

Figure 4.5: AIA sample output for the time period **(9:00-10:00)AM** which was sampled from Tellers service channel arrivals during a normal day

Table 4.3: AIA output expressions for Tellers service channel arrivals

Time		Arrival Rate Functions (Tellers Arrivals)	
From	**To**	**Normal Day Expressions**	**Rush Day Expressions**
8:00	9:00	0.25 + EXPO(0.865)	- (0.5) + EXPO(0.695)
9:00	10:00	- (0.001) + EXPO(0.95)	- (0.5) + EXPO(0.589)
10:00	11:00	- (0.001) + EXPO(0.79)	- (0.5) + EXPO(0.52)
11:00	12:00	- (0.001) + EXPO(0.63)	- (0.5) + EXPO(0.517)
12:00	13:00	- (0.001) + EXPO(0.8)	- (0.5) + EXPO(0.6)

Table 4.4: AIA output expressions for ATM service channel arrivals

Time		Arrival Rate Function	
From	**To**	**Normal Days Expressions**	**Rush Days Expressions**
8:00	9:00	8 + EXPO(47)	- (0.001) + EXPO(2.95)
9:00	10:00		- (0.001) + EXPO(1.77)
10:00	11:00		- (0.001) + EXPO(1.15)
11:00	12:00		- (0.001) + EXPO(0.85)
12:00	13:00		- (0.001) + EXPO(0.95)
13:00	14:00		- (0.001) + EXPO(1.54)
14:00	15:00		- (0.001) + EXPO(3.3)
15:00	16:00		- (0.001) + EXPO(4.35)
16:00	17:00		0.5 + EXPO(5.41)
17:00	18:00		- (0.001) + EXPO(2.8)
18:00	19:00		- (0.001) + EXPO(4.15)
19:00	20:00		- (0.5) + EXPO(5.2)

Table (4.4) shows that during normal day's hours, average number of ATM customers' arrivals was very small (**9 Customers/Day**) as previously shown in table (4.2); thus, it was better to handle this period as one single period with one single expression for the entire operating hours.

4.5.1.2. Service Rates

The service processing rate was assumed to be homogeneous for all the tellers. Banking administrations usually circulate employees as to enhance their skills and improve performance levels; therefore it was assumed that all staff members have similar skills and performance levels. The service process was modeled using statistics collected on the average service times for all tellers. Figure (4.6) illustrates minimum, most likely, and maximum service times for different service channels during normal and rush days. It was noticed during rush days that service process was a little bit faster than normal days; thus, average service time was smaller. This is probably because of the nature of the requested service (i.e., most of the customers require to withdraw salary only). Therefore, the triangular distribution is used because it can capture processes with small or large degrees of variability and its parameters are fairly easy to understand (Kelton et al., 2004).

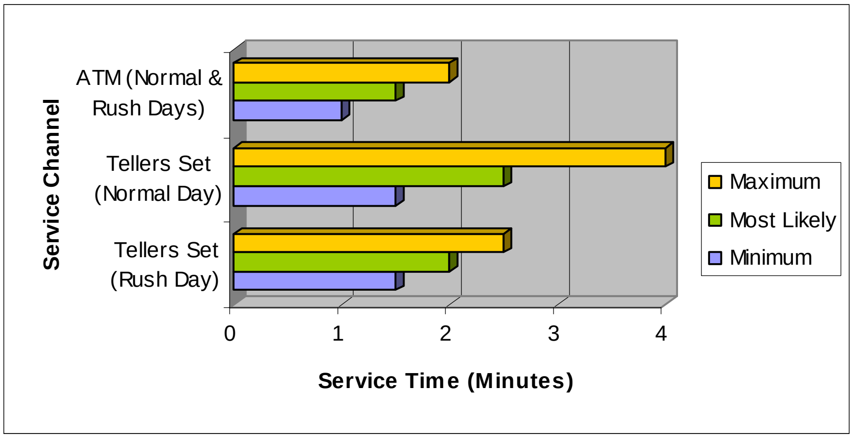


Figure 4.6: Service rates for service channels

4.5.2. Model Conceptualization and Transfer

4.5.2.1. Model Conceptualization

Any real-life system studied by simulation techniques is viewed as a system. Therefore, a system, in general, is a collection of entities and resources which are logically related and which are of interest to a particular application (Perros, 2007). The real-world system under investigation is abstracted by a conceptual model. In order to build a conceptual model for a system, it is important to make a set of assumptions about it. These assumptions constitute a model. Assumptions are expressed in mathematical or logical relationship. The following assumptions were adopted for the purpose of modeling the system under investigation:

- Bank opens at **8:30AM** and offers services for customers through tellers group until **1:00PM**. At **1:00PM** the bank closes but the customers in the bank at that time will be served. Customers come to the tellers' area with escorts.
- ATM services available for customers' usage between **8:00AM** and **8:00PM** only.
- Each teller serves customers from the same queue only.
- All tellers work at the same speed.
- During normal days, only two permanent tellers are working with the possibility to activate a temporary teller come from the back office if number of customers exceeds 30 customers. During rush days, two temporary tellers will be working in addition to the two permanent tellers but if the number of customers exceeds 50 customer in the lobby, a third temporary teller will be activated.

- Tellers do not have lunch hours, but do leave the counter from time-to-time. However, a teller will finish serving the current customers in the queue before leaving the counter.
- By default, all tellers can handle all types of customer transactions. There are no special service queues, but it might happen from time-to-time to let any teller serves a specific type of customers during day hours.
- There is no queue capacity limitation. This means that the building is large enough for the assumption of an infinite capacity is reasonable.
- When faced with several queues, customers tend to pick the shortest. However, all tellers will have an equal opportunity to serve any customer. All queues follow a First-In First-Out (FIFO) priority.
- Reneging and jockeying are neglected. However, a small percentage of customers may balk during normal and rush days.
- ATM machine may fail during period of operation due to power supply failure. If the failure was during branch office working hours, ATM customer will enter the bank and join tellers' area queues to be served; otherwise he/she may leave without being served.
- The management tends to operate the power generator during bad electricity supply days if it was expected to coincide with a rush day as to minimize fail period for ATM. This means that ATM machine may fail with less frequency and duration with comparison to normal day failures.

As previously explained in chapter (3), Arena, the simulation package which is used in this study, has been developed based on the principle of *flow-oriented simulation*. The idea behind flow-oriented simulation is that it is possible to represent a real situation as a series of delays and processes through which entities flow. This way of modeling corresponds with the way in which people often represent a system intuitively. If you ask someone how he/she thinks a certain process works, often this person will draw a diagram using blocks and arrows to indicate the activities that are carried out and the sequence in which they are performed. Figures (4.7) and (4.8) show a flow chart for a flow-oriented system with boundaries for each service channel. The entrance and exit of the system are located on the service channel boundary. This is done because the entities that flow through the service channel must come from somewhere and, after flowing through the service channel, they must go somewhere. In the model we do not consider where entities come from or where they leave to; this is something outside the service channel boundary. Therefore, in the simulation model entities must be created to simulate their entrance into the system and, after passing through the system, they must also be disposed of.

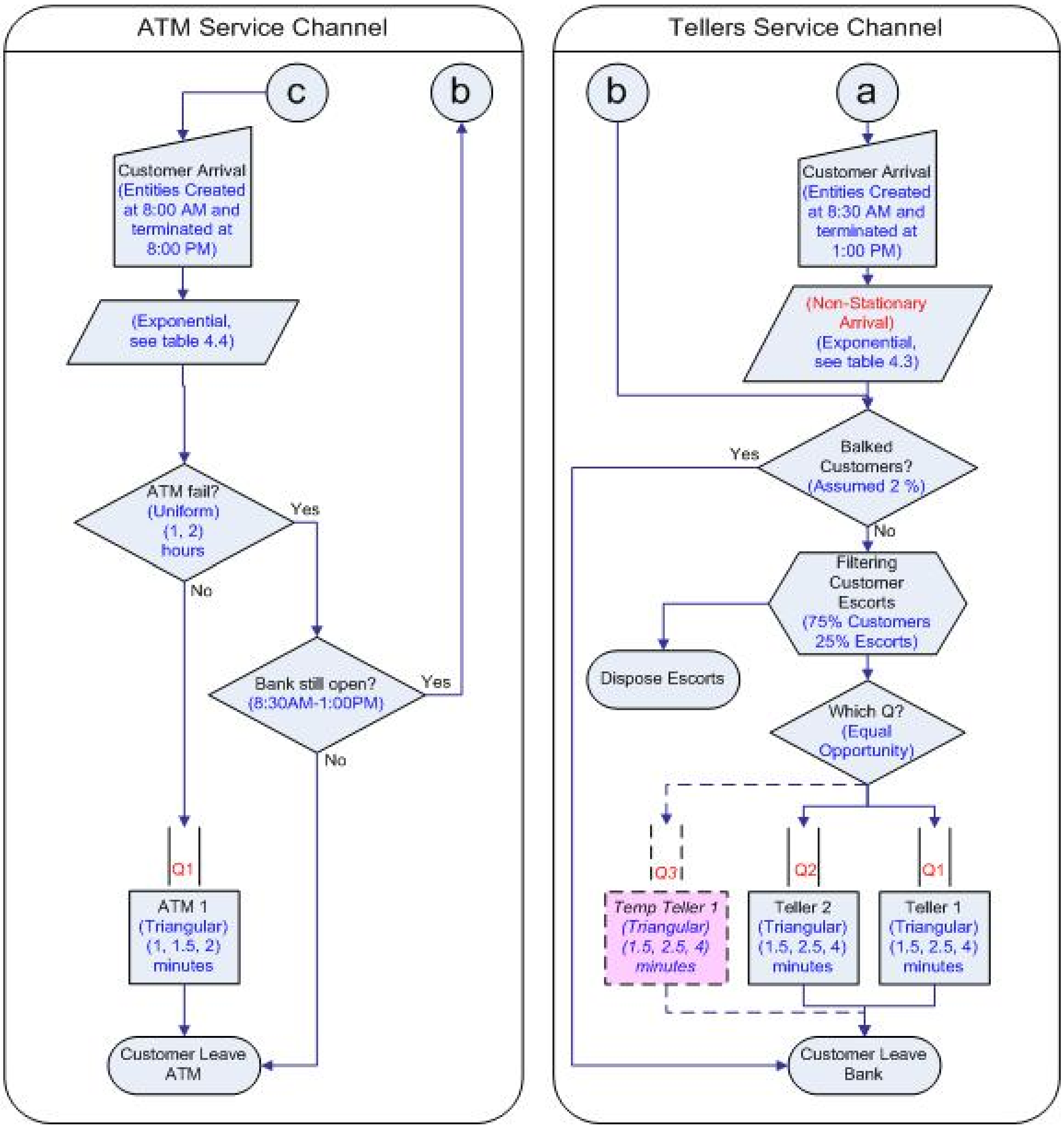


Figure 4.7: Basic conceptual model for normal day configuration

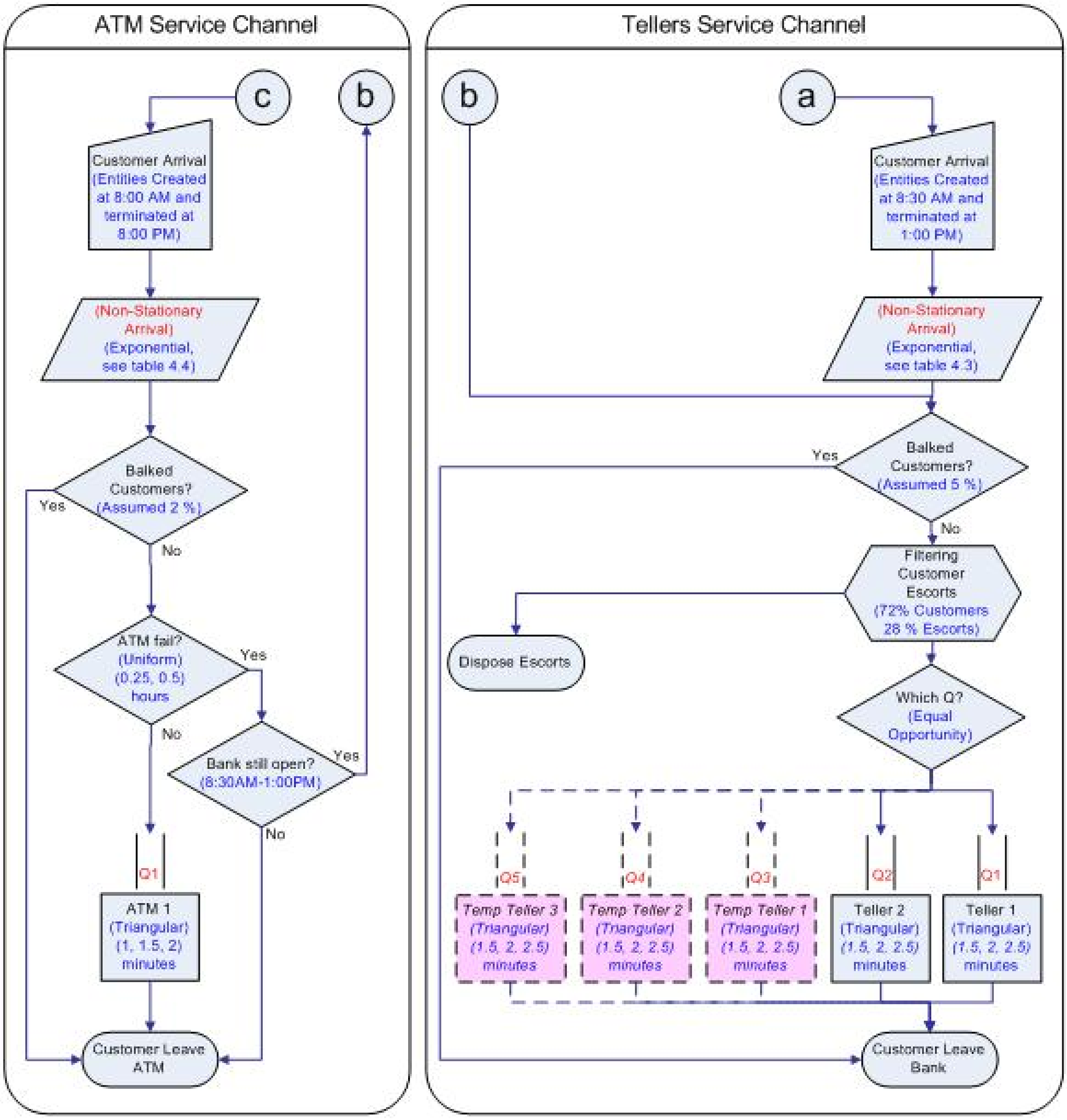


Figure 4.8: Basic conceptual model for rush day configuration

4.5.2.2. Overview of Basic Model

In this section, screen shots of the actual Arena flowchart models will be referred to. The underlying details will be explained more thoroughly in the sections to follow and the analysis of these models will be handled in Chapter Five.

The flowchart of the basic model (as-is model) has three major components: (i) the control logic and monitoring elements sub-models, (ii) the tellers̓ service distribution channel sub-model, and (iii) the ATM service distribution channel sub-model as shown in Figures (4.9) and (4.10). The basic model configurations and alternatives have been developed using Arena software package version 7.01. The key entities in the simulation model being investigated are customers arriving to the bank and wait in the queuing service lines.

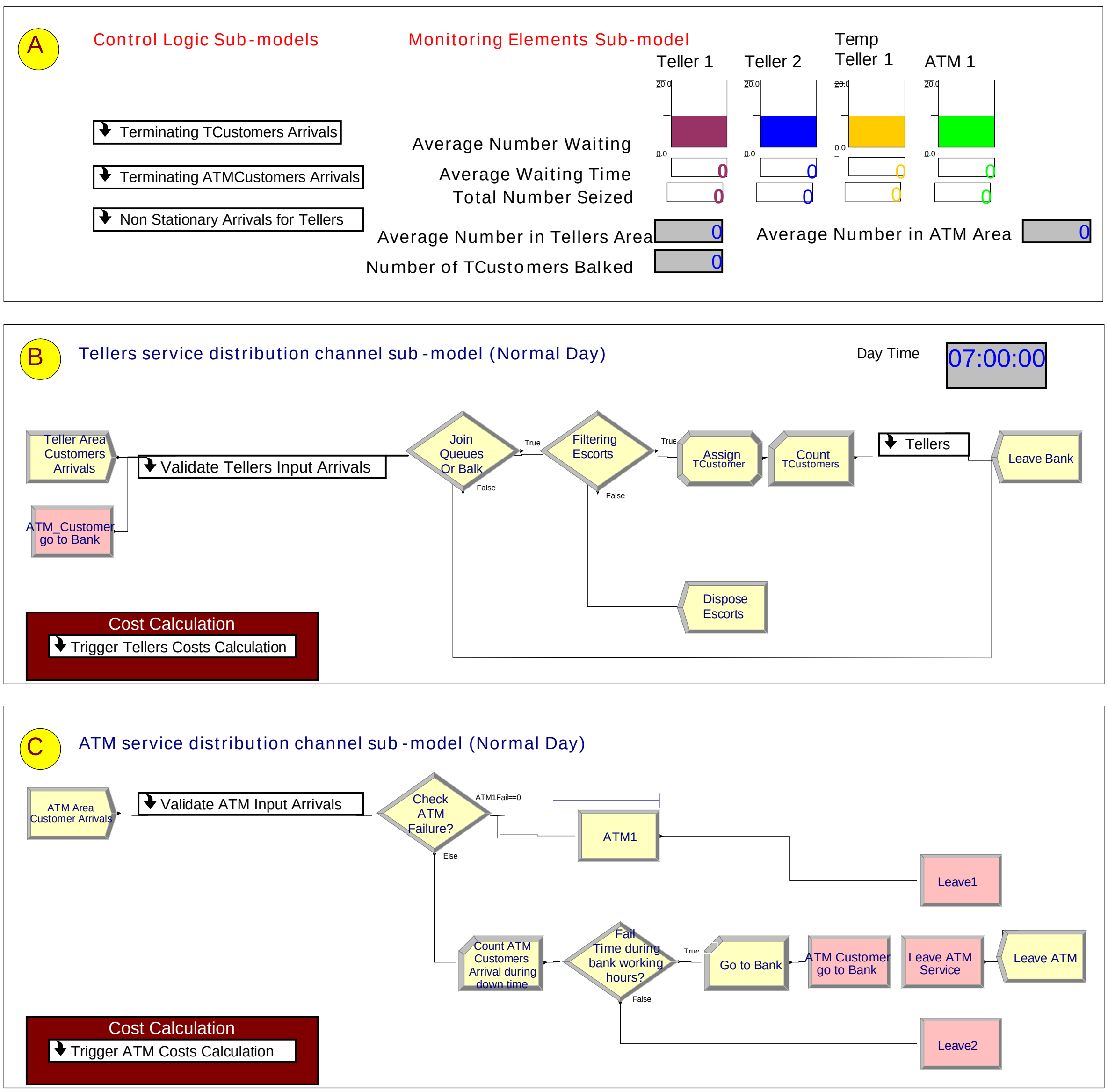


Figure 4.9: Components of a normal day basic model configuration

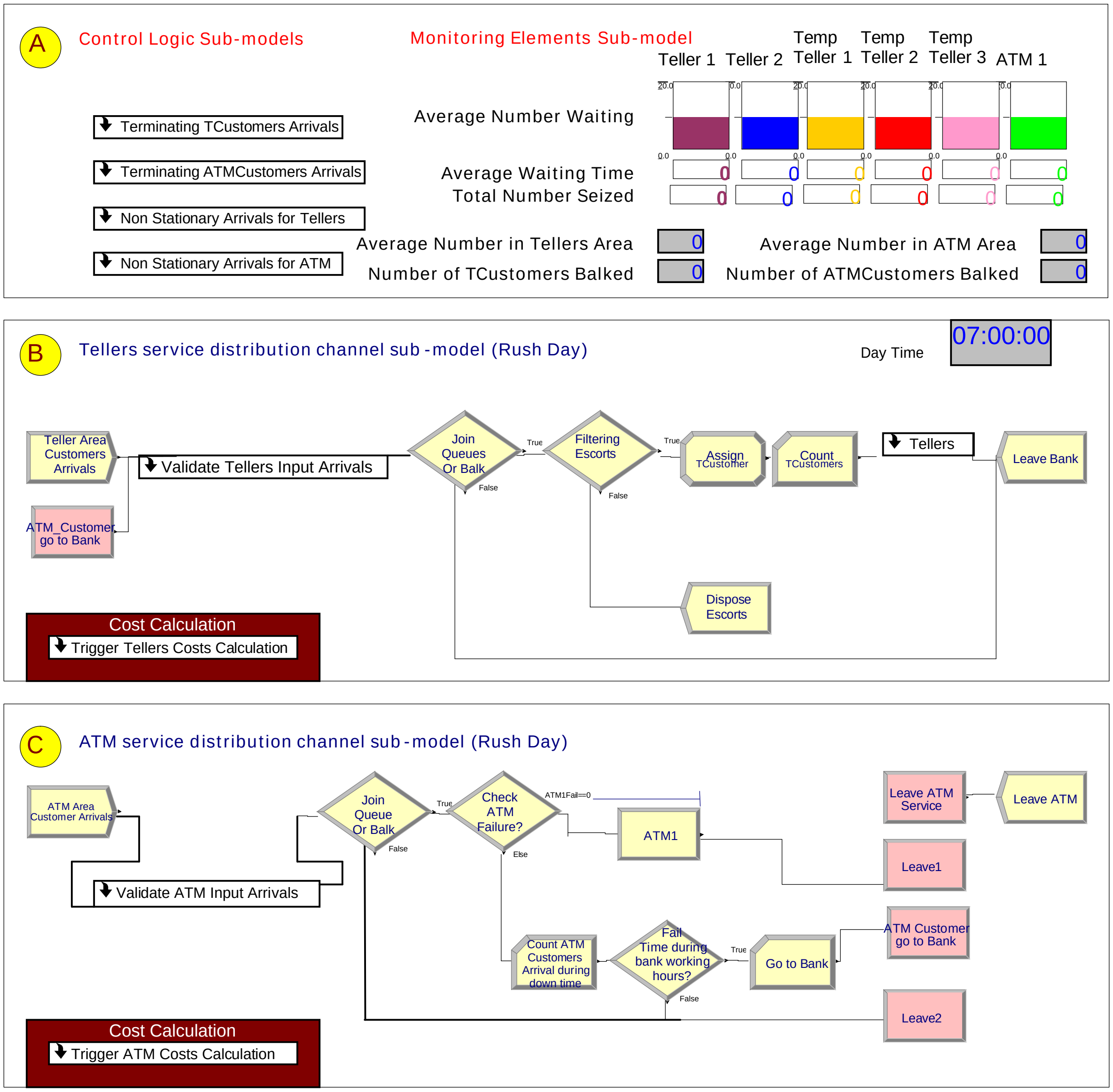


Figure 4.10: Components of a rush day basic model configuration

Customers Creation, Arrival and Termination Process Description

Control logic sub-models component shown in Figures (4.9-A) and (4.10-A) handles the process of creating and terminating customer arrivals during normal and rush days. For example, the **Non Stationary Arrivals for Tellers** sub-model shown in Fig. (4.11) uses a control entity created every **60** minutes – see Fig. (4.12) – to alter the values of the exponential arrival expression for tellers' area as explained in table (4.3):

$$T\_Arrival\_Rate\_constant + \mathbf{EXPO}\ (\ T\_Arrival\_Rate\_mean\ ) \quad \text{..........................} \quad (4.3)$$

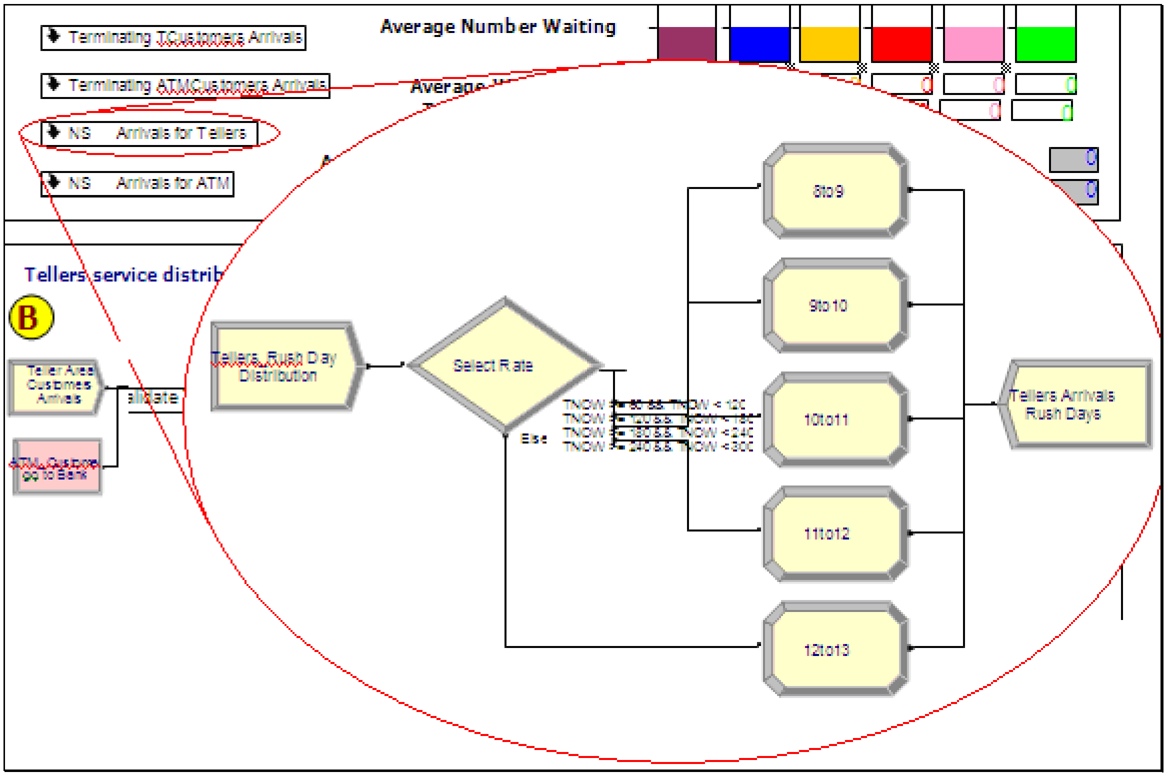


Figure 4.11: "**Non-Stationary arrivals for tellers**" sub-model

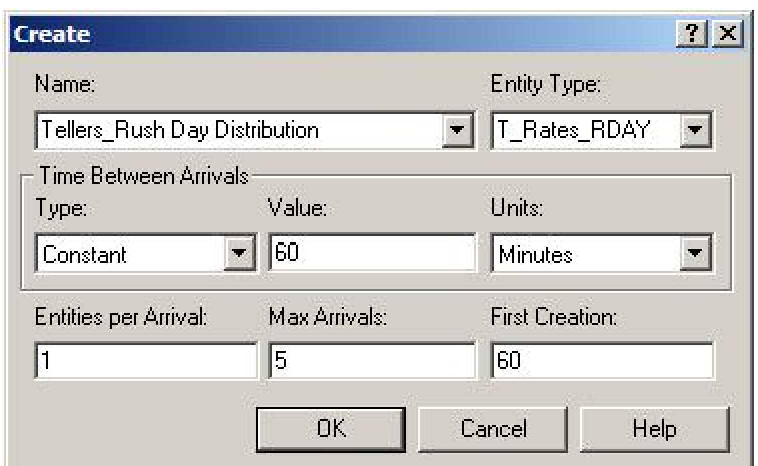


Figure 4.12: Create module for "**Non-Stationary arrivals for tellers**" sub-model

Five control entities will be created representing five working hours of bank daily operating hours. Each control entity will be directed via **Decide** module – Fig. (4.13) – to the appropriate **Assign** module which contains the new values for the expression (4.3) before being disposed as shown in Fig. (4.14). Expression (4.3) represents the value of time between arrivals in the **Create** module for the "**Tellers Service Distribution Channel**" sub-model as shown in Fig. (4.15).

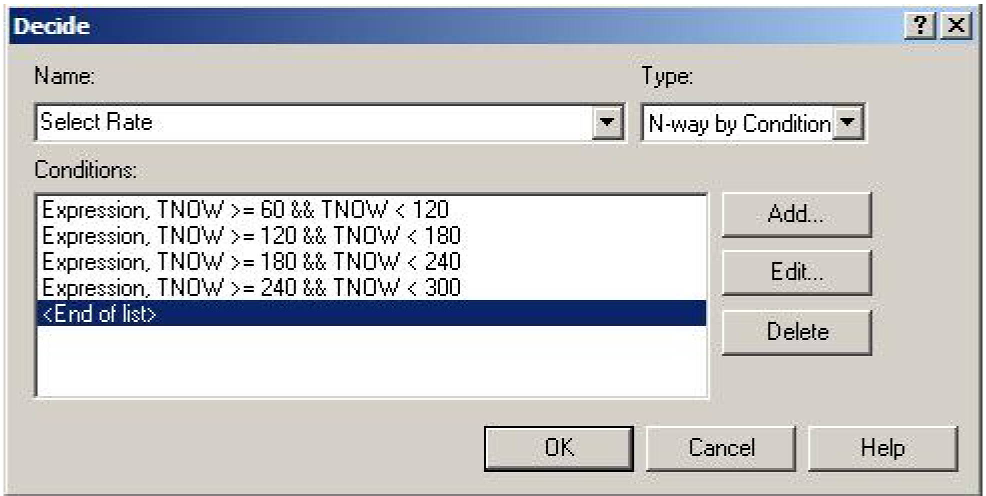


Figure 4.13: Decide module for "**Non-Stationary arrivals for tellers**" sub-model

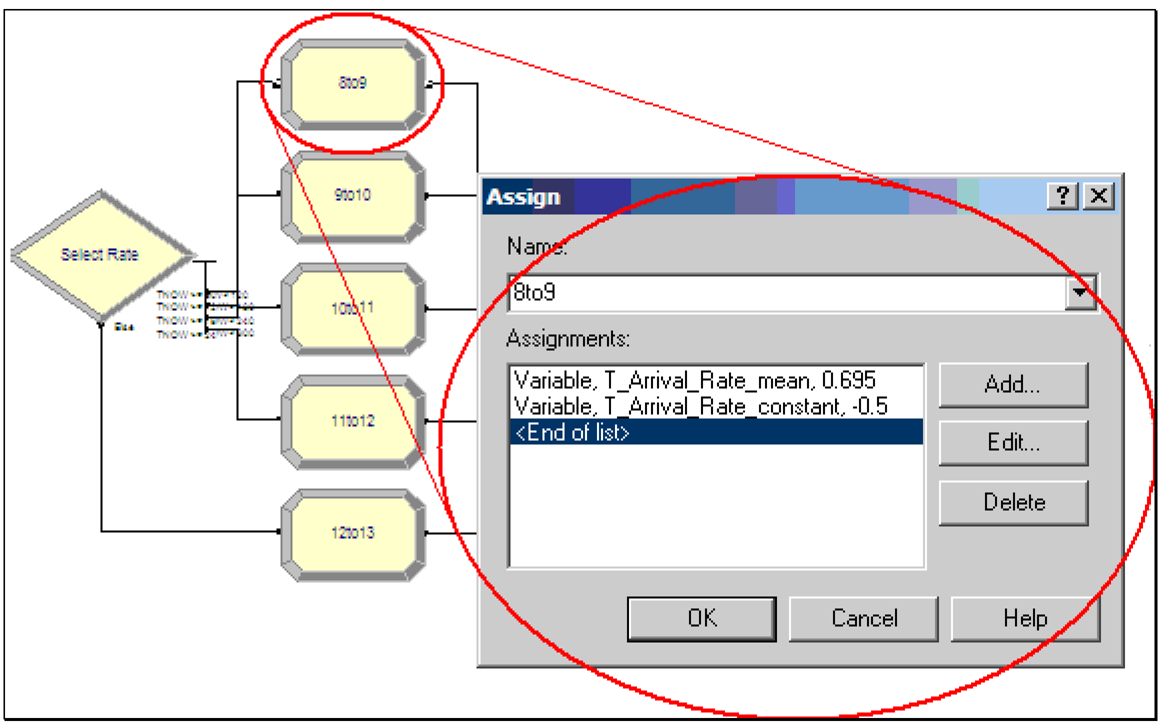


Figure 4.14: Assign module for "**Non-Stationary arrivals for tellers**" sub-model

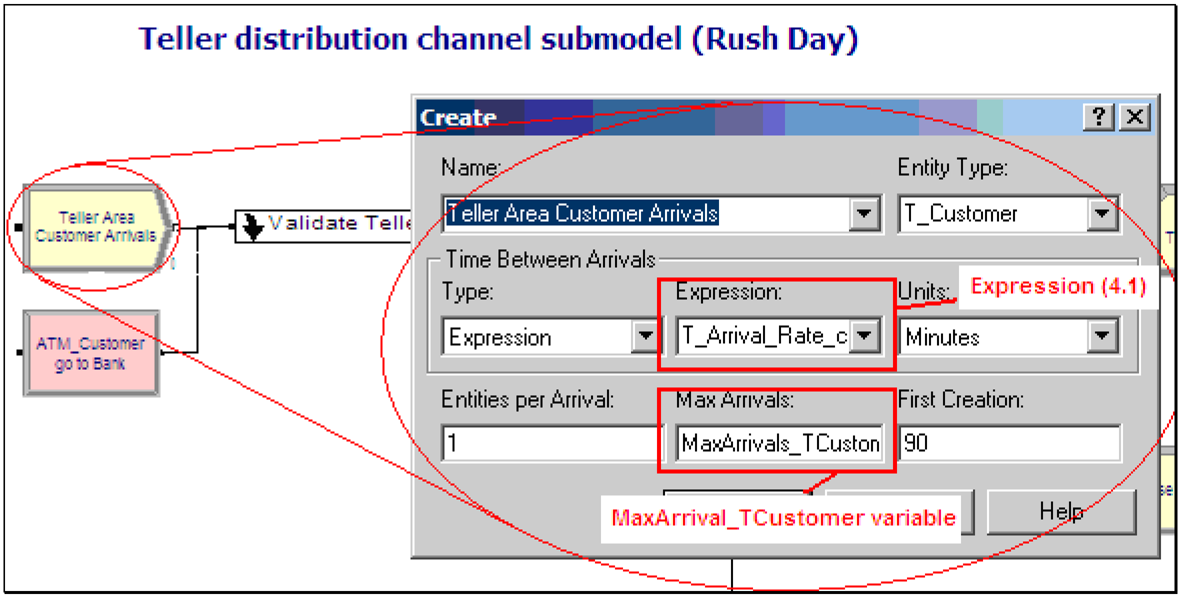


Figure 4.15: **Create** module for "**Tellers distribution channel**" sub-model

The "***Max Arrivals***" value shown in Fig. (4.15) is represented by a control variable associated with "***Terminating TCustomers Arrivals***" sub-model shown in Fig. (4.16). The "***Terminating TCustomers Arrivals***" sub-model main function is to *terminate* customers' arrivals. A control entity will be created when **TNOW = 360 minute** (i.e. **1:00PM**, the bank closing time) and will pass through "***Terminate TCustomers***" **Assign** module which will alter the value of "***MaxArrivals_TCustomer***" variable in the "***Max Arrivals***" field from **99999** to **1** (i.e. terminating customers arrivals). After bank closing time (i.e.**1:00PM**), the model will simulate the process of working until all customers in the bank were being served.

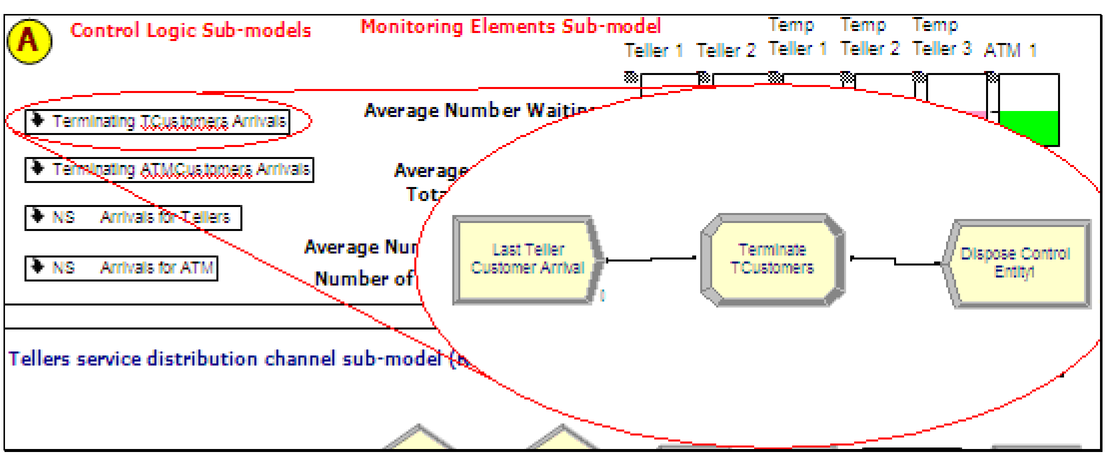


Figure 4.16: "**Terminating TCustomers Arrivals**" sub-model

The "***ATM_Customer go to Bank***" **Station** module is an advanced transfer module that will receive ATM customers once a failure was detected during working hours (**Failure** module will be explained later in this section). The other control logic sub-models for ATM service channel shown in Figures (4.9-A) and (4.10-A) will behave the same way as described previously for tellers service channel with an exception for the closing time of ATM machine will be at **8:00PM**; thus, the number of the control entities which will drive the expression of ATM customer arrivals will be **12** control entity representing **12** hour of operation. Within this context, it worth to indicate that ATM customers arrivals during normal days do not follow non stationary arrivals since number of arrivals was very low; thus, there will be no need for a sub-model as to control entity creation (customer arrival).

Monitoring and Validation Sub-Models Description

Monitoring and validation sub-models were integrated into the basic model as to provide the researcher with sufficient details for the state of resources and entities during the period of model run. Figure (4.17) shows the elements of the monitoring component while Fig. (4.18) shows customers arrivals validation sub-models. The validation model counts number of entities (customers' arrival rate) per hour as to be compared with the actual (observed) average customers' arrival rates during day hours. "***Time per day?***" **Decide** module will check the simulation time "***TNOW***" and routes the entities according to the period of time interval to the appropriate counter (**Record** module) which will count number of customer arrivals during that time interval.

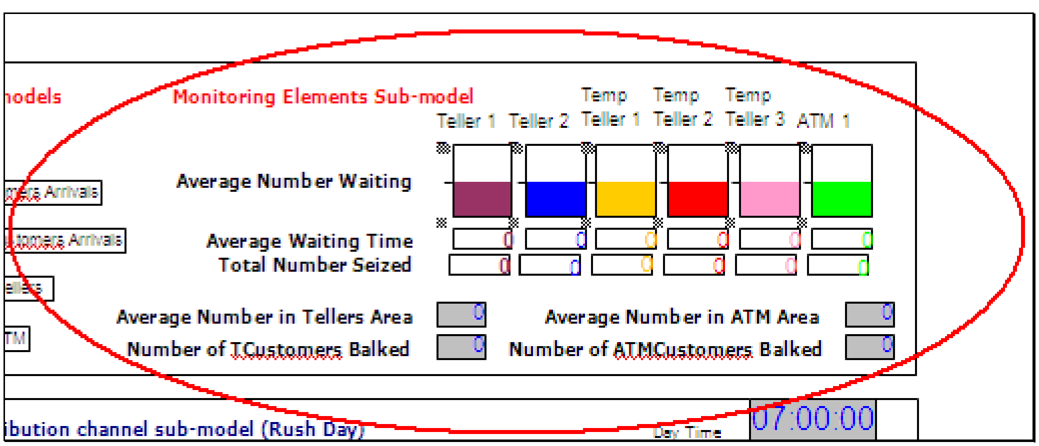


Figure 4.17: "**Monitoring elements**" sub-model

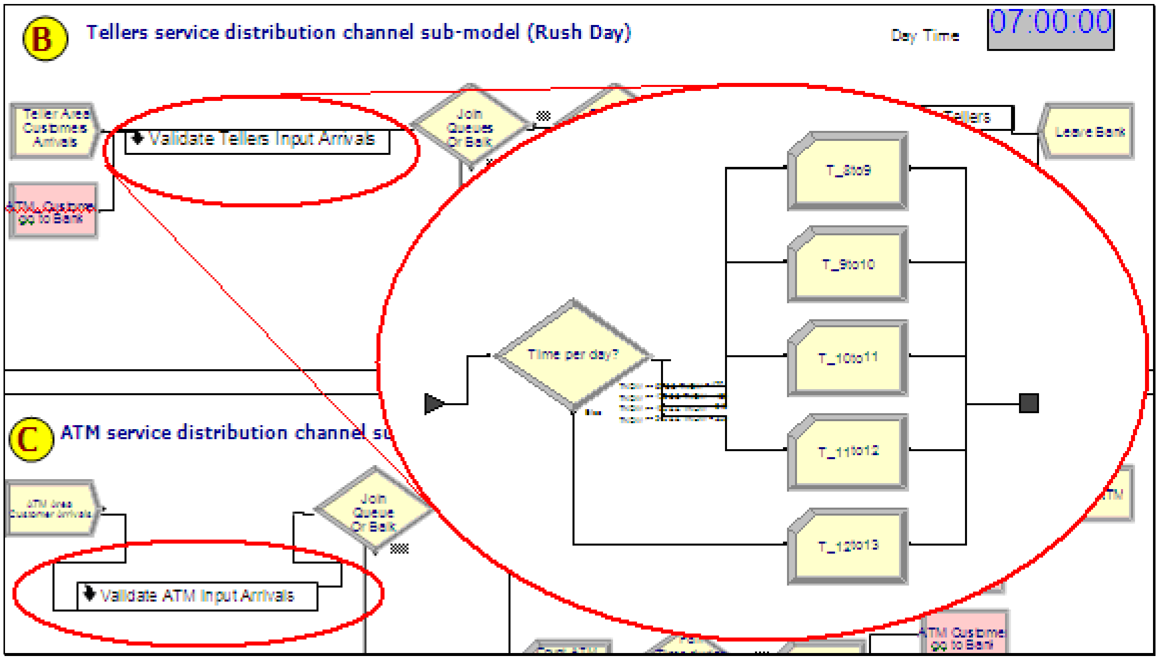


Figure 4.18: Customers arrivals validation sub-models

Teller Service Distribution Channel Sub-Model Description

After the tellers validation sub-model, the entity enters a **Decide** module for determining the number of balked customers as shown in Fig. (4.19). It was assumed that **5%** of the total customers will balk during **rush days** and **2%** during **normal days**.

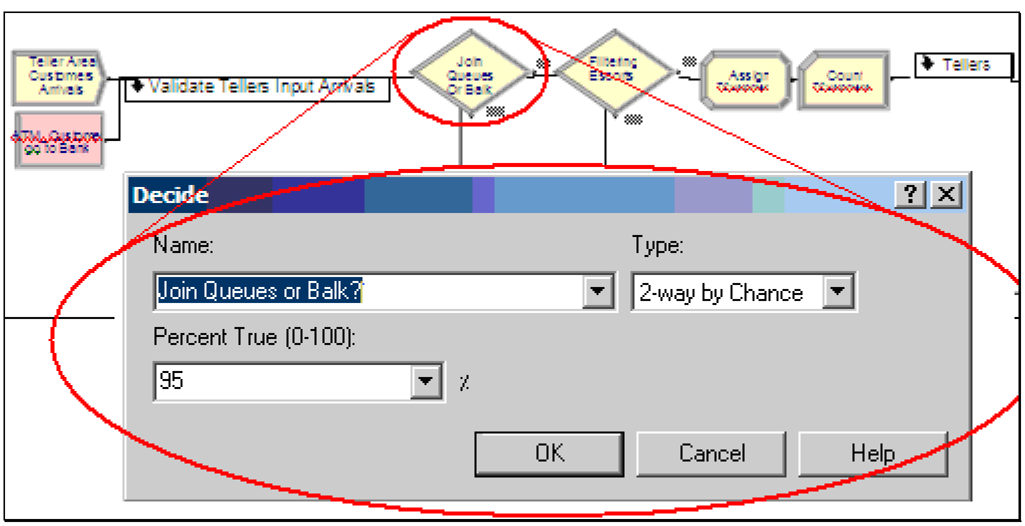


Figure 4.19: Decide module for the number of balked customers

Another **Decide** module was placed next to the first **Decide** block for the purpose of filtering *escorts* who comes with customers. It was found from data collection statistics that **29%** of arrivals during **rush days** was found to be escorts and **25%** for **normal days**.

As the entity leaves the second **Decide** block, it moves on to an **Assign** module where it is assigned a new entity type "***T_Customer***" as shown in Fig. (4.20). This is useful for collecting statistics of the actual entities which were waiting in the queues after excluding escorts. The **Record** module counts "***T_Customer***" entities before entering "***Tellers***" sub-model.

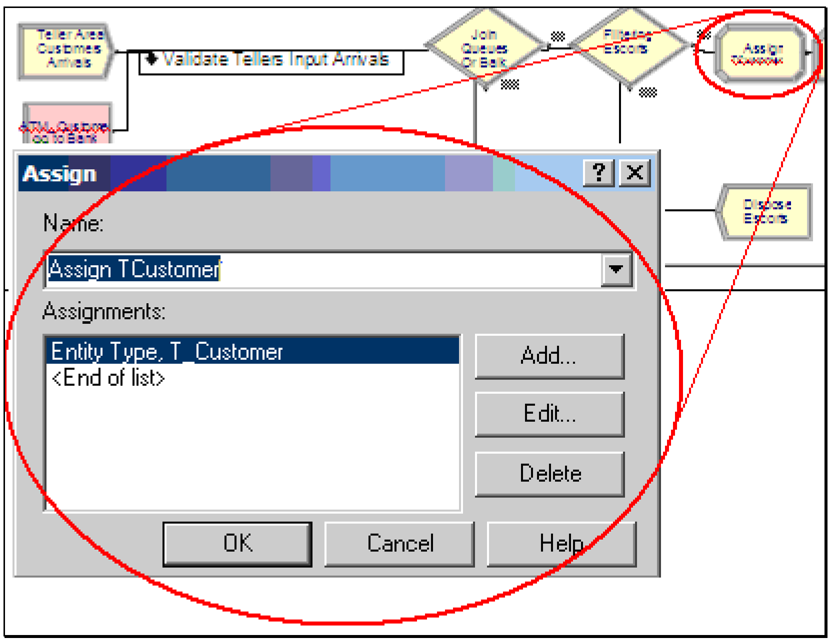


Figure 4.20: Assign module for assigning new entity type "***T_Customer***"

When customers arrive to the "***Tellers***" sub-model, they are immediately routed through a **Decide** module to one of the teller queues as shown in Fig. (4.21) and customers will have an equal opportunity to select which queue line to join as shown in Fig. (4.22). All tellers were assumed to have the same level of skills; thus, service rates similarity was considered. Figure (4.23) shows the **Process** module for a typical teller resource during **Rush Days**.

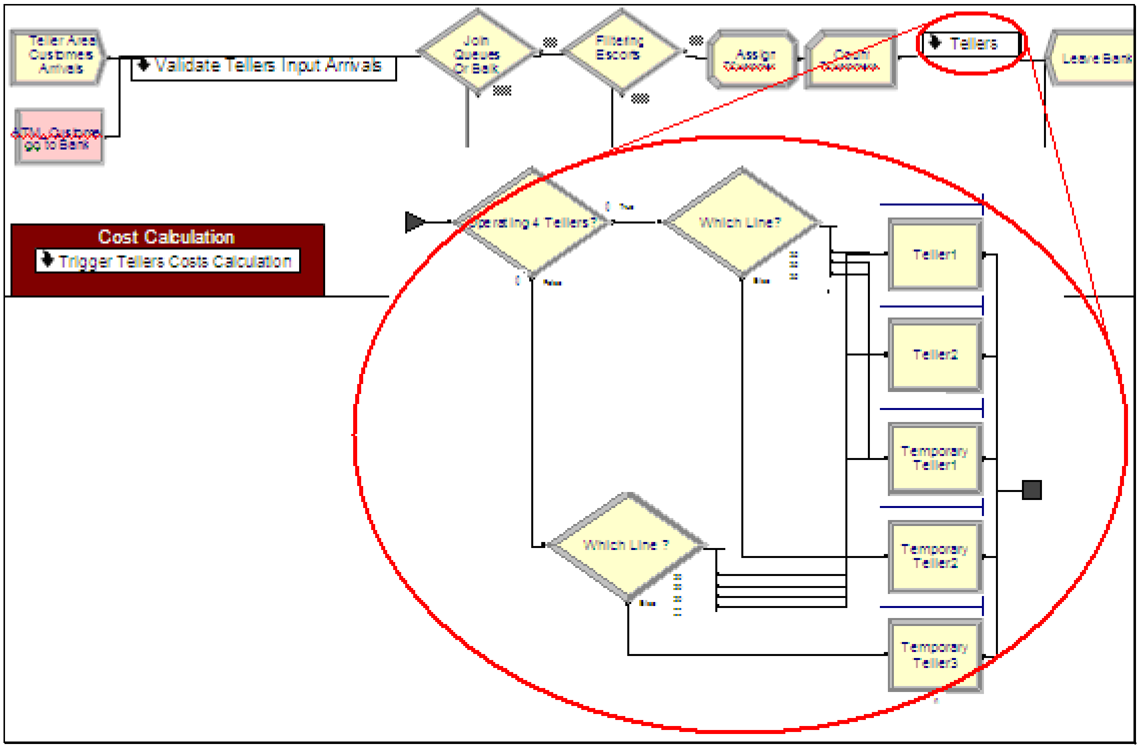


Figure 4.21: "***Tellers***" sub-model

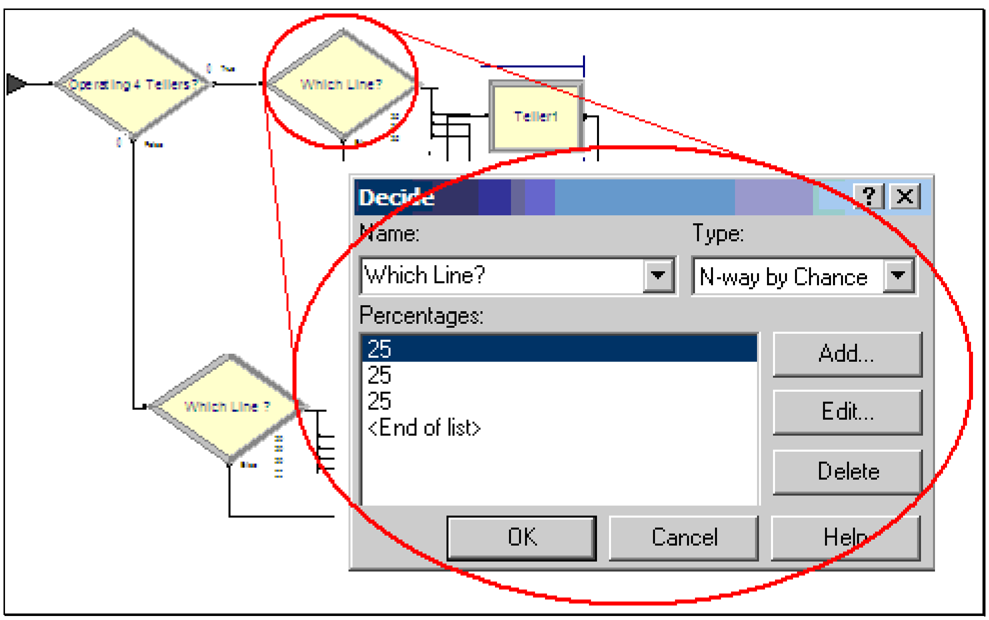


Figure 4.22: "***Which Line?***" **Decide** module for "***Tellers***" sub-model

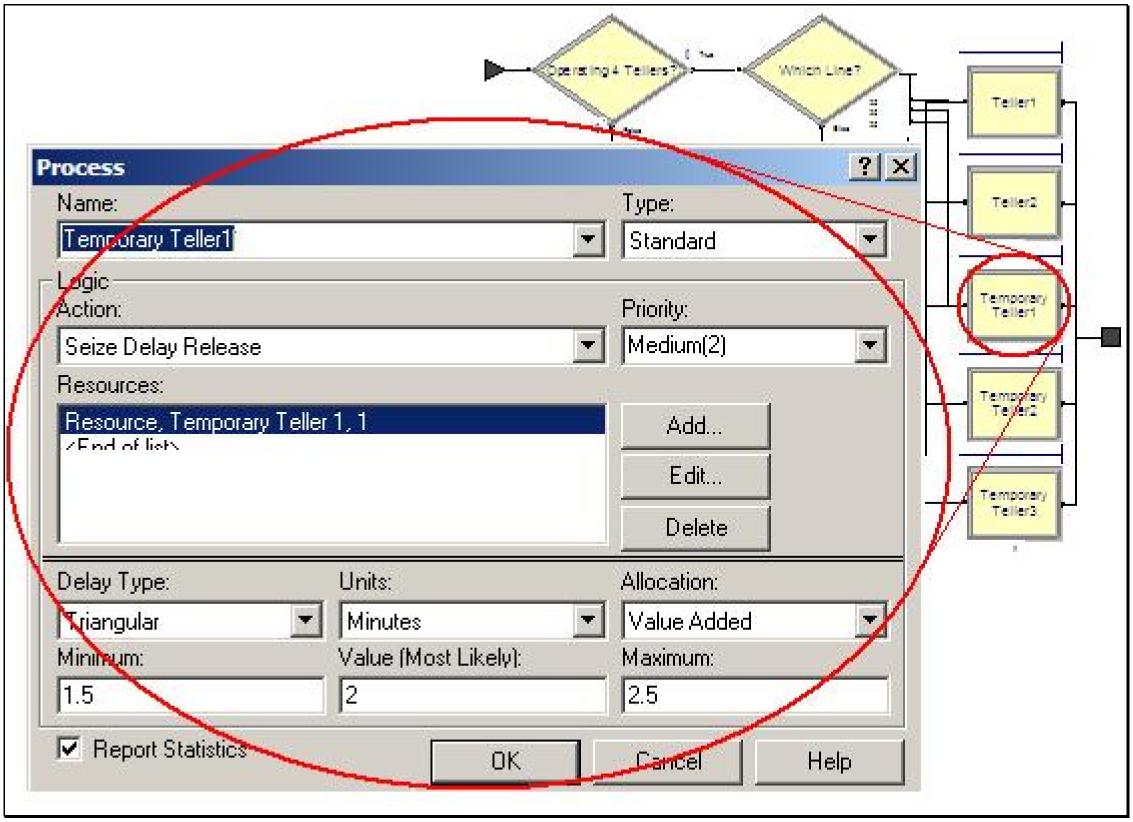


Figure 4.23: Typical **Process** module for "***Tellers***" sub-model

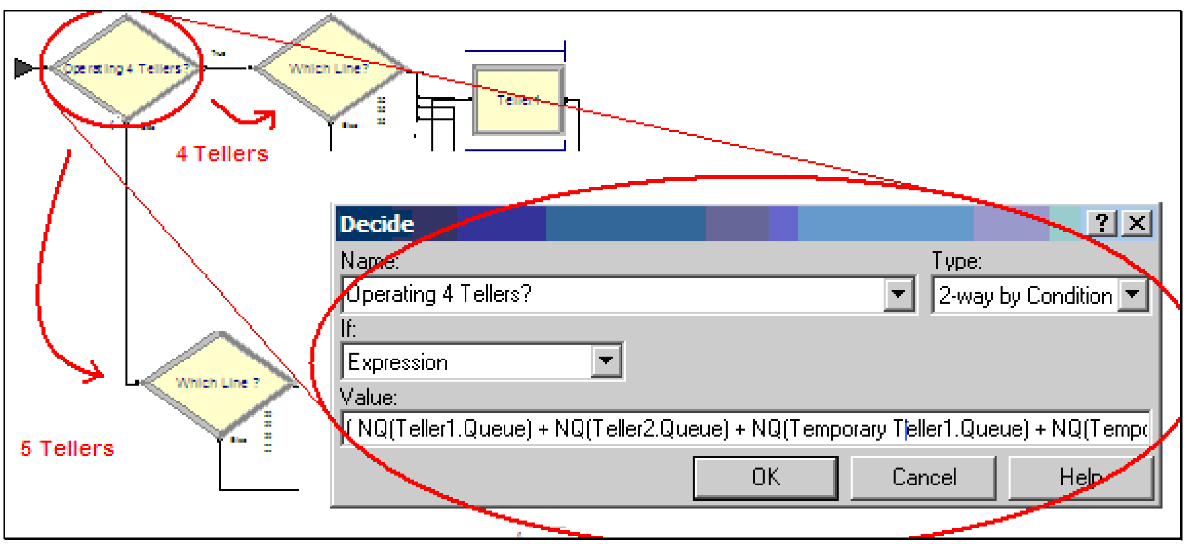


Figure 4.24: "***Tellers***" sub-model in the rush day configuration

Number of operating tellers was changing during day hours. By default, four tellers will be working until the number of waiting customers in the lobby exceeds **50** customers, which is the point at which a fifth teller will start working until customers become below **50**. A **Decide** module was placed to check this condition as shown in Fig. (4.24). For a normal day configuration, two permanent tellers will be working until the number of waiting customers in the lobby exceeds**30** customers.

ATM Service Distribution Channel Sub-Model Description

After the ATM validation sub-model, the entity enters a **Decide** module for determining the number of balked customers. It was assumed that **2%** of the total ATM customers will balk during **Rush Days** and **0%** during **Normal Days**; thus, balk was *not* assumed to occur during **Normal Days**.

ATM machine was expected to fail from time-to-time due to electricity outage which was occurring frequently in Gaza Strip area during data collection period, therefore, a second **Decide** block was placed next to the first block for detecting ATM machine failures as shown in Fig. (4.25). The "***ATM1Fail***" expression will check the status of "***ATM1***" resource via "***STATE***" keyword as shown in Fig. (4.26). Figure (4.27) shows the definition of failure for"***ATM1***" resource **up** and **down** times. The customer will continue to be served unless no failures were detected.

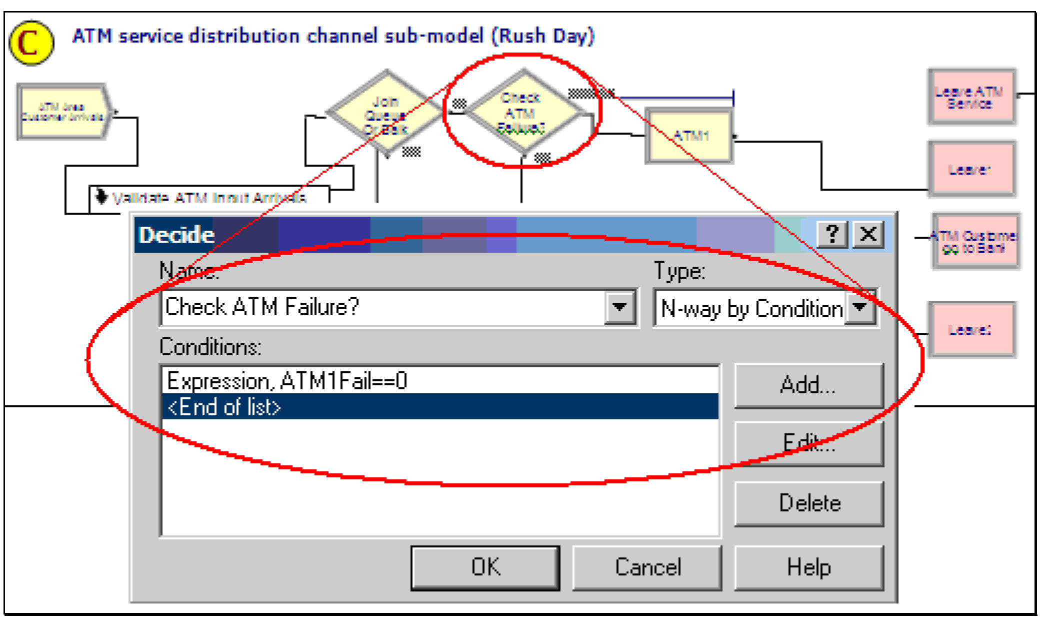


Figure 4.25: Decide module for detecting ATM failures

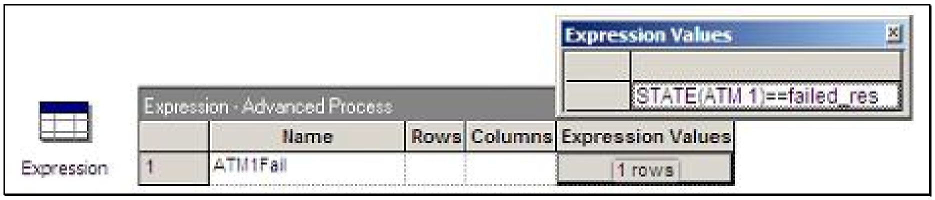


Figure 4.26: Expression module for detecting ATM failures via**STATE** keyword

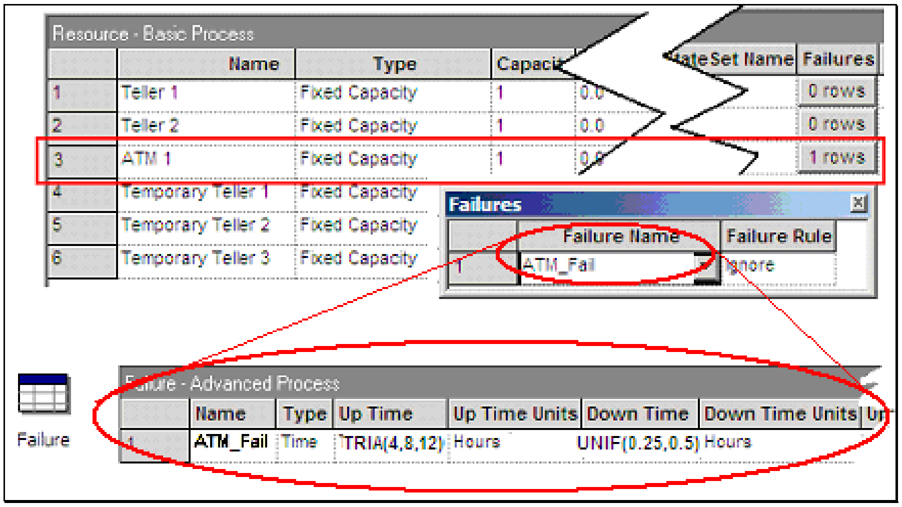


Figure 4.27: Definition of **Failure** module for "**ATM1**" resource **up** and **down** times

The **Ignore** failure rule starts the time duration of the failure immediately, but will allow the busy resource (ATM machine) to finish processing the current customer before failing. If the failure was during the official working hours for the bank (i.e. between **8:30AM** and **1:00PM**) the customer will go to the bank as shown in Figures (4.28) and (4.10-B), otherwise he/she will leave without being served.

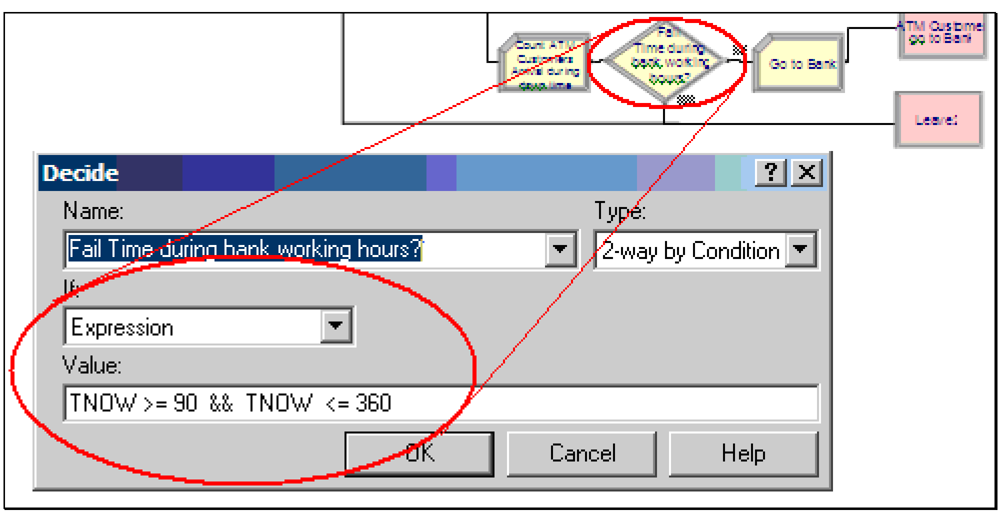


Figure 4.28: Decide module for checking if ATM customers will go to bank or not

Costs Collection Sub-Models Description

The "***Cost Calculation***" sub-models shown in Fig. (4.29) were used for the purpose of collecting costs accurately at a specific time points (like the branch office closing time after serving all customers in the lobby area) which is not applicable to be calculated directly by Arena. When all the customers leave the bank, a*control entity* will be created to trigger the cost calculation process. Different **Record** modules were used to register *total service* and *total waiting time costs* in order to obtain the minimum *aggregate* cost and *optimal* capacity as previously explained in Fig. (3.3). Table (4.5) shows the estimated costs for *resources* (Tellers, Temp. Tellers, ATM, MFS), and *entities* (Customers) per hour. It worth to indicate that Tellers and ATM costs were estimated by PIB financial department; meanwhile customer waiting costs and MFS were estimated by the researcher.

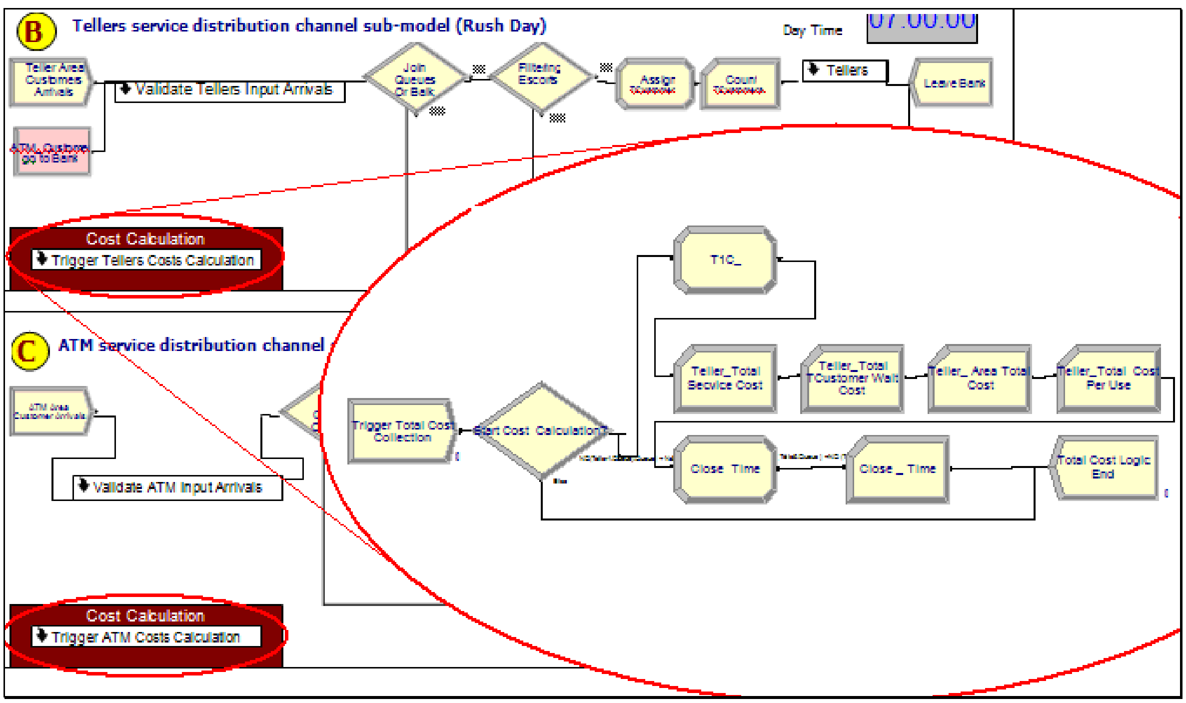


Figure 4.29: "***Cost Calculation***" sub-models

Customer waiting cost is the cost associated with making a customer wait in line. This cost is estimated using the average customer's monthly income obtained from previous study for (Al-Hendi, 2007) through a questionnaire completed by **609** respondents. Average customer monthly income was found to be **$550**. After some simple calculations, the waiting cost is estimated to be **$2.86** per hour.

MFS costs are estimated based on a discussion with technology professionals for the required equipments and initial costs in order to operate SMS and WAP applications. The estimated cost for operating MFS gateway is found to be **$0.09** per hour; meanwhile cost per transaction is estimated to be **$0.36**.

Table 4.5: Estimated costs for resources and entities

Item	Type	Cost ($/Hour)	Cost ($/Transaction)
Permanent Teller	Resource	8.37	1.16
Temporary Teller	Resource	8.37 (1)	1.16
ATM Machine	Resource	1.05	5.2 (2)
MFS Gateway (3)	Resource	0.09	0.36
Customer	Entity	2.86	(Not Applicable)

(1) The estimated cost is considered to be the same as permanent teller.

(2) The rate for cost per use reflects low number of customers was using this service during the past year as a result of Israeli siege to Gaza Strip area as it was not allowed to enter the material required to make ATM cards.

(3) The estimated cost includes fixed costs. It was calculated based on the assumption that 40,000 SMS message will be used monthly as agreed upon with technology professionals.

4.5.3. Model Verification and Validation

A significant element of any simulation study is the Verification and Validation of the simulation model. Without reliable verification and validation techniques there are no grounds on which to place confidence in any simulation study results.

Verification is concerned with building the model right. It is utilized in the comparison of the conceptual model to the computer representation that implements that conception (Jenkins et al., 1998) as clarified in Fig. (4.30), it asks the questions: Is the model implemented correctly in the computer.

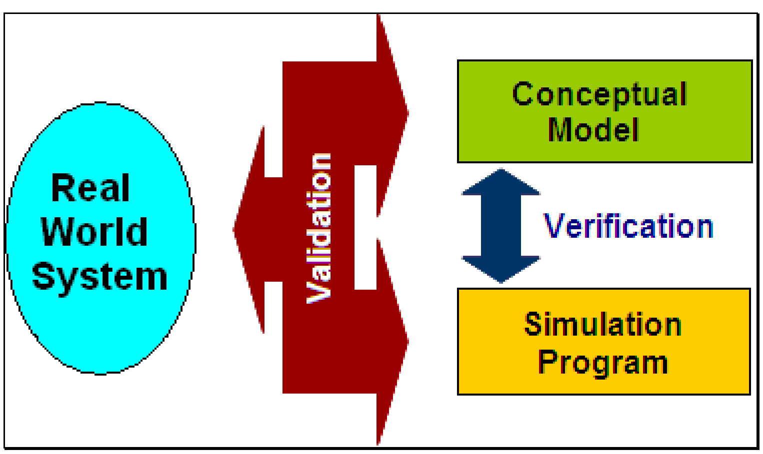


Figure 4.30: Model verification and validation relations

Validation, on the other hand is concerned with building the right model. It is utilized to determine if the computer model is an accurate representation of the real system for the purpose at hand (Jenkins et al., 1998).

Verification and validation are processes that collect evidence of a model's correctness or accuracy for a specific scenario; thus, verification and validation cannot prove that a model is correct and accurate for all possible conditions and applications, but, rather, it can provide evidence that a model is sufficiently accurate. Therefore, the verification and validation process is completed when sufficiency is reached (Thacker et al., 2004).

4.5.3.1. Model Verification

Two techniques were used to achieve acceptable levels of verification for this study. As previously detailed, flowcharts were prepared for the system prior to the model building phase. After the model has been developed, the researcher has subjected the model to special input testing. Verification has been conducted by close observation of the animated interface during extended runs of the model. Conflicts or inconsistencies in the behavior of the icons have led to examination of the code and re-correction of incorrect code.

At a number of times during the model building phases the model was shown to three Arena simulation analysts who were having a few opinions regarding the use of animation as a part of the project and conceptual model assumptions. These opinions were noted, and discussed with some other researchers in order to have a better understanding for the whole picture. In general the discussions did not lead to significant levels of feedback that require major change for the basic model design or assumptions.

4.5.3.2. Model Validation

Two broad techniques were used to validate the model. The *first* of these, and the most extensively used, was the animation. The model's operational behavior is displayed graphically as the model moves through time.

The basic model was running for **100** replications (see the next section) for each day type (i.e. **Normal** and **Rush Days**). The researcher observed carefully the behavior of queues in front of the various tellers and ATM service channels, in addition to customers waiting time to assist in the validation process. The model generally satisfied the expectations. The average number of people in the queues was seen to be sensible and close to the real system being analyzed. Figures (4.31) and (4.32) show the simulation model output for the average, minimum average and maximum average of customers waiting to be served in the queues during **Normal** and **Rush Days** compared to the actual arrivals.

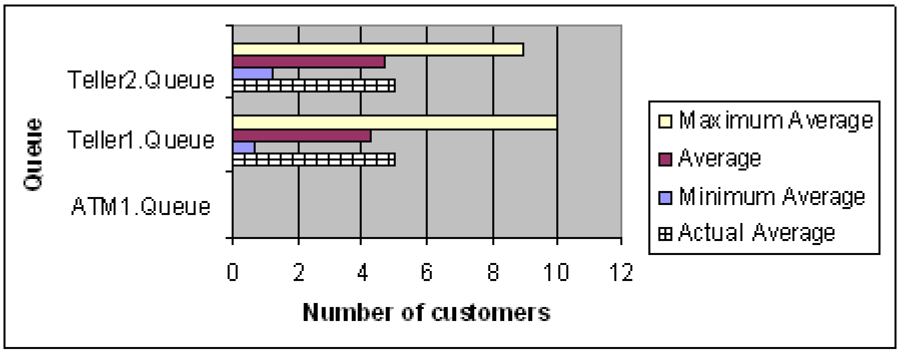


Figure 4.31: Simulated average number of customers waiting to be served in the queues during **Normal Days** compared to the actual average arrivals

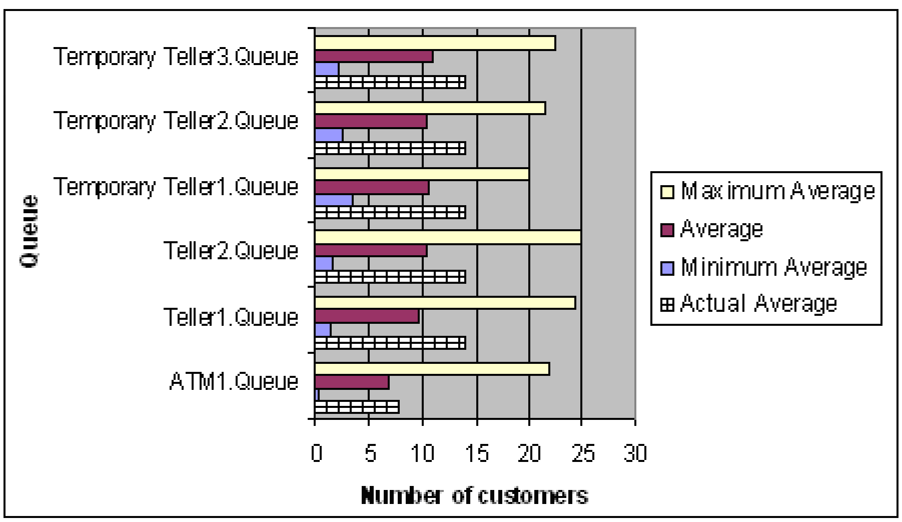


Figure 4.32: Simulated average number of customers waiting to be served in the queues during **Rush Days** compared to the actual average arrivals

To facilitate this stage of validation, substantial reporting of quantitative monitoring elements was appended to the animation interface as previously shown in Fig. (4.17). This provided the researcher with sufficient details for the state of resources and entities during the period of model run. The average actual waiting time for teller service channel customers was observed to be around **15 minutes** and **50 minutes** during normal and rush days respectively. These observations are close to the average waiting time response for the simulation model. The simulated response was found to be **17 minutes** and **43 minutes** during normal and rush days respectively.

The *second* validation technique was a graphical comparison of the actual and simulated *input* arrivals. A sub-model was designed for the purpose of counting the number of customer arrivals during each hour of operation for the tellers and ATM service channels run time periods as previously shown in Fig. (4.18). A simple comparison with the actual (observed) number of customer arrivals during day hours was used to establish validity levels for input arrivals of the model. Both the actual data and the simulated data were plotted, per service channel during **Normal** and **Rush Days** as shown in Figures (4.33), (4.34), (4.35), and (4.36). The simulation input data seems to be a close fit to the actual collected data. The close fit between statistical input data collected from the field and simulation model at this stage has provided the researcher with sufficient confidence to proceed for further development of the model.

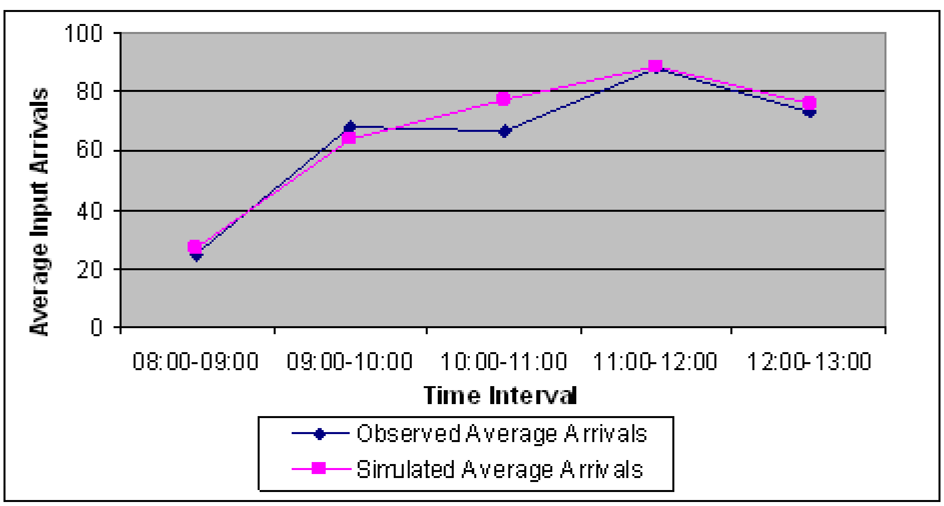


Figure 4.33: Comparison between simulated and observed average input arrivals for tellers' service distribution channel during normal day hours

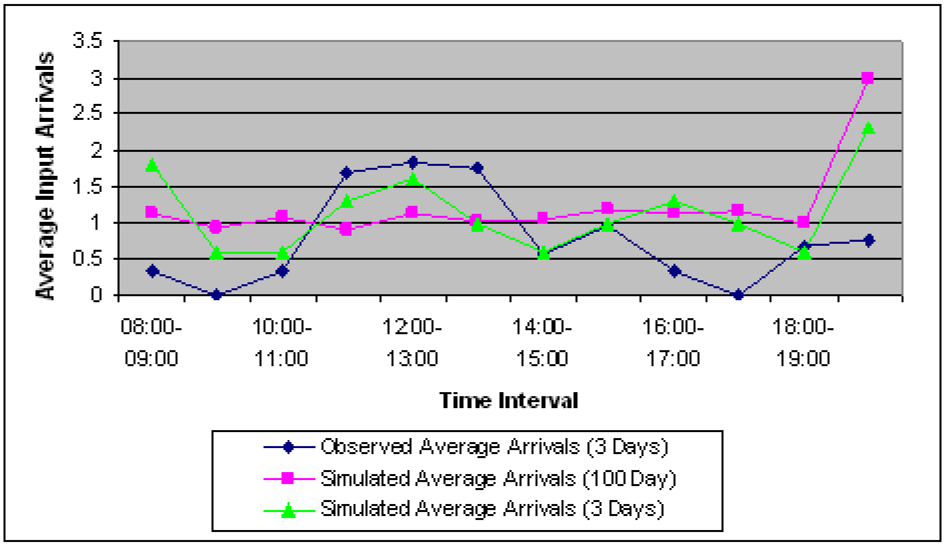


Figure 4.34: Comparison between simulated and observed average input arrivals for ATM service distribution channel during normal day hours

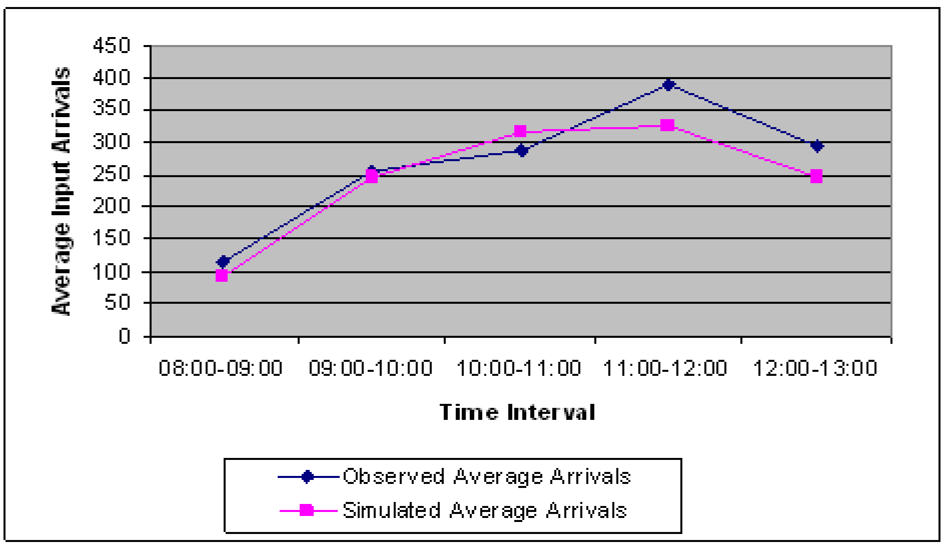


Figure 4.35: Comparison between simulated and observed average input arrivals for tellers' service distribution channel during rush day hours

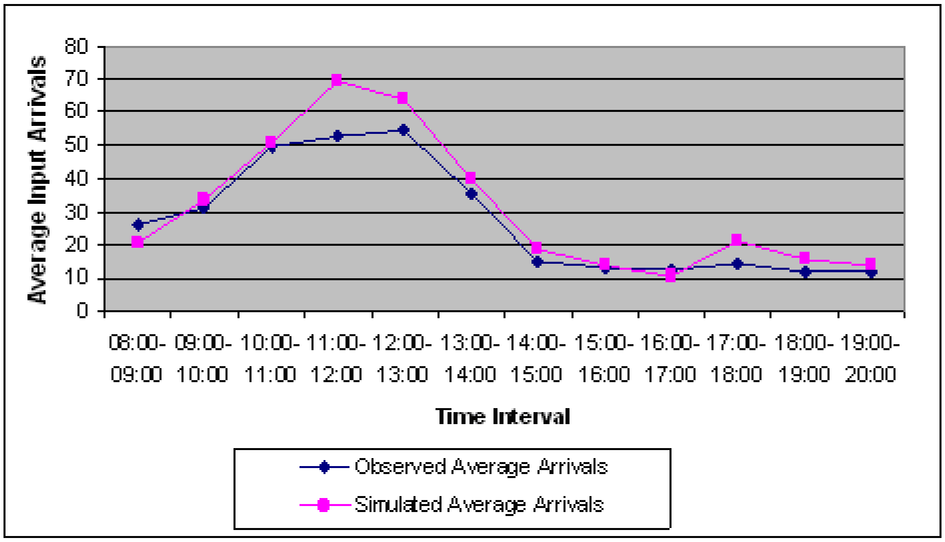


Figure 4.36: Comparison between simulated and observed average input arrivals for ATM service distribution channel during rush day hours

4.6. SIMULATION RUN AND OPTIMIZATION PHASE

4.6.1. Experimental Design

An essential step when designing any simulation model is to simulate the process over a specified period of time. It is important to tell Arena how long to run the simulation model and how many replications we need.

Most simulations can be classified as either *terminating* or *steady-state (long run)* (Kelton et al., 2004). A terminating simulation – in contrary to steady-state – for a single run will terminate according to some model specified rule or condition, which is the same as the case being analyzed in this study. The bank opens at **8:30AM** with no customers present meanwhile ATM machine starts operating at **8:00AM**. The bank closes its doors at **1:00PM**, and then continues its operation until all customers are flushed out. The ATM machine continues its operation until **8:00 PM** as it was not possible to collect data after this time limit; therefore the single simulation run was selected to start from **7:00AM** to **9:00PM** (**840** minutes) with a one hour time margin at the beginning and at the end of each work day for the purpose of monitoring and validating customers' behavior during the simulation run.

With a terminating simulation, confidence intervals can be used to improve the level of accuracy for output statistics, thus providing more confidence with the results. The "***Half Width***" statistic is included in **Arena Reports** as to help determining the reliability of the results from the replications. The way to reduce the half width of the confidence interval is to increase the sample size (number of replications "***n***") (Kelton et al., 2004). Figure (4.37) shows the effect of increasing the number of replications on "***T_Customer***" entity waiting time statistic accuracy. The half width for (n=10) is large with comparison to (n=100).

It is important to note that entries in the half width will be accurate as long as we do not make more than **100** replications due to a limitation in the **Crystal Reports** software used with Arena (Kelton et al., 2004), therefore **100** replications value was set in the "***Replication Parameters***" window as it is desirable to have accurate results.

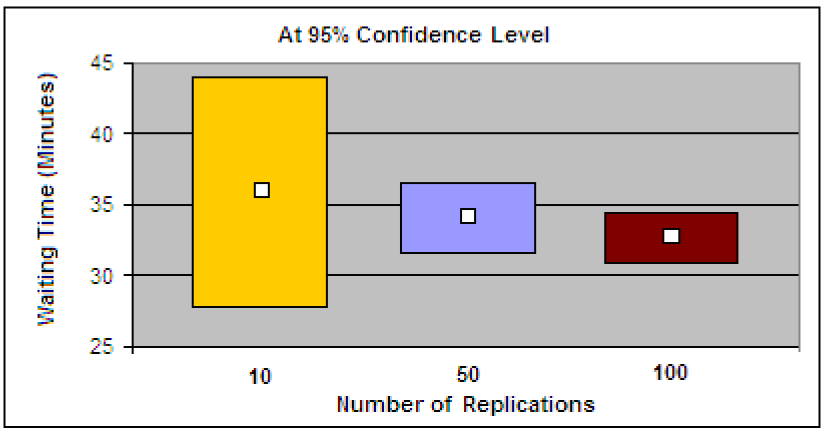


Figure 4.37: The effect of increasing number of replications on "***T_Customer***" entity waiting time accuracy (The "***Half Width***" statistic)

4.6.2. Building Regression Models and RSM Plots

Alternatives are potential opportunities for the case being analyzed. In this case study, two steps to the problem of evaluating servicing opportunities via cell phones were followed. The first step handled the use of *Response Surface Methodology (RSM)* and *Meta-Modes* that approximates the relationships between different combinations of possible opportunities and its responses with statistical models (typically regression models). The second step investigated the impact of early adopters of MFS on the current banking distribution channels for PIB as a possible way to improve the overall quality of services and reduce the need for additional space for queues.

4.6.2.1. The Use of Response Surface Method and Meta-Model

The use of Response Surface Methodology and Meta-Model procedure was involving the following steps: (1) Using 2^k *Factorial* designs for screening, (2) Using *Central Composite Design (CCD)* for building second order regression models, and (3) Optimizing model parameters during early adopters' stage.

The 2^k Factorial experiment design was developed with the physical experiments in mind (like industrial applications) and can easily be used in computer simulation experiments as well (Kelton et al., 2003). It is useful for shedding some light on which input parameters (factors) are most important and how they affect the responses of the experiment. The 2^k Factorial experiment design technique is based on identifying two values, or *levels*, of each of model input factors. There is no general prescription on how to set these levels, but it is important to set them to be "opposite" in nature but not so extreme that they are unrealistic (Kelton and Barton, 2003).

If we have k input factors, then will have 2^k different combinations of the input factors, each defining a different opportunity of the model. Referring to the two levels of each factor as the "–1" and "+1" level, this can form what is called a *design matrix* describing exactly what each of the 2^k different model opportunities are in terms of their input factor levels. Each row represents a particular combination of factor levels, and is called a *design point*.

For this study, set of opportunities were developed for modifying *Permanent* and *Temporary* Tellers (PT & TT) (factors A and B respectively) staffing levels under two distinct levels of MFS usage (factor C) as to examine the impact of different combinations on the responses of the model (like average total cost, average waiting time … etc.), thus we have three input controls (k = 3 factors), and $2^3 = 8$ runs representing *cubic points* for the *full factorial* experiment as shown in Fig. (4.38).

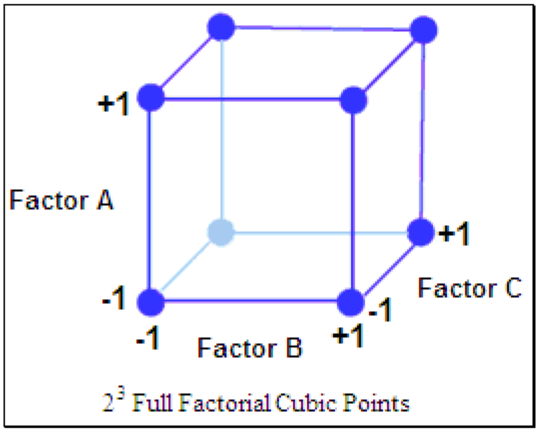


Figure 4.38: Cubic points of 2^3 full factorial design
Source: Modified from (Sanchez, 2007)

Permanent and Temporary Tellers staffing levels were considered to be *controlled* input parameters (factors) for the simulation experiment as we can control the values of these factors meanwhile MFS usage factor was found to be *uncontrolled* as we do not have clear image on the percentage of usage at any specific point of time.

Central Composite Design (CCD) is a two level (2^k) factorial design, augmented by n_0 *Center Points*, and two *Star (Axial) Points* positioned at ($\pm\alpha$) for each factor as shown in Figure (4.39) for a three factors experiment design. Setting ($\alpha = 1$) locates the star points on the centers of the *faces* of the cube, giving a Face centered Central Composite (CCF) design.

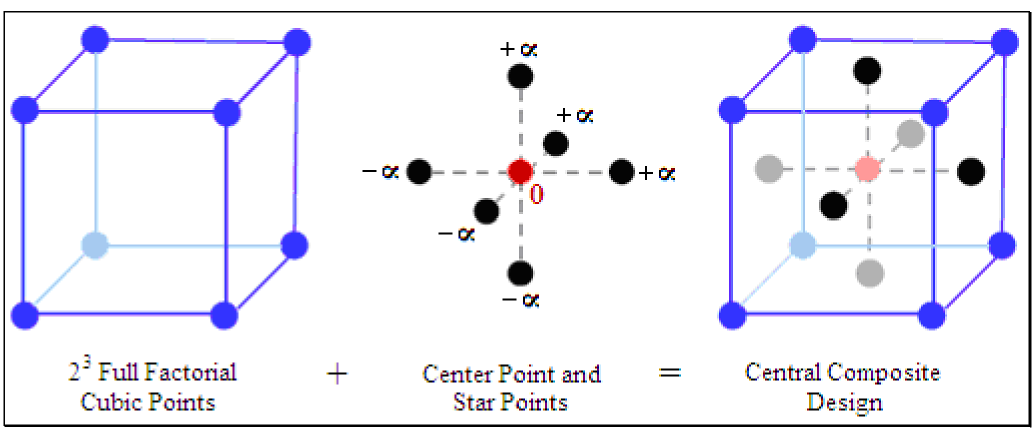


Figure 4.39: Construction of Central Composite Design (CCD)
Source: Modified from (Sanchez, 2007)

CCD is useful in RSM for building a*second order* (quadratic) regression model for the response variable without needing to use a complete *three* level (3^k) factorial experiment for evaluating main and quadratic effects and interactions.

Tables (4.6) and (4.7) shows the design matrix after using CCD for both normal and rush days configurations. Arena Process Analyzer was used to run the simulation experiment for these design points and record the responses for: (1) Tellers channel cost and wait time, (2) ATM channel cost and wait time, and (3) Possible revenue and net profit that might be generated as a result for using MFS.

Table 4.6: Design matrix for normal day configuration

Design Point	Design Point Type	Factor 1: Number of Permanent Tellers		Factor 2: Number of Temporary Tellers		Factor 3: Percent of Usage for MFS	
		Coded	Natural	Coded	Natural	Coded	Natural
1	Factorial	-1	1	-1	0	-1	20
2	Factorial	+1	3	-1	0	-1	20
3	Factorial	-1	1	+1	2	-1	20
4	Factorial	+1	3	+1	2	-1	20
5	Factorial	-1	1	-1	0	+1	60
6	Factorial	+1	3	-1	0	+1	60
7	Factorial	-1	1	+1	2	+1	60
8	Factorial	+1	3	+1	2	+1	60
9	Center	0	2	0	1	0	40
10	Axial	$-\alpha$ (*)	1	0	1	0	40
11	Axial	$+\alpha$ (*)	3	0	1	0	40
12	Axial	0	2	$-\alpha$ (*)	0	0	40
13	Axial	0	2	$+\alpha$ (*)	2	0	40
14	Axial	0	2	0	1	$-\alpha$ (*)	20
15	Axial	0	2	0	1	$+\alpha$ (*)	60
(*) $\alpha = 1$							

The outputs of Arena Process Analyzer were then processed by Design Experts (DX) software (Statease, n.d.) (See Appendix-F for much details) in order to perform statistical analysis based on CCD experiment design as to construct response surface plots in addition to regression models for the responses that might be used later by decision makers to predict the outputs of simulation experiment. The use of meta-models can help to find the combination of input factor values that *optimizes* (i.e., minimizes or maximizes, as appropriate under some constraints) responses which is the task that will be handled in the next step.

Table 4.7: Design matrix for rush day configuration

Design Point	Design Point Type	Factor 1: Number of Permanent Tellers		Factor 2: Number of Temporary Tellers		Factor 3: Percent of Usage for MFS	
		Coded	Natural	Coded	Natural	Coded	Natural
1	Factorial	-1	3	-1	0	-1	20
2	Factorial	+1	5	-1	0	-1	20
3	Factorial	-1	3	+1	2	-1	20
4	Factorial	+1	5	+1	2	-1	20
5	Factorial	-1	3	-1	0	+1	60
6	Factorial	+1	5	-1	0	+1	60
7	Factorial	-1	3	+1	2	+1	60
8	Factorial	+1	5	+1	2	+1	60
9	Center	0	4	0	1	0	40
10	Axial	$-\alpha$ (*)	3	0	1	0	40
11	Axial	$+\alpha$ (*)	5	0	1	0	40
12	Axial	0	4	$-\alpha$ (*)	0	0	40
13	Axial	0	4	$+\alpha$ (*)	2	0	40
14	Axial	0	4	0	1	$-\alpha$ (*)	20
15	Axial	0	4	0	1	$+\alpha$ (*)	60

(*) $\alpha = 1$

4.6.2.2. Analyzing the Impact of Early Adopters of MFS

As previously explained in chapter (2),*Early Adopters* are part of a system known as the "Diffusion of Innovations Theory" which was developed by (Rogers, 2003). In general, an early adopter is someone who picks up new technology more quickly than the rest of society. Early adopters test out and prove the potential merits of products for the rest of the population, which slowly follows through on the growing trend. As a result, every early adopter is an important part of the process behind releasing a technological innovation.

A recent study by (Al-Hendi, 2007) founds that **36.5%** of Palestinian population are willing to use 3G mobile based applications. The interest in 3G technologies by Palestinian society may reflect the interest in the new ITC trends and innovations. MFS is a new promising application that can work under 3G and 2G technologies which may indicate that **36.5%** of PIB customers are likely to use MFS. This part of the study will evaluate the impact of the **36.5%** early adopters of customers on PIB Tellers and ATM service delivery channels in terms of cost, waiting time, and possibly revenue generation. DX will be used for locating the sweet spot with multiple responses optimization that maximize, minimize or target specific levels responses and factors.

4.6.3. Arena Basic Model Changes

The model that includes MFS has only a couple of key differences from the basic model. First, it has new resources (Permanent and/or Temporary Tellers) whose primary function is to serve more customers. This modification is made using **Process** module(s) in the "***Tellers***" sub-model as previously shown in Figure (4.21) and explained in tables (4.6) and (4.7). The second change is related to the addition of MFS channel and its percentage of usage. Figure (4.40) shows the **Decide** module placement to allow **36.5%** of customers use MFS channel.

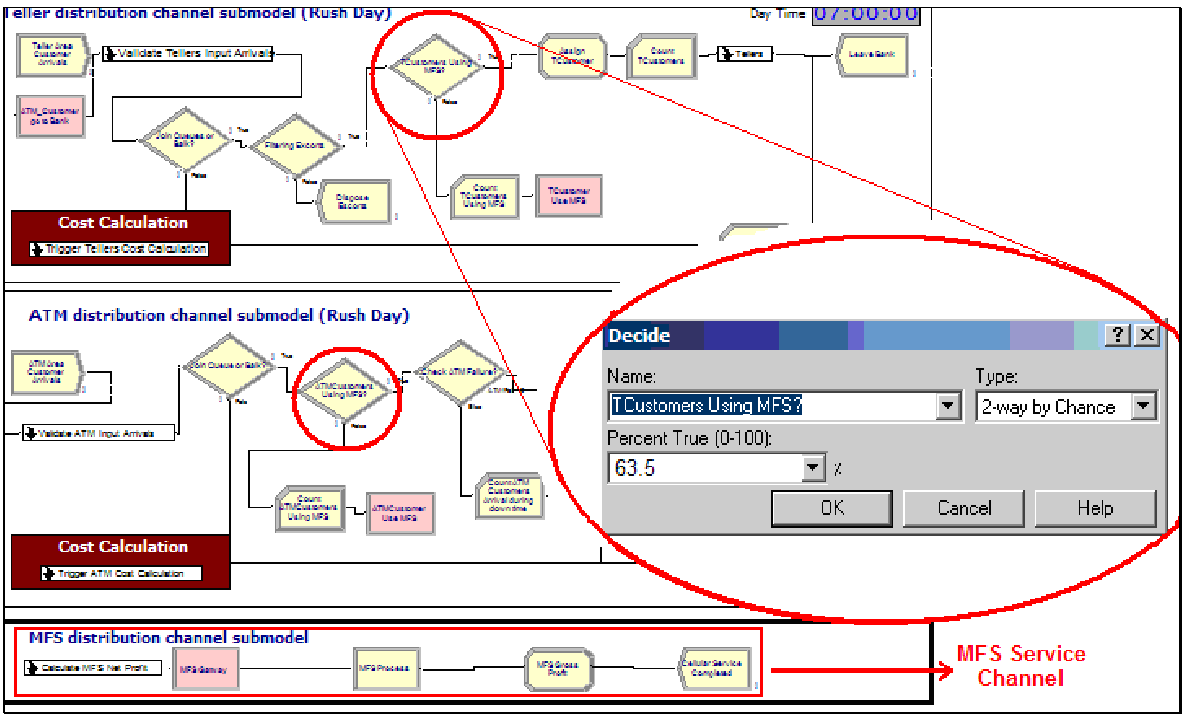


Figure 4.40: Decide module placement to allow **36.5%** of customers use MFS channel

All MFS customers will be directed to a Station module through a **Route** module. The "***Calculate MFS Net Profit***" sub-model will take care of calculating the amount of net profit that will be generated by customers who will use this service. Figure (4.41) shows the modules of this sub-model.

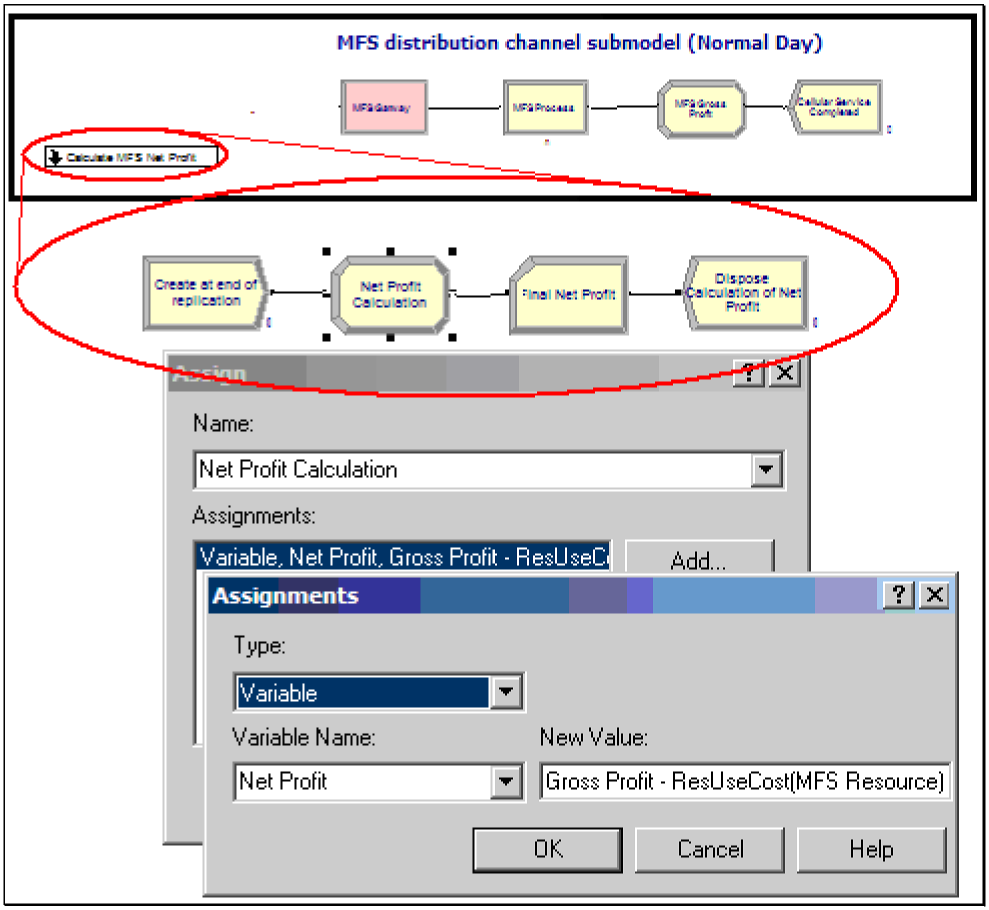


Figure 4.41: Modules of "***Calculate MFS Net Profit***" sub-model

4.7. CONCLUSION

Arena software package version (7.01) used in fitting and analyzing the collected data, and building the simulation model. In addition, other packages like Change Point Analyzer (CPA) version (2.3) used to determine the change of pattern in a sequence of data for **60 days** representing different arrival rates. Changed point analysis revealed two different segments for normal and rush days. Design Expert (DX) version (7.1) software used for analyzing simulation experiment outputs statistically, and optimizing the required input parameters through response surface methodology, and building meta-models for the responses of interest through Central Composite Design (CCD).

CHAPTER FIVE

RESEARCH ANALYSIS AND FINDINGS

This chapter consists of the following sections:

5.1. INTORDUCTION

5.2. META-MODEL DATA: NORMAL DAY CONFIGURATION

5.3. META-MODEL DATA: RUSH DAY CONFIGURATION

5.4. IMPACT OF MFS EARLY ADOPTERS

5.5. CONCLUSION

CHAPTER FIVE

RESEARCH ANALYSIS AND FINDINGS

5.1. INTORDUCTION

This chapter will analyze the results of the key responses for the simulation experiment through constructing Response Surface plots and Meta-Models. DX software output results will be presented and discussed thoroughly in the light of research objectives. Impact of MFS adoption for PIB branch will be investigated and regression models will be developed for this purpose, in addition for finding the sweet spot area that optimizes the branch office operations under **36.5%** of MFS usage of early adopters.

5.2. META-MODEL DATA: NORMAL DAY CONFIGURATION

Arena Process Analyzer was used to run the simulation experiment for the design points of a **Normal Day** configuration and record the responses for: (1) Tellers channel cost and wait time, (2) ATM channel cost and wait time, and (3) Possible net profit that might be generated as a result of using MFS. Table (5.1) shows simulation experiment outputs for these responses of interest. It is clear from the table (5.1) that responses 3 and 4 are not changing whatever were the input parameters. This happened due to the low number of customers who were using ATM machine during normal days (on average only **9 Customers/Day**), which means that queues were never built up and the cost of waiting time was zero leaving the total cost of ATM machine to be around **12.608 USD/Day** (which is the service cost of **12** hours of operation for ATM machine).

Table 5.1: Design matrix with simulation model responses for a normal day

Design Point		Factor 1	Factor 2	Factor 3	Simulation Model Responses				
					Response 1	Response 2	Response 3	Response 4	Response 5
No	Type	A:PT (Number)	B:TT (Number)	C:MFS (%)	Teller Area Total Cost ($/Day)	T_Customer Wait Time (Minutes)	ATM Total Cost ($/Day)	ATM Customer Wait Time (Minutes)	Net Profit for using MFS ($/Day)
1	F	1	0	20	1131.512	115.000	12.608	0.000	9.016
2	F	3	0	20	152.407	2.700	12.608	0.000	9.109
3	F	1	2	20	332.102	21.000	12.608	0.000	8.900
4	F	3	2	20	237.375	2.700	12.608	0.000	9.109
5	F	1	0	60	112.475	14.000	12.609	0.000	26.732
6	F	3	0	60	128.870	0.700	12.609	0.000	26.688
7	F	1	2	60	179.748	10.000	12.609	0.000	26.601
8	F	3	2	60	212.829	0.700	12.609	0.000	26.688
9	A	1	1	40	214.420	18.000	12.609	0.000	17.720
10	A	3	1	40	177.829	1.300	12.608	0.000	18.052
11	A	2	0	40	112.766	3.900	12.609	0.000	18.170
12	A	2	2	40	174.438	1.400	12.609	0.000	18.170
13	A	2	1	20	242.217	11.000	12.609	0.000	8.976
14	A	2	1	60	132.382	1.400	12.609	0.000	26.480
15	C	2	1	40	155.511	3.900	12.609	0.000	18.170

5.2.1. Total Cost Response of Tellers Service Channel "Response 1"

5.2.1.1. Response Model Equation

The response equation in terms of actual factors for the *Tellers Service Channel Total Cost* response "**Response 1**" is shown in model equation (5.1):

Model (5.1)

1/Sqrt(Teller Area Total Cost -40.00) =

-0.15287	
+0.14004	* PT
+0.05953	* TT
+4.61000E-003	* MFS
-0.052702	* PT * TT
-9.42985E-004	* PT * MFS
-1.10296E-003	* TT * MFS
-0.022407	* PT ^2
+7.15132E-003	* TT ^2
-1.85114E-005	* MFS ^2
+3.39027E-004	* PT * TT * MFS
+8.26882E-003	* PT ^2 * TT

Sig.=0.0007 F=169.65 Adj. R(SQR)=0.9925

5.2.1.2. Response Model Analysis of Variance

The response column titled "**Response 1**" data in table (5.1) from the CCD experiment is analyzed by use of an Analysis of Variance (ANOVA). An ANOVA table is constructed as shown in table (5.2). The ANOVA table allows judging the significance of the *main effect* for each input parameter (factor) as well as *interactions* between two factors or between three factors. In this case, only factor terms shown in table (5.2) are found to be significant meanwhile the insignificant terms were excluded by DX software backward regression elimination procedure. This is seen by looking at the column marked "**Prob>F**". Small numbers for "**Prob>F**" (*should be below* ***0.05***) mean the effect is significant. For example, the probability that the effect seen when varying factor "**A**" would happen by chance only **18** times in **1000** experiments, while the effect seen for varying "**B**" would happen by chance only **16** times in **1000** experiments. Factor "**C**" would happen by chance only **one** time in **1000** experiments. This leads to conclude that changing "**A**", "**B**", and "**C**" input parameters in addition to the other factor terms listed in table (5.2) "**AB**", "**AC**", "**BC**", "$\mathbf{A^2}$", "$\mathbf{B^2}$", "$\mathbf{C^2}$", "**ABC**", "$\mathbf{A^2B}$" has a dramatic effect on the response of the tellers channel total cost.

Table 5.2: ANOVA for total cost response "**Response 1**" of table (5.1)

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Sig.
Model	**0.007309239**	**11**	**0.000664476**	**169.6546331**	**0.0007**	**significant**
A-PT	*0.000439149*	*1*	*0.000439149*	*112.1238226*	*0.0018*	*significant*
B-TT	*0.000479979*	*1*	*0.000479979*	*122.5485894*	*0.0016*	*significant*
C-MFS	*0.00267784*	*1*	*0.00267784*	*683.7084585*	*0.0001*	*significant*
AB	*0.000294288*	*1*	*0.000294288*	*75.13784017*	*0.0032*	*significant*
AC	*0.001167246*	*1*	*0.001167246*	*298.0221161*	*0.0004*	*significant*
BC	*0.000577753*	*1*	*0.000577753*	*147.5123044*	*0.0012*	*significant*
A^2	*0.000513972*	*1*	*0.000513972*	*131.2277124*	*0.0014*	*significant*
B^2	*0.000131506*	*1*	*0.000131506*	*33.5762914*	*0.0102*	*significant*
C^2	*0.000140985*	*1*	*0.000140985*	*35.99647091*	*0.0093*	*significant*
ABC	*0.000367807*	*1*	*0.000367807*	*93.90871973*	*0.0023*	*significant*
A^2B	*0.000109397*	*1*	*0.000109397*	*27.93145894*	*0.0132*	*significant*
Residual	1.17499E-05	3	3.91664E-06			
Cor Total	0.007320989	14				

The model **F-value** of **169.65** implies the model is significant. There is only a **0.07%** chance that a model **F-Value** this large could occur due to noise. Table (5.3) shows the statistical summery of the response model. The "**Pred R-Squared**" of **0.8843** is in reasonable agreement with the "**Adj R-Squared**" of **0.9925**. "**Adeq Precision**" measures the signal to noise ratio. A ratio greater than **4** is desirable. The ratio of **49.400** indicates an adequate signal. The value of "**Adj R-Squared**" implies that **99.25%** of the variability in the response is explained by model terms listed in table (5.2). The remaining percentage, **0.75%** of the variability in the response is due to random error term "ε" representing whatever inaccuracy such a model might have in approximating the actual simulation response.

Table 5.3: Summery statistics of "**Response 1**" regression model of table (5.1)

Std. Dev.	0.00197905	**R-Squared**	0.998395036
Mean	0.08468378	**Adj R-Squared**	0.992510169
C.V. %	2.33698896	**Pred R-Squared**	0.884276598
PRESS	0.00084721	**Adeq Precision**	49.40011594

The Variance Inflation Factors (VIF) values shown in table (5.4) indicate that multicollinearity among the response model terms is not present. All VIF values are small and less than 10.

Table 5.4: Post-ANOVA information for the individual terms of "**Response 1**" in table (5.1)

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.094277821	1	0.001063708	0.090892625	0.097663016	
A-PT	0.00662683	1	0.000625831	0.004635155	0.008618504	1
B-TT	-0.015491591	1	0.0013994	-0.019945111	-0.011038072	5
C-MFS	0.016364108	1	0.000625831	0.014372434	0.018355783	1
AB	-0.006065146	1	0.0006997	-0.008291905	-0.003838386	1
AC	-0.012079143	1	0.0006997	-0.014305903	-0.009852383	1
BC	-0.008498181	1	0.0006997	-0.010724941	-0.006271422	1
A^2	-0.014137819	1	0.001234155	-0.018065454	-0.010210184	1.3
B^2	0.007151317	1	0.001234155	0.003223682	0.011078951	1.3
C^2	-0.007404566	1	0.001234155	-0.011332201	-0.003476931	1.3
ABC	0.006780549	1	0.0006997	0.004553789	0.009007308	1
A^2B	0.008268823	1	0.001564577	0.003289637	0.013248009	5

5.2.1.3. Response Model Diagnostics

It is clear from Fig. (5.1) that Tellers Channel Total Cost response "**Response 1**" is roughly normally distributed since the points lay on the normal line or close to it.

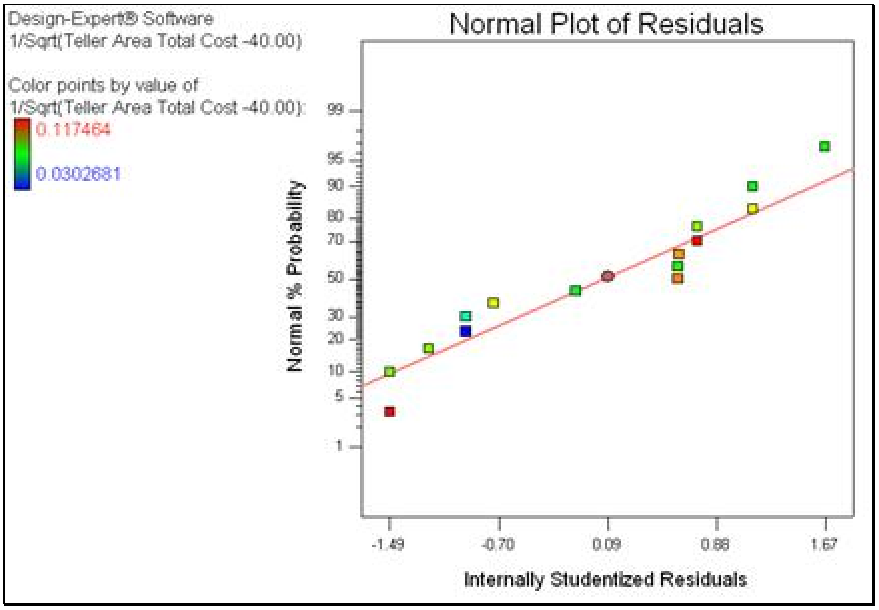


Figure 5.1: Normal plot of residuals for "**Response 1**" in table (5.1)

The fit of predicted versus actual data (from the simulation) is shown in Fig. (5.2). The points are scattered randomly around the zero line with a band of ±2.5. There is no pattern here that suggests the model needs to be changed.

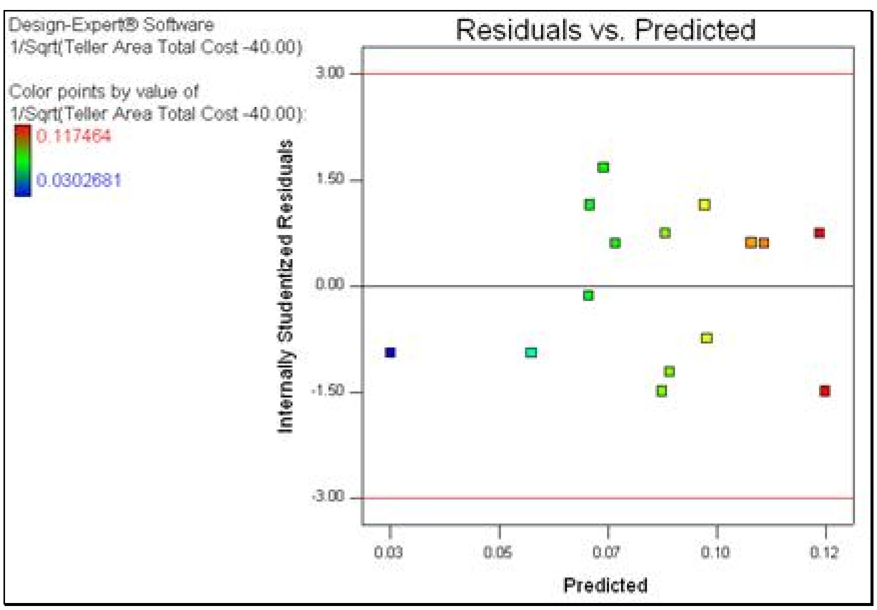


Figure 5.2: Residuals vs predicted plot for "**Response 1**" in table (5.1)

5.2.1.4. Comparing Predicted to Simulated Response

Table (5.5) shows a comparison of the predicted response estimated from the regression model to the simulated response obtained from the simulation experiment. The two responses are very close to conclude that Tellers Channel Total Cost regression model (5.1) can be used as a proxy for the simulation response "**Response 1**" during normal days.

Table 5.5: Comparing predicted to simulated response "**Response 1**" in table (5.1)

Design Point		Factor 1	Factor 2	Factor 3	Teller Area Total Cost ($/Day)	
No	Type	A:PT (Number)	B:TT (Number)	C:MFS (%)	Simulated Response	Predicted Response
1	Factorial	1	0	20	1131.512	1101.330
2	Factorial	3	0	20	152.407	153.659
3	Factorial	1	2	20	332.102	327.881
4	Factorial	3	2	20	237.375	240.296
5	Factorial	1	0	60	112.475	111.649
6	Factorial	3	0	60	128.870	129.330
7	Factorial	1	2	60	179.748	177.543
8	Factorial	3	2	60	212.829	214.077
9	Axial	1	1	40	214.420	225.042
10	Axial	3	1	40	177.829	172.829
11	Axial	2	0	40	112.766	113.150
12	Axial	2	2	40	174.438	175.405
13	Axial	2	1	20	242.217	241.145
14	Axial	2	1	60	132.382	133.827
15	Center	2	1	40	155.511	152.507

5.2.2. Waiting Time Response of Tellers Service Channel "Response 2"

5.2.2.1. Response Model Equation

The response equation in terms of actual factors for the *Tellers Service Channel Waiting Time* response "**Response 2**" for customers is shown in model equation (5.2):

Model (5.2)

1/Sqrt(T_Customer Wait Time + 15.00)	*=*	
	-0.153476198	
	0.179331307	** PT*
	0.083445046	** TT*
	0.005745774	** MFS*
	-0.028014894	** PT * TT*
	-0.001042729	** PT * MFS*
	-0.001228126	** TT * MFS*
	-0.021180524	** PT^2*
	-2.72823E-05	** MFS^2*
	0.000409375	** PT * TT * MFS*

	Model (5.2)
Sig.<0.0001 F=76.59 Adj. R(SQR)=0.9798	[Continued]

5.2.2.2. Response Model Analysis of Variance

The response column titled "**Response 2**" data in table (5.1) from the CCD experiment is analyzed by use of an Analysis of Variance (ANOVA). An ANOVA table is constructed as shown in table (5.6). Factor terms shown in table (5.6) are found to be significant meanwhile the insignificant terms were excluded by DX software backward regression elimination procedure. This is seen by looking at the column marked "**Prob>F**". Small numbers for "**Prob>F**" (*should be below* ***0.05***) mean the effect is significant. Factor terms set "**A**", "**B**", "**C**", "**AB**", "**AC**", "**BC**", "**A²**", "**C²**", and "**ABC**" has a dramatic effect on the response of Customers Waiting Time response model for Tellers' Service Channel.

Table 5.6: ANOVA for "**Response 2**" of table (5.1)

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Sig.
Model	**0.028757**	**9**	**0.003195**	**76.59583**	**< 0.0001**	**significant**
A-PT	*0.017024*	*1*	*0.017024*	*408.0964*	*< 0.0001*	*significant*
B-TT	*0.001219*	*1*	*0.001219*	*29.21849*	*0.0029*	*significant*
C-MFS	*0.004566*	*1*	*0.004566*	*109.4436*	*0.0001*	*significant*
AB	*0.001084*	*1*	*0.001084*	*25.98289*	*0.0038*	*significant*
AC	*0.001284*	*1*	*0.001284*	*30.77105*	*0.0026*	*significant*
BC	*0.000536*	*1*	*0.000536*	*12.85564*	*0.0158*	*significant*
A^2	*0.001256*	*1*	*0.001256*	*30.11146*	*0.0027*	*significant*
C^2	*0.000333*	*1*	*0.000333*	*7.993589*	*0.0368*	*significant*
ABC	*0.000536*	*1*	*0.000536*	*12.85564*	*0.0158*	*significant*
Residual	0.000209	5	4.17E-05			
Cor Total	0.028966	14				

The model **F-value** of **76.59** implies the model is significant. There is only a **0.01%** chance that a model **F-Value** this large could occur due to noise. Table (5.7) shows the statistical summery of the response model. The "**Pred R-Squared**" of **0.8494** is in reasonable agreement with the "**Adj R-Squared**" of **0.9798**. "**Adeq Precision**" measures the signal to noise ratio. A ratio greater than **4** is desirable. The ratio of **31.576** indicates an adequate signal. The value of "**Adj R-Squared**" implies that **97.98%** of the variability in the response is explained by model terms listed in table (5.6). The remaining percentage, **2.02%** of the variability in the response is due to random error term "ε" representing whatever inaccuracy such a model might have in approximating the actual simulation response.

Table 5.7: Summery statistics of "**Response 2**" regression model of table (5.1)

Std. Dev.	0.00645877	**R-Squared**	0.99279915
Mean	0.212869831	**Adj R-Squared**	0.979837621
C.V. %	3.034140628	**Pred R-Squared**	0.849448911
PRESS	0.004360836	**Adeq Precision**	31.57686102

The Variance Inflation Factors (VIF) values shown in table (5.8) indicate that multicollinearity among the response model terms is not present. All VIF values are small and less than 10.

Table 5.8: Post-ANOVA information for the individualterms of "**Response 2**" of table (5.1)

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.234265473	1	0.003275194	0.225846319	0.242684627	
A-PT	0.041260187	1	0.002042442	0.036009922	0.046510452	1
B-TT	0.011040245	1	0.002042442	0.00578998	0.01629051	1
C-MFS	0.02136707	1	0.002042442	0.016116805	0.026617335	1
AB	-0.011639881	1	0.00228352	-0.017509856	-0.005769906	1
AC	-0.012667066	1	0.00228352	-0.01853704	-0.006797091	1
BC	-0.008187506	1	0.00228352	-0.014057481	-0.002317532	1
A^2	-0.021180524	1	0.003859853	-0.031102592	-0.011258456	1.19047619
C^2	-0.010912939	1	0.003859853	-0.020835007	-0.00099087	1.19047619
ABC	0.008187506	1	0.00228352	0.002317532	0.014057481	1

5.2.2.3. Response Model Diagnostics

It is clear from Fig. (5.3) that Customers Waiting Time response for Tellers Service Channel is roughly normally distributed since the points lay on the normal line or close to it.

The fit of predicted versus actual data (from the simulation) is shown in Fig. (5.4). The points are scattered randomly around the zero line with a band of ±2.5. There is no pattern here that suggests the model needs to be changed.

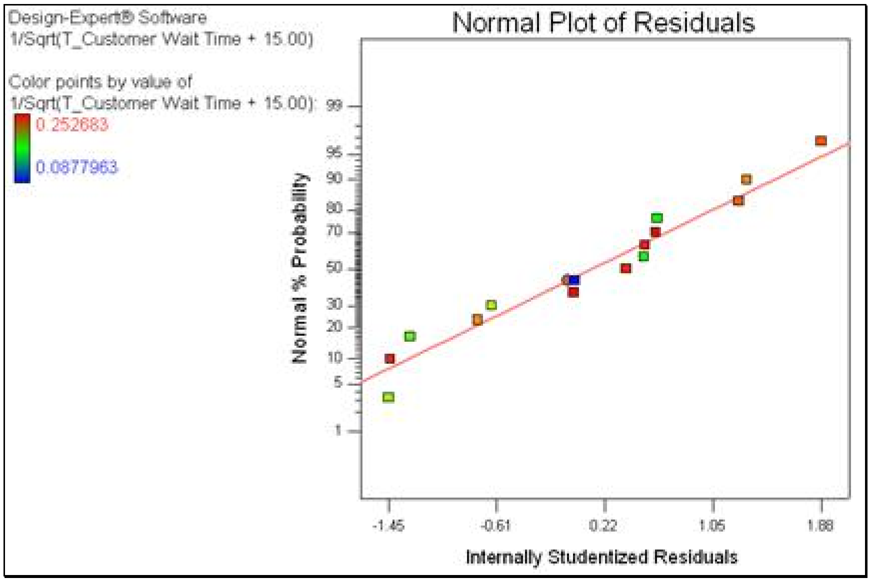


Figure 5.3: Normal plot of residuals for "**Response 2**" in table (5.1)

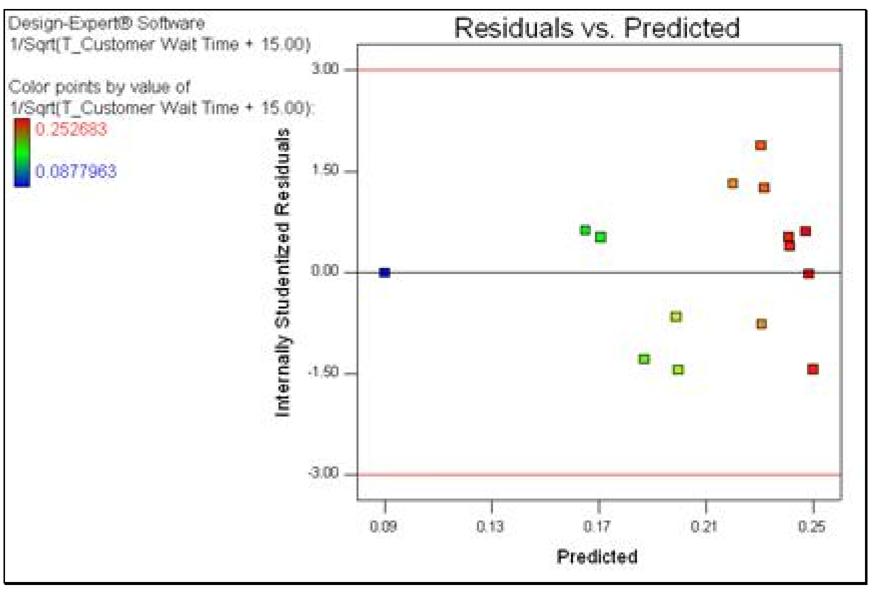


Figure 5.4: Residuals vs predicted plot for "**Response 2**" in table (5.1)

5.2.2.4. Comparing Predicted to Simulated Response

Table (5.9) shows a comparison of the predicted response estimated from the regression model to the simulated response obtained from the simulation experiment. The two responses are very close to conclude that Customers Waiting Time regression model (5.2) for Tellers Service Channel can be used as a proxy for the simulation response "**Response 2**" during normal days.

Table 5.9: Comparison between predicted to simulated response "**Response 2**" in table (5.1)

Design Point		Factor 1	Factor 2	Factor 3	Customers Waiting Time (Minutes)	
No	Type	A:PT (Number)	B:TT (Number)	C:MFS (%)	Simulated Response	Predicted Response
1	Factorial	1	0	20	115.000	114.650
2	Factorial	3	0	20	2.700	3.050
3	Factorial	1	2	20	21.000	21.320
4	Factorial	3	2	20	2.700	3.240
5	Factorial	1	0	60	14.000	13.100
6	Factorial	3	0	60	0.700	0.650
7	Factorial	1	2	60	10.000	9.700
8	Factorial	3	2	60	0.700	0.800
9	Axial	1	1	40	18.000	18.870
10	Axial	3	1	40	1.300	0.460
11	Axial	2	0	40	3.900	5.060
12	Axial	2	2	40	1.400	1.620
13	Axial	2	1	20	11.000	9.500
14	Axial	2	1	60	1.400	1.700
15	Center	2	1	40	3.900	3.220

5.2.3. Net Profit Response of Using MFS Channel "Response 5"

5.2.3.1. Response Model Equation

The response equation in terms of actual factors for the expected *Net Profit* response "**Response 5**" that might be generated as a result of using MFS by a portion of the *current* customers' base is shown in model equation (5.3):

Model (5.3)

$$(\text{Net Profit})^{-1.3} = 0.112830285 - 0.003417844 \cdot MFS + 2.9498E\text{-}05 \cdot MFS^2$$

Sig.<0.0001 F=57855.22 Adj. R(SQR)=0.9998

5.2.3.2. Response Model Analysis of Variance

The response column titled "**Response 5**" data in table (5.1) from the CCD experiment is analyzed by use of an Analysis of Variance (ANOVA). An ANOVA table is constructed as shown in table (5.10). Factor terms shown in table (5.10) are found to be significant meanwhile the insignificant terms were excluded by DX software backward regression elimination procedure. This is seen by looking at the column marked "**Prob>F**". Small numbers for "**Prob>F**" (*should be below **0.05***) mean the effect is significant. Only factor terms "**C**", and "**C^2**" has a dramatic effect on the response of Net Profit. This means that only MFS will affect the generation of profit.

Table 5.10: ANOVA for "**Response 5**" of table (5.1)

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Sig.
Model	**0.004942**	**2**	**0.002471**	**57855.22**	**< 0.0001**	**significant**
C-MFS	*0.004478*	*1*	*0.004478*	*104843.9*	*< 0.0001*	
C^2	*0.000464*	*1*	*0.000464*	*10866.49*	*< 0.0001*	
Residual	5.12E-07	12	4.27E-08			
Cor Total	0.004942	14				

The model **F-value** of **57855.22** implies the model is significant. There is only a **0.01%** chance that a model **F-Value** this large could occur due to noise. Table (5.11) shows the statistical summery of the response model. The "**Pred R-Squared**" of **0.9998** is in reasonable agreement with the "**Adj R-Squared**" of **0.9998**. "**Adeq Precision**" measures the signal to noise ratio. A ratio greater than **4** is desirable. The ratio of **457.917** indicates an adequate signal. The value of "**Adj R-Squared**" implies that **99.98%** of the variability in the response is explained by model terms listed in table (5.10). The remaining percentage, **0.02%** of the variability in the response is due to random error term "ε" representing whatever inaccuracy such a model might have in approximating the actual simulation response.

Table 5.11: Summery statistics of "**Response 5**" regression model of table (5.1)

Std. Dev.	0.000207	**R-Squared**	0.999896
Mean	0.031179	**Adj R-Squared**	0.999879
C.V. %	0.662795	**Pred R-Squared**	0.999838
PRESS	8.01E-07	**Adeq Precision**	457.9169

The Variance Inflation Factors (VIF) values shown in table (5.12) indicate that multicollinearity among the response model terms is not present. All VIF values are small and less than 10.

Table 5.12: Post-ANOVA information for the individual terms of "**Response 5**" of table (5.1)

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.023313	1	9.24E-05	0.023112	0.023515	
C-MFS	-0.02116	1	6.54E-05	-0.0213	-0.02102	1
C^2	0.011799	1	0.000113	0.011553	0.012046	1

5.2.3.3. Response Model Diagnostics

Figure (5.5) indicates that Net Profit response is roughly normally distributed since the points lay on the normal line or close to it.

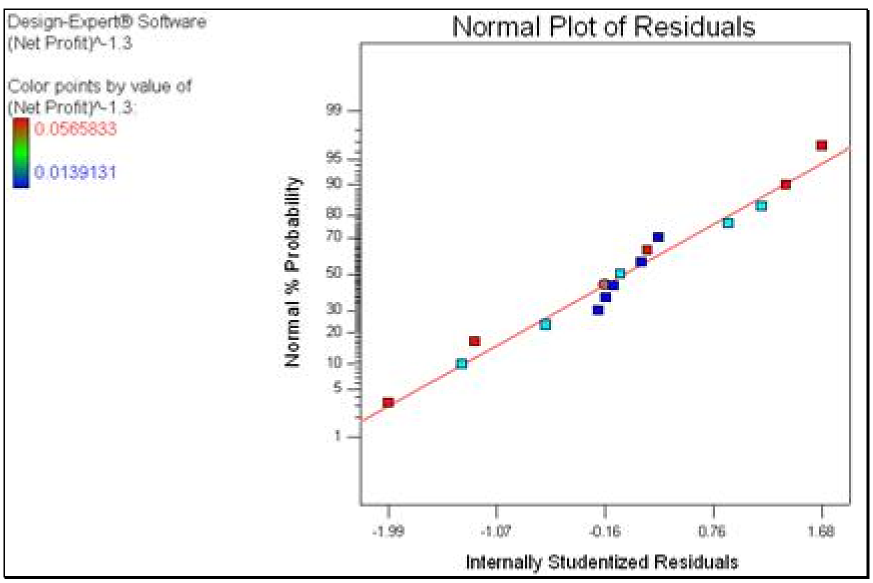


Figure 5.5: Normal plot of residuals for "**Response 5**" in table (5.1)

The fit of predicted versus actual data (from the simulation) is shown in Fig. (5.6). Watch for residuals increasing in size as the predicted values increase (i.e. a megaphone shape "<"), thus variance of Net Profit data exhibits constant variance. There is no pattern here that suggests the model needs to be changed.

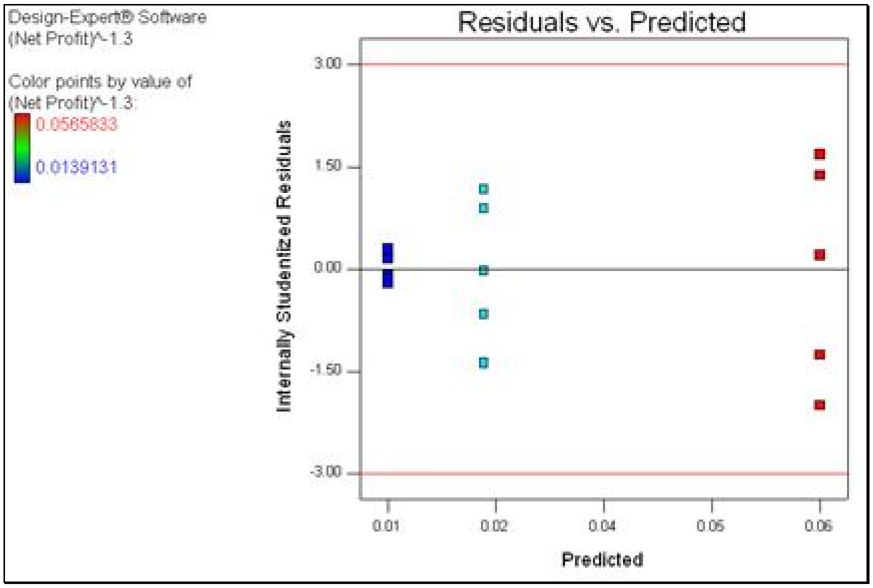


Figure 5.6: Residuals vs predicted plot for "**Response 5**" in table (5.1)

5.2.3.4. Comparing Predicted to Simulated Response

Table (5.13) shows a comparison of the predicted response estimated from the regression model to the simulated response obtained from the simulation experiment. The two responses are very close to conclude that MFS Net Profit regression model (5.3) can be used as a proxy for the simulation response "**Response 5**" during normal days.

Table 5.13: Comparing predicted to simulated responses "**Response 5**" in table (5.1)

Design Point		Factor 1	Factor 2	Factor 3	MFS Net Profit ($/Day)	
No	Type	A:PT (Number)	B:TT (Number)	C:MFS (%)	Simulated Response	Predicted Response
1	Factorial	1	0	20	9.116	9.147
2	Factorial	3	0	20	9.177	9.147
3	Factorial	1	2	20	9.194	9.147
4	Factorial	3	2	20	9.143	9.147
5	Factorial	1	0	60	26.662	26.742
6	Factorial	3	0	60	26.766	26.742
7	Factorial	1	2	60	26.782	26.742
8	Factorial	3	2	60	26.701	26.742
9	Axial	1	1	40	17.920	18.017
10	Axial	3	1	40	17.890	18.017
11	Axial	2	0	40	18.090	18.017
12	Axial	2	2	40	18.020	18.017
13	Axial	2	1	20	9.109	9.147
14	Axial	2	1	60	26.800	26.742
15	Center	2	1	40	18.170	18.017

5.3. META-MODEL DATA: RUSH DAY CONFIGURATION

Arena Process Analyzer was used to run the simulation experiment for the design points of a **Rush Day** configuration and record the responses for: (1) Tellers channel cost and wait time, (2) ATM channel cost and wait time, and (3) Possible net profit that might be generated as a result of using MFS. Table (5.14) shows simulation experiment outputs for these responses of interest.

Table 5.14: Design matrix with simulation model responses for a rush day

Design Point		Factor 1	Factor 2	Factor 3	Simulation Model Responses				
					Response 1	Response 2	Response 3	Response 4	Response 5
No	Type	A:PT (Number)	B:TT (Number)	C:MFS (%)	Teller Area Total Cost ($/Day)	T_Customer Wait Time (Minutes)	ATM Total Cost ($/Day)	ATM Customer Wait Time (Minutes)	Net Profit for using MFS ($/Day)
1	F	3	0	20	2562.276	77.750	235.343	12.448	20.736
2	F	5	0	20	616.451	12.655	249.240	13.230	20.709
3	F	3	2	20	920.868	22.623	236.826	12.531	20.586
4	F	5	2	20	646.211	10.797	242.258	12.801	20.868
5	F	3	0	60	214.259	5.573	18.912	0.353	61.810
6	F	5	0	60	228.349	1.207	17.871	0.294	62.421
7	F	3	2	60	298.466	5.493	18.841	0.349	61.856
8	F	5	2	60	312.495	1.207	17.871	0.294	62.421
9	A	3	1	40	574.865	17.019	50.546	2.129	41.218
10	A	5	1	40	339.033	3.671	56.414	2.412	41.237
11	A	4	0	40	391.758	9.335	51.972	2.202	41.405
12	A	4	2	40	465.549	8.740	51.133	2.162	41.383
13	A	4	1	20	821.993	19.146	240.881	12.776	20.907
14	A	4	1	60	243.404	2.131	17.7880	0.293	62.373
15	C	4	1	40	423.513	8.829	50.882	2.146	41.485

5.3.1. Total Cost Response of Tellers Service Channel "Response 1"

5.3.1.1. Response Model Equation

The final equation in terms of actual factors for the *Total Cost* response "**Response 1**" of Tellers Service Channel during Rush Days is shown in model equation (5.4):

Model (5.4)

1/Sqrt(Tellers Total Cost + 474.00)	***=***	
-0.051250471		
0.024432865	**** PT***	
0.034920594	**** TT***	
0.001190072	**** MFS***	
-0.012851538	**** PT * TT***	
-0.000156489	**** PT * MFS***	
-0.000305074	**** TT * MFS***	
-0.001897449	**** PT^2***	
-2.83235E-06	**** MFS^2***	
5.68383E-05	**** PT * TT * MFS***	
0.001182091	**** PT^2 * TT***	
Sig.<0.0001	**F=185.34**	**Adj. R(SQR)=0.9925**

5.3.1.2. Response Model Analysis of Variance

The response column titled "**Response 1**" data in table (5.14) from the CCD experiment is analyzed by use of an Analysis of Variance (ANOVA). An ANOVA table is constructed as shown in table (5.15). Most of factor terms shown in table (5.15) are found to be significant meanwhile the insignificant terms were excluded by DX software backward regression elimination procedure. This is seen by looking at the column marked "**Prob>F**". Small numbers for "**Prob>F**" (*should be below* ***0.05***) mean the effect is significant. Factor term "**B**" is considered to be insignificant but it was added again to the model terms list by DX automatically as to make the model hierarchical and have a proper predictive model (Anderson. 2003). In other words, parent (lower order) terms (in our case "**B**") is added to complete the family of any higher-order terms (**'AB**", "**BC**", "**ABC**", "A^2**B**") as to preserve hierarchy (Statease, n.d.) and be able of constructing actual equation shown in model (5.4). Factor term "A^2" "**Prob>F**" value is above **0.05** and below **0.1**, indicating that this term seems not having significant effect, and at the same time it can not be regarded as insignificant as it is below**0.1**, therefore this term is added to the model.

Factor terms set "**A**", "**C**", "**AB**", "**AC**", "**BC**", "C", "A**BC**", and "A^2**B**" has a dramatic effect on the response of Total Cost of Tellers Service Channel during rush days.

Table 5.15: ANOVA for total cost response "**Response 1**" of table (5.14)

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Sig.
Model	**0.000387644**	**10**	**3.87644E-05**	**185.3430318**	**< 0.0001**	**Significant**
A-PT	*3.50601E-05*	*1*	*3.50601E-05*	*167.6315311*	*0.0002*	*Significant*
B-TT	*9.27388E-07*	*1*	*9.27388E-07*	*4.434087687*	*0.1030*	*Insignificant*
C-MFS	*0.000269999*	*1*	*0.000269999*	*1290.938945*	*< 0.0001*	*Significant*
AB	*1.00581E-05*	*1*	*1.00581E-05*	*48.09069025*	*0.0023*	*Significant*
AC	*3.17768E-05*	*1*	*3.17768E-05*	*151.9335081*	*0.0002*	*Significant*
BC	*1.93299E-05*	*1*	*1.93299E-05*	*92.42129391*	*0.0007*	*Significant*
A^2	*1.43286E-06*	*1*	*1.43286E-06*	*6.850909144*	*0.0590*	-
C^2	*3.59394E-06*	*1*	*3.59394E-06*	*17.18360757*	*0.0143*	*Significant*
ABC	*1.03379E-05*	*1*	*1.03379E-05*	*49.42817285*	*0.0022*	*Significant*
A^2B	*2.23574E-06*	*1*	*2.23574E-06*	*10.68968095*	*0.0308*	*Significant*
Residual	8.36598E-07	4	2.0915E-07			
Cor Total	0.000388481	14				

The model **F-value** of **185.34** implies the model is significant. There is only a **0.01%** chance that a model **F-Value** this large could occur due to noise. Table (5.16) shows the statistical summery of the response model. The "**Pred R-Squared**" of **0.8978** is in reasonable agreement with the "**Adj R-Squared**" of **0.9924**. "**Adeq Precision**" measures the signal to noise ratio. A ratio greater than **4** is desirable. The ratio of **50.457** indicates an adequate signal. The value of "**Adj R-Squared**" implies that **99.24%** of the variability in the response is explained by model terms listed in table (5.15). The remaining percentage, **0.86%** of the variability in the response is due to random error term "ε" representing whatever inaccuracy such a model might have in approximating the actual simulation response.

Table 5.16: Summery statistics of "**Response 1**" regression model of table (5.14)

Std. Dev.	0.000457329	**R-Squared**	0.997846487
Mean	0.032241551	**Adj R-Squared**	0.992462705
C.V. %	1.418445275	**Pred R-Squared**	0.897802779
PRESS	3.97017E-05	**Adeq Precision**	50.45719168

The Variance Inflation Factors (VIF) values shown in table (5.17) indicate that multicollinearity among the response model terms is not present. All VIF values are small and less than 10.

Table5.17: Post-ANOVA informationfor the individual terms of "**Response 1**" of table (5.14)

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.033473749	1	0.000231908	0.03282987	0.034117629	
A-PT	0.001872433	1	0.00014462	0.001470904	0.002273963	1
B-TT	-0.000680951	1	0.00032338	-0.001578798	0.000216897	5
C-MFS	0.005196146	1	0.00014462	0.004794617	0.005597676	1
AB	-0.00112128	1	0.00016169	-0.001570204	-0.000672356	1
AC	-0.001993014	1	0.00016169	-0.002441938	-0.00154409	1
BC	-0.001554424	1	0.00016169	-0.002003348	-0.0011055	1
A^2	-0.000715358	1	0.000273306	-0.001474178	4.34614E-05	1.19
C^2	-0.001132939	1	0.000273306	-0.001891759	-0.00037412	1.19
ABC	0.001136765	1	0.00016169	0.000687841	0.001585689	1
A^2B	0.001182091	1	0.00036155	0.000178267	0.002185915	5

5.3.1.3. Response Model Diagnostics

It is clear from Fig. (5.7) that Total Cost response for Tellers Service Channel is roughly normally distributed since the points lay on the normal line or very close to it.

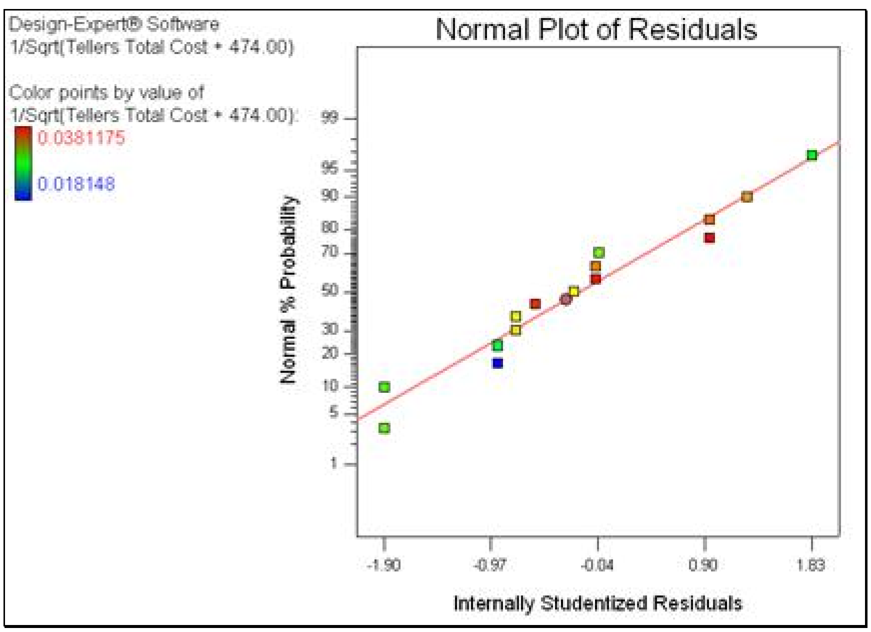


Figure 5.7: Normal plot of residuals for "**Response 1**" in table (5.14)

The fit of predicted versus actual data (from the simulation) is shown in Fig. (5.8). The points are scattered randomly around the zero line with a band of ±2.5. There is no pattern here that suggests the model needs to be changed.

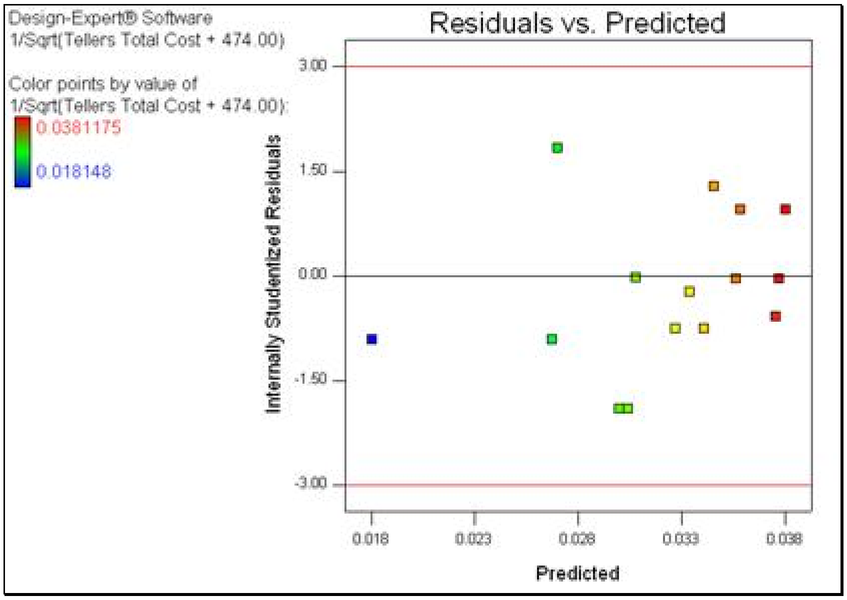


Figure 5.8: Residuals vs predicted plot for "**Response 1**" in table (5.14)

5.3.1.4. Comparing Predicted to Simulated Response

Table (5.18) shows a comparison of the predicted response estimated from the regression model to the simulated response obtained from the simulation experiment. The two responses are close enough to accept that Tellers Channel Total Cost regression model (5.4) can be used to approximate the simulation response "**Response 1**".

Table 5.18: Comparing predicted to simulated response "**Response 1**" in table (5.14)

Design Point		Factor 1	Factor 2	Factor 3	Tellers Area Total Cost ($/Day)	
No	Type	A:PT (Number)	B:TT (Number)	C:MFS (%)	Simulated Response	Predicted Response
1	Factorial	3	0	20	2562.276	2528.36
2	Factorial	5	0	20	616.451	601.175
3	Factorial	3	2	20	920.868	910.278
4	Factorial	5	2	20	646.211	630.308
5	Factorial	3	0	60	214.259	218.122
6	Factorial	5	0	60	228.349	228.140
7	Factorial	3	2	60	298.466	303.060
8	Factorial	5	2	60	312.495	312.247
9	Axial	3	1	40	574.865	574.281
10	Axial	5	1	40	339.033	359.824
11	Axial	4	0	40	391.758	383.233
12	Axial	4	2	40	465.549	455.915
13	Axial	4	1	20	821.993	883.160
14	Axial	4	1	60	243.404	135.712
15	Center	4	1	40	423.513	418.465

5.3.2. Waiting Time Response of Tellers Service Channel "Response 2"

5.3.2.1. Response Model Equation

The final equation in terms of actual factors for the *Tellers Service Channel Waiting Time* response "**Response 2**" for customers is shown in model equation (5.5):

		Model (5.5)
1/Sqrt(TCustomer Wait time)	*=*	
0.397666526		
-0.025948407	** PT*	
-0.025829552	** MFS*	
0.004427399	** PT * MFS*	
0.000240131	** MFS^2*	
Sig.<0.0001	**F=242.86**	**Adj. R(SQR)= 0.9857**

5.3.2.2. Response Model Analysis of Variance

The response column titled "**Response 2**" data in table (5.14) from the CCD experiment is analyzed by use of an Analysis of Variance (ANOVA). An ANOVA table is constructed as shown in table (5.19). All factor terms shown in table (5.19) are found to be significant meanwhile the insignificant terms were excluded by DX software backward regression elimination procedure. This is seen by looking at the column marked "**Prob>F**". Small numbers for "**Prob>F**" (*should be below* ***0.05***) mean the effect is significant. Factor terms set "**A**", "**C**", "**AC**", and "**C^2**" has a dramatic effect on the response of Customers Waiting Time for Tellers Service Channel during rush days.

Table 5.19: ANOVA for customers waiting time response "**Response 2**" of table (5.14)

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Sig.
Model	**0.813936155**	**4**	**0.203484039**	**242.8673385**	**< 0.0001**	**significant**
A-PT	*0.228455795*	*1*	*0.228455795*	*272.6722508*	*< 0.0001*	*significant*
C-MFS	*0.492000794*	*1*	*0.492000794*	*587.2250427*	*< 0.0001*	*significant*
AC	*0.06272595*	*1*	*0.06272595*	*74.86623857*	*< 0.0001*	*significant*
C^2	*0.030753616*	*1*	*0.030753616*	*36.70582206*	*0.0001*	*significant*
Residual	0.008378403	10	0.00083784			
Cor Total	0.822314557	14				

The model **F-value** of **242.86** implies the model is significant. There is only a **0.01%** chance that a model **F-Value** this large could occur due to noise. Table (5.20) shows the statistical summery of the response model. The "**Pred R-Squared**" of **0.9739** is in reasonable agreement with the "**Adj R-Squared**" of **0.9857**. "**Adeq Precision**" measures the signal to noise ratio. A ratio greater than **4** is desirable. The ratio of **44.634** indicates an adequate signal. The value of "**Adj R-Squared**" implies that **98.57%** of the variability in the response is explained by model terms listed in table (5.19).

The remaining percentage, **1.43%** of the variability in the response is due to random error term "ε" representing whatever inaccuracy such a model might have in approximating the actual simulation response.

Table 5.20: Summery statistics of "**Response 2**" regression model of table (5.14)

Std. Dev.	0.028945471	**R-Squared**	0.989811195
Mean	0.41731968	**Adj R-Squared**	0.985735673
C.V. %	6.936042599	**Pred R-Squared**	0.973933536
PRESS	0.021434833	**Adeq Precision**	44.63447779

The Variance Inflation Factors (VIF) values shown in table (5.21) indicate that multicollinearity among the response model terms is not present. All VIF values are small and less than 10.

Table5.21: Post-ANOVA informationfor the individual terms of "**Response 2**" of table (5.14)

	Coefficient		**Standard**	**95% CI**	**95% CI**	
Factor	**Estimate**	**df**	**Error**	**Low**	**High**	**VIF**
Intercept	0.353284673	1	0.012944808	0.324441843	0.382127502	
A-PT	0.151147542	1	0.009153362	0.130752582	0.171542503	1
C-MFS	0.221810909	1	0.009153362	0.201415949	0.242205869	1
AC	0.088547974	1	0.010233769	0.065745715	0.111350233	1
C^2	0.096052511	1	0.015854087	0.060727403	0.131377619	1

5.3.2.3. Response Model Diagnostics

Figure (5.9) shows that total cost response for tellers service channel is roughly normally distributed since the points lay on the normal line or very close to it.

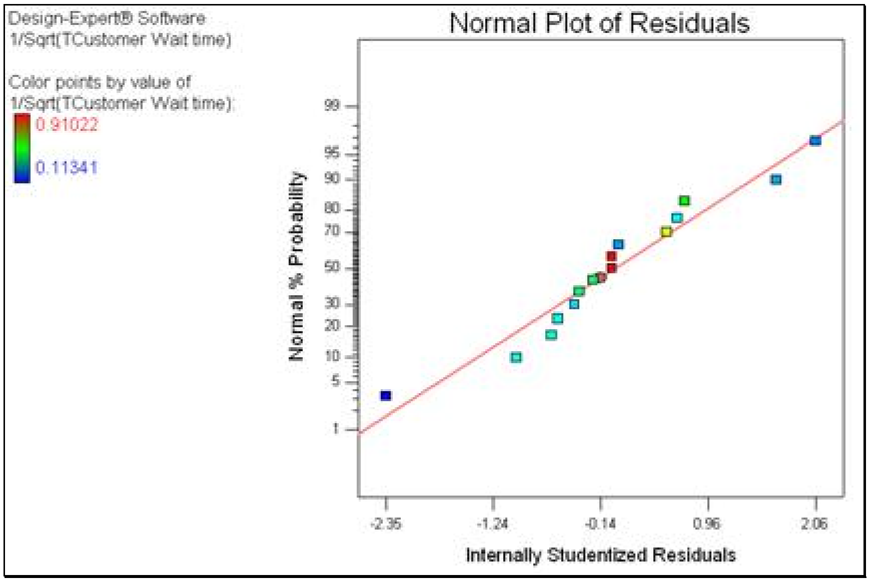


Figure 5.9: Normal plot of residuals for "**Response 2**" in table (5.14)

The fit of predicted versus actual data (from the simulation) is shown in Fig. (5.10). The points are scattered randomly around the zero line with a band of ±2.5. There is no pattern here that suggests the model needs to be changed.

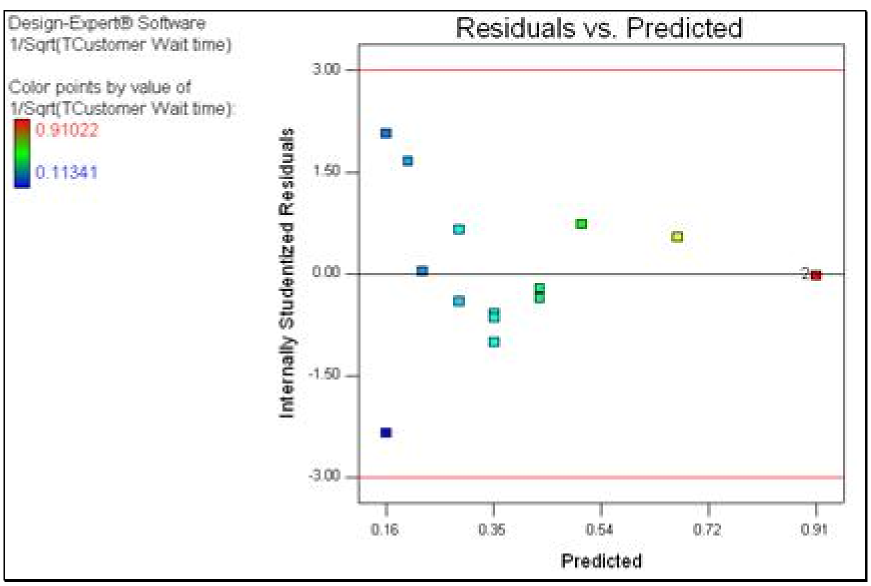


Figure 5.10: Residuals vs predicted plot for "**Response 2**" in table (5.14)

5.3.2.4. Comparing Predicted to Simulated Response

Table (5.22) shows a comparison of the predicted response estimated from the regression model to the simulated response obtained from the simulation experiment. The two responses are close enough to accept that Tellers Channel Customers Waiting Time regression model (5.5) can be used to approximate the simulation response"**Response 2**".

Table 5.22: Comparing predicted to simulated response "**Response 2**" in table (5.14)

Design Point		Factor 1	Factor 2	Factor 3	Customers Waiting Time (Minutes)	
No	Type	A:PT (Number)	B:TT (Number)	C:MFS (%)	Simulated Response	Predicted Response
1	Factorial	3	0	20	77.75	36.763
2	Factorial	5	0	20	12.655	11.880
3	Factorial	3	2	20	22.623	36.763
4	Factorial	5	2	20	10.797	11.880
5	Factorial	3	0	60	5.573	5.371
6	Factorial	5	0	60	1.207	1.205
7	Factorial	3	2	60	5.493	5.371
8	Factorial	5	2	60	1.207	1.205
9	Axial	3	1	40	17.019	24.474
10	Axial	5	1	40	3.671	3.930
11	Axial	4	0	40	9.335	8.012
12	Axial	4	2	40	8.74	8.012
13	Axial	4	1	20	19.146	19.316
14	Axial	4	1	60	2.131	2.220
15	Center	4	1	40	8.829	8.012

5.3.3. Total Cost Response of ATM Service Channel "Response 3"

5.3.3.1. Response Model Equation

The final equation in terms of actual factors for the expected total cost of ATM service channel is shown in model equation (5.6):

1/Sqrt(ATM Total Cost)	=	**Model (5.6)**
0.011893895		
0.002088997	* MFS	
2.69093E-05	* MFS^2	
Sig.<0.0001	F=4704.63	Adj. R(SQR)= 0.9985

5.3.3.2. Response Model Analysis of Variance

The response column titled "**Response 3**" data in table (5.14) from the CCD experiment is analyzed by use of an Analysis of Variance (ANOVA). An ANOVA table is constructed as shown in table (5.23). Factor terms shown in table (5.23) are found to be significant meanwhile the insignificant terms were excluded by DX software backward regression elimination procedure. This is seen by looking at the column marked "**Prob>F**". Small numbers for "**Prob>F**" (*should be below **0.05***) mean the effect is significant. Only factor terms "**C**", and "$\mathbf{C^2}$" has a dramatic effect on the response of ATM service channel total cost. This means that only MFS usage will affect the ATM channel total cost during rush days.

Table 5.23: ANOVA for ATM channel total cost response "**Response 3**" of table (5.14)

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Sig.
Model	**0.072355684**	**2**	**0.036177842**	**4704.63839**	**< 0.0001**	**significant**
C-MFS	*0.071969492*	*1*	*0.071969492*	*9359.055526*	*< 0.0001*	*significant*
C^2	*0.000386193*	*1*	*0.000386193*	*50.22125364*	*< 0.0001*	*significant*
Residual	*9.22779E-05*	*12*	*7.68982E-06*			
Cor Total	*0.072447962*	*14*				

The model **F-value** of **4704.63** implies the model is significant. There is only a **0.01%** chance that a model **F-Value** this large could occur due to noise. The larger the **F-value**, the more likely that the variance contributed by the model is significantly larger than random error. Table (5.24) shows the statistical summery of the response model. The "**Pred R-Squared**" of 0.9980 is in reasonable agreement with the "**Adj R-Squared**" of 0.9985. "**Adeq Precision**" measures the signal to noise ratio. A ratio greater than **4** is desirable. The ratio of **136.814** indicates an adequate signal. The value of "**Adj R-Squared**" implies that **99.85%** of the variability in the response is explained by model terms listed in table (5.23).

The remaining percentage, **0.15%** of the variability in the response is due to random error term "ε" representing whatever inaccuracy such a model might have in approximating the actual simulation response.

Table 5.24: Summery statistics of "**Response 3**" regression model of table (5.14)

Std. Dev.	0.002773053	**R-Squared**	0.998726287
Mean	0.145684479	**Adj R-Squared**	0.998514002
C.V. %	1.903465105	**Pred R-Squared**	0.998009824
PRESS	0.000144184	**Adeq Precision**	136.8141478

The Variance Inflation Factors (VIF) values shown in table (5.25) indicate that multicollinearity among the response model terms is not present. All VIF values are small and less than 10.

Table5.25: Post-ANOVA informationfor the individual terms of "**Response 3**" of table (5.14)

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.138508662	1	0.001240147	0.135806614	0.141210711	
C-MFS	0.084834835	1	0.000876916	0.082924198	0.086745471	1
C^2	0.010763725	1	0.001518864	0.007454405	0.014073045	1

5.3.3.3. Response Model Diagnostics

Figure (5.11) shows that Total Cost response for ATM service channel is roughly normally distributed since the points lay on the normal line or very close to it.

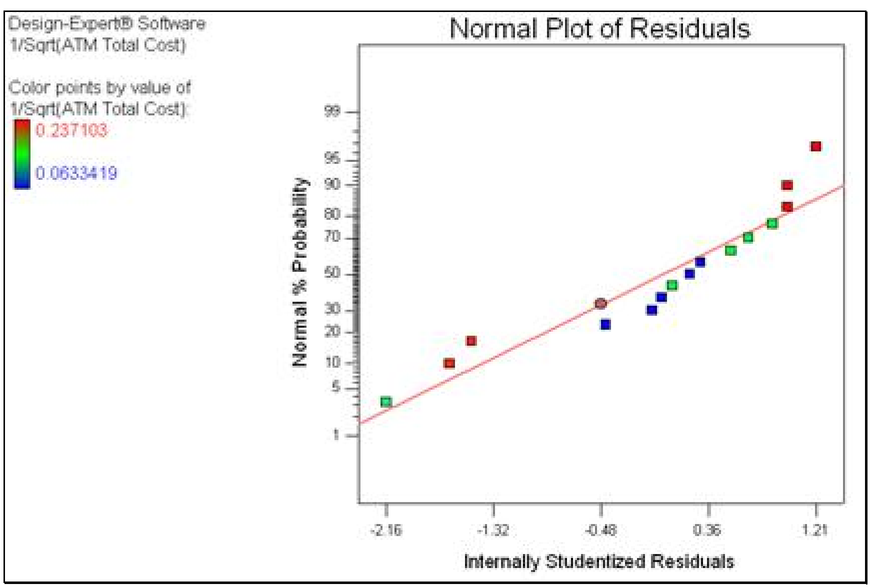


Figure 5.11: Normal plot of residuals for "**Response 3**" in table (5.14)

The fit of predicted versus actual data (from the simulation) is shown in Fig. (5.12). Watch for residuals increasing in size as the predicted values increase (i.e. a megaphone shape "<"), thus variance of ATM Channel Total Cost data during rush days exhibits constant variance.

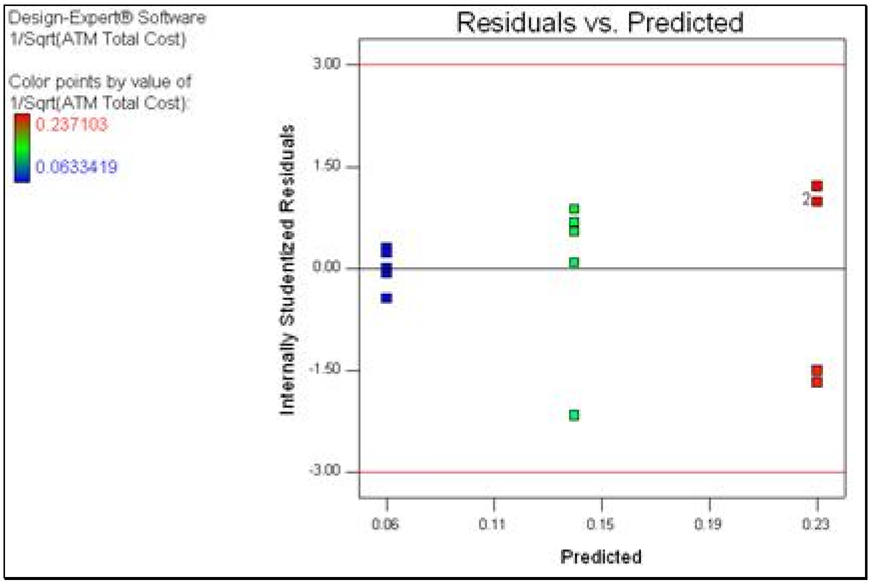


Figure 5.12: Residuals vs predicted plot for "**Response 3**" in table (5.14)

5.3.3.4. Comparing Predicted to Simulated Response

Table (5.26) shows a comparison of the predicted response estimated from the regression model to the simulated response obtained from the simulation experiment. The two responses are close enough to accept that ATM Channel Total Cost regression model (5.6) can be used to approximate the simulation response "**Response 3**".

Table 5.26: Comparing predicted to simulated response "**Response 3**" in table (5.14)

Design Point		Factor 1	Factor 2	Factor 3	ATM Channel Total Cost ($/Day)	
No	Type	A:PT (Number)	B:TT (Number)	C:MFS (%)	Simulated Response	Predicted Response
1	Factorial	3	0	20	235.343	240.836
2	Factorial	5	0	20	249.24	240.836
3	Factorial	3	2	20	236.826	240.836
4	Factorial	5	2	20	242.258	240.836
5	Factorial	3	0	60	18.912	18.246
6	Factorial	5	0	60	17.871	18.246
7	Factorial	3	2	60	18.841	18.246
8	Factorial	5	2	60	17.871	18.246
9	Axial	3	1	40	50.546	52.209
10	Axial	5	1	40	56.414	52.209
11	Axial	4	0	40	51.972	52.209
12	Axial	4	2	40	51.133	52.209
13	Axial	4	1	20	240.881	240.836
14	Axial	4	1	60	17.788	18.246
15	Center	4	1	40	50.882	52.209

5.3.4. Waiting Time Response of ATM Service Channel "Response 4"

5.3.4.1. Response Model Equation

The final equation in terms of actual factors for the expected ATM customer waiting time during rush days is shown in model equation (5.7):

Sqrt(ATM Customer Wait Time + 2.00) =	**Model (5.7)**
6.89087885	
*-0.183974336 * MFS*	
*0.001574887 * MFS^2*	
Sig.<0.0001 F=8999.33 Adj. R(SQR)= 0.9992	

5.3.4.2. Response Model Analysis of Variance

The response column titled "**Response 4**" data in table (5.14) from the CCD experiment is analyzed by use of an Analysis of Variance (ANOVA). An ANOVA table is constructed as shown in table (5.27). Factor terms shown in table (5.27) are found to be significant meanwhile the insignificant terms were excluded by DX software backward regression elimination procedure. This is seen by looking at the column marked "**Prob>F**".

Small numbers for "**Prob>F**" (*should be below* ***0.05***) mean the effect is significant. Only factor terms "**C**", and "**C^2**" has a dramatic effect on the response of ATM customer waiting time. This means that only MFS usage will affect the ATM channel customers waiting time during rush days.

Table 5.27: ANOVA for ATM channel total cost response "**Response 4**" of table (5.14)

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Sig.
Model	**14.77111493**	**2**	**7.385557463**	**8999.339673**	**< 0.0001**	**significant**
C-MFS	*13.44830558*	*1*	*13.44830558*	*16386.82937*	*< 0.0001*	*significant*
C^2	*1.322809346*	*1*	*1.322809346*	*1611.849978*	*< 0.0001*	*significant*
Residual	0.009848133	12	0.000820678			
Cor Total	14.78096306	14				

The model **F-value** of 8999.33 implies the model is significant. There is only a **0.01%** chance that a model **F-Value** this large could occur due to noise. The larger the **F-value**, the more likely that the variance contributed by the model is significantly larger than random error. Table (5.28) shows the statistical summery of the response model. The "**Pred R-Squared**" of 0.9989 is in reasonable agreement with the "**Adj R-Squared**" of 0.9992. "**Adeq Precision**" measures the signal to noise ratio. A ratio greater than **4** is desirable. The ratio of **181.034** indicates an adequate signal. The value of "**Adj R-Squared**" implies that **99.92%** of the variability in the response is explained by model terms listed in table (5.27).

The remaining percentage, **0.08%** of the variability in the response is due to random error term "ε" representing whatever inaccuracy such a model might have in approximating the actual simulation response.

Table 5.28: Summery statistics of "**Response 4**" regression model of table (5.14)

Std. Dev.	0.028647473	**R-Squared**	0.999333729
Mean	2.471693575	**Adj R-Squared**	0.999222683
C.V. %	1.159022028	**Pred R-Squared**	0.998958951
PRESS	0.015387707	**Adeq Precision**	181.0349655

The Variance Inflation Factors (VIF) values shown in table (5.29) indicate that multicollinearity among the response model terms is not present. All VIF values are small and less than 10.

Table5.29: Post-ANOVA informationfor the individual terms of "**Response 4**" of table (5.14)

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	2.051723839	1	0.012811539	2.023809892	2.079637785	
C-MFS	-1.159668296	1	0.009059126	-1.179406437	-1.139930156	1
C^2	0.629954605	1	0.015690867	0.595767142	0.664142067	1

5.3.4.3. Response Model Diagnostics

Figure (5.13) shows ATM customers waiting time response is roughly normally distributed since the points lay on the normal line or very close to it.

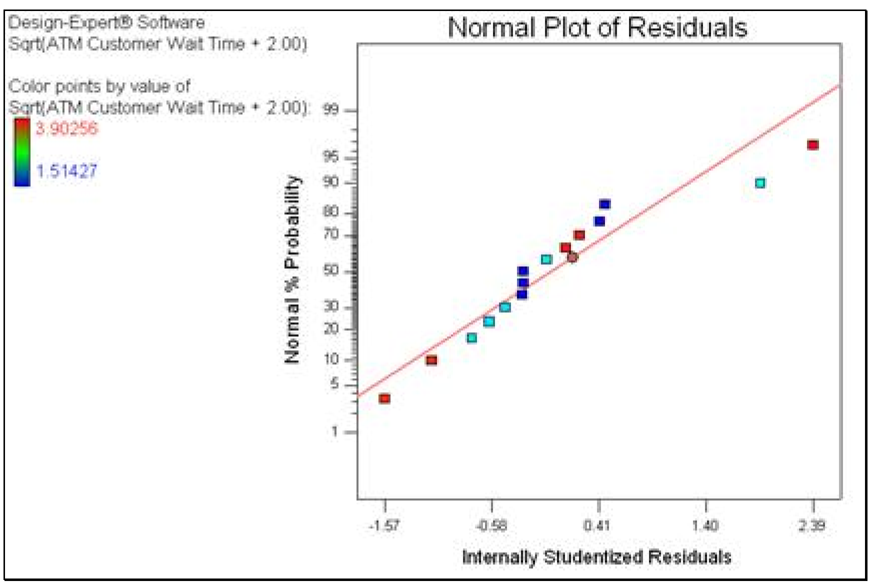


Figure 5.13: Normal plot of residuals for "**Response 4**" in table (5.14)

The fit of predicted versus actual data (from the simulation) is shown in Fig. (5.14). Watch for residuals increasing in size as the predicted values increase (i.e. a megaphone shape "<"), thus variance of ATM customers waiting time data exhibits constant variance.

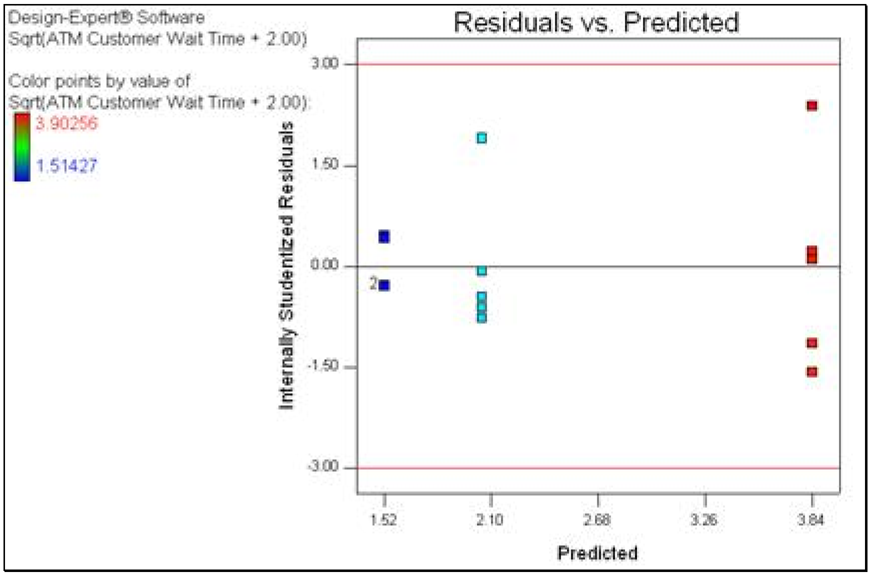


Figure 5.14: Residuals vs predicted plot for "**Response 4**" in table (5.14)

5.3.4.4. Comparing Predicted to Simulated Response

Table (5.30) shows a comparison of the predicted response estimated from the regression model to the simulated response obtained from the simulation experiment. The two responses are close enough to accept that ATM Channel Waiting Time regression model (5.7) can be used to approximate the simulation response "**Response 4**".

Table 5.30: Comparing predicted to simulated response "**Response 4**" in table (5.14)

Design Point		Factor 1	Factor 2	Factor 3	ATM Customer Wait Time (Minutes)	
No	Type	A:PT (Number)	B:TT (Number)	C:MFS (%)	Simulated Response	Predicted Response
1	Factorial	3	0	20	12.448	12.756
2	Factorial	5	0	20	13.230	12.756
3	Factorial	3	2	20	12.531	12.756
4	Factorial	5	2	20	12.801	12.756
5	Factorial	3	0	60	0.353	0.316
6	Factorial	5	0	60	0.294	0.316
7	Factorial	3	2	60	0.349	0.316
8	Factorial	5	2	60	0.294	0.316
9	Axial	3	1	40	2.129	2.209
10	Axial	5	1	40	2.412	2.209
11	Axial	4	0	40	2.202	2.209
12	Axial	4	2	40	2.162	2.209
13	Axial	4	1	20	12.776	12.756
14	Axial	4	1	60	0.293	0.316
15	Center	4	1	40	2.146	2.209

5.3.5. Net Profit Response of Using MFS Channel "Response 5"

5.3.5.1. Response Model Equation

The final equation in terms of actual factors for the expected profit response that might be generated during rush days as a result for using MFS by a portion of the current customer base is shown in model equation (5.8):

1/Sqrt(Net Profit)	***=***	**Model (5.8)**
0.318676454		
-0.00584155	**** MFS***	
4.4066E-05	**** MFS^2***	
Sig.<0.0001	**F=54773.54**	**Adj. R(SQR)= 0.9998**

5.3.5.2. Response Model Analysis of Variance

The response column titled "**Response 5**" data in table (5.14) from the CCD experiment is analyzed by use of an Analysis of Variance (ANOVA). An ANOVA table is constructed as shown in table (5.31). Factor term shown in table (5.31) is found to be significant meanwhile the insignificant terms were excluded by DX software backward regression elimination procedure. This is seen by looking at the column marked "**Prob>F**". Small numbers for "**Prob>F**" (*should be below **0.05***) mean the effect is significant. Only factor term "**C**", and "$\mathbf{C^2}$" has a dramatic effect on the response of net profit to be generated during rush days. This means that only MFS usage will affect the net profit variable.

Table 5.31: ANOVA for ATM channel total cost response "**Response 5**" of table (5.14)

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Sig.
Model	**0.022496072**	**2**	**0.011248036**	**54773.54299**	**< 0.0001**	**significant**
C-MFS	*0.021460439*	*1*	*0.021460439*	*104503.9576*	*< 0.0001*	*significant*
C^2	*0.001035633*	*1*	*0.001035633*	*5043.128364*	*< 0.0001*	*significant*
Residual	2.46426E-06	12	2.05355E-07			
Cor Total	0.022498536	14				

The model **F-value** of **54773.54** implies the model is significant. There is only a **0.01%** chance that a model **F-Value** this large could occur due to noise. The larger the

F-value, the more likely that the variance contributed by the model is significantly larger than random error. Table (5.32) shows the statistical summery of the response model. The "**Pred R-Squared**" of 0.9998 is in reasonable agreement with the "**Adj R-Squared**" of 0.9998. "**Adeq Precision**" measures the signal to noise ratio. A ratio greater than **4** is desirable. The ratio of **457.173** indicates an adequate signal. The value of "**Adj R-Squared**" implies that **99.98%** of the variability in the response is explained by model terms listed in table (5.31).

Table 5.32: Summery statistics of "**Response 5**" regression model of table (5.14)

Std. Dev.	0.000453161	**R-Squared**	0.99989047
Mean	0.167270969	**Adj R-Squared**	0.999872215
C.V. %	0.270914568	**Pred R-Squared**	0.999828859
PRESS	3.85041E-06	**Adeq Precision**	457.1738348

The remaining percentage, **0.02%** of the variability in the response is due to random error term "ε" representing whatever inaccuracy such a model might have in approximating the actual simulation response.

The Variance Inflation Factors (VIF) values shown in table (5.33) indicate that multicollinearity among the response model terms is not present. All VIF values are small and less than 10.

Table5.33: Post-ANOVA informationfor the individual terms of "**Response 5**" of table (5.14)

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.155520037	1	0.00020266	0.155078479	0.155961595	
C-MFS	-0.046325413	1	0.000143302	-0.046637642	-0.046013184	1
C^2	0.017626398	1	0.000248207	0.017085602	0.018167194	1

5.3.5.3. Response Model Diagnostics

Figure (5.15) shows that net profit response is roughly normally distributed since the points lay on the normal line or close to it.

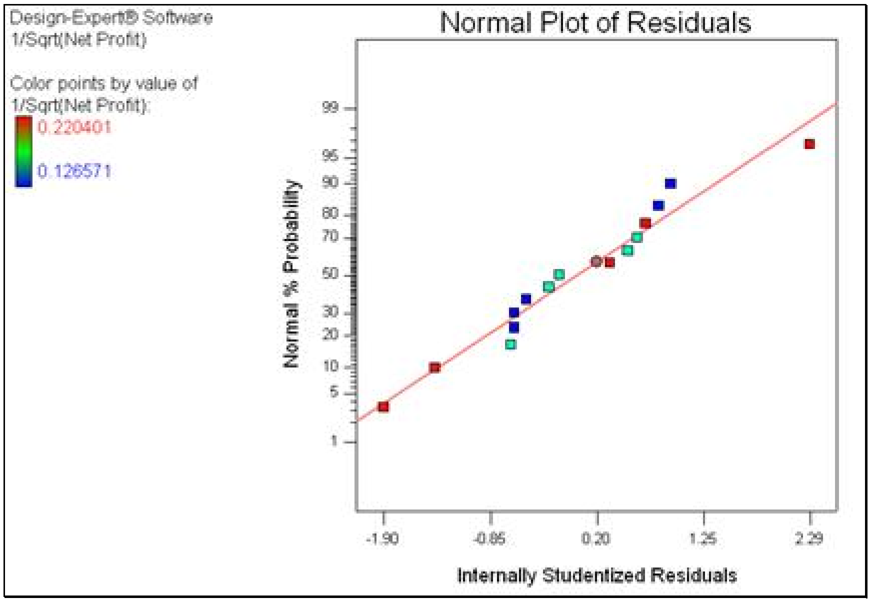


Figure 5.15: Normal plot of residuals for "**Response 5**" in table (5.14)

The fit of predicted versus actual data (from the simulation) is shown in Fig. (5.16). Watch for residuals increasing in size as the predicted values increase (i.e. a megaphone shape "<"), thus variance of Net Profit data exhibits constant variance.

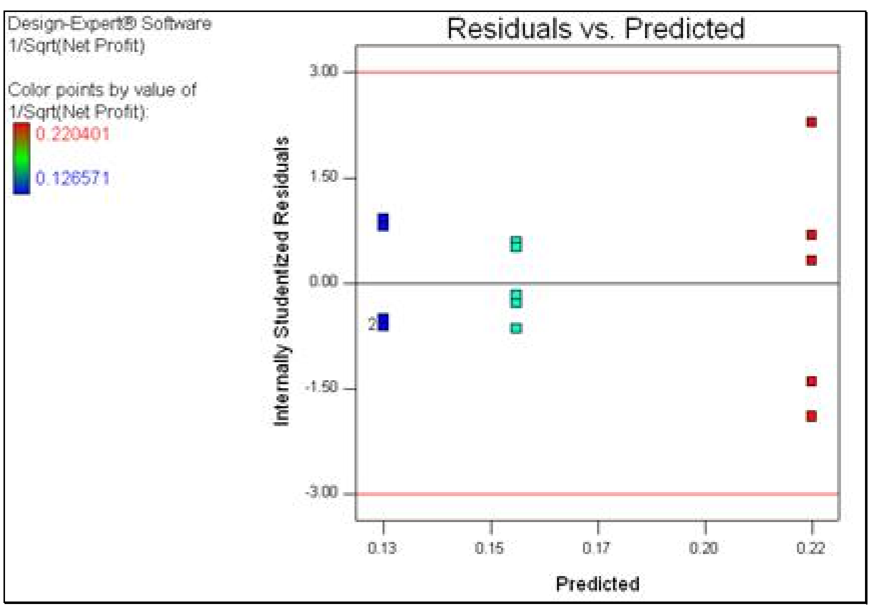


Figure 5.16: Residuals vs predicted plot for "**Response 5**" in table (5.14)

5.3.5.4. Comparing Predicted to Simulated Response

Table (5.34) shows a comparison of the predicted response estimated from the regression model to the simulated response obtained from the simulation experiment. The two responses are close enough to accept that Net Profit regression model (5.8) can be used to approximate the simulation response "**Response 5**" for a rush day.

Table 5.34: Comparing predicted to simulated response "**Response 5**" in table (5.14)

Design Point		Factor 1	Factor 2	Factor 3	MFS Net Profit ($/Day)	
No	**Type**	**A:PT** (Number)	**B:TT** (Number)	**C:MFS** (%)	**Simulated Response**	**Predicted Response**
1	Factorial	3	0	20	20.736	20.760
2	Factorial	5	0	20	20.709	20.760
3	Factorial	3	2	20	20.586	20.760
4	Factorial	5	2	20	20.868	20.760
5	Factorial	3	0	60	61.810	62.175
6	Factorial	5	0	60	62.421	62.175
7	Factorial	3	2	60	61.856	62.175
8	Factorial	5	2	60	62.421	62.175
9	Axial	3	1	40	41.218	41.345
10	Axial	5	1	40	41.237	41.345
11	Axial	4	0	40	41.405	41.345
12	Axial	4	2	40	41.383	41.345
13	Axial	4	1	20	20.907	20.760
14	Axial	4	1	60	62.373	62.175
15	Center	4	1	40	41.485	41.345

5.4. IMPACT OF MFS EARLY ADOPTERS

This section describes the analysis of the basic simulation models for normal and rush days configurations compared to the MFS-based simulation models in terms of MFS usage effect on the current branch office service delivery channels for the responses of interest being explained previously in this study. Detailed analysis for the impact of MFS early adopters is performed by using the optimization through RSM and Meta-Models techniques in order to locate the sweet spot area with multiple responses that minimize costs, maximize profits, and target specific levels of customers waiting time for each day type (i.e. normal and rush days).

5.4.1. Analyzing the Normal Day Configuration

The responses of the basic simulation model were compared to the MFS-based simulation model responses. The results shown in table (5.35) indicates that the **36.5%** of MFS early adopters will reduce customers waiting time to **(4.91 minutes)** on average with a total cost of **(165.657 $/Day)**, which is about half the total cost of tellers area without using MFS. At this level of MFS usage, there is a possibility to generate **(16.041 $/Day)** net profit from the *current* customers base during normal days.

Table 5.35: Comparing basic and MFS-based simulation models responses for the current normal day configuration

Simulation Model	PT (Number)	TT (Number)	MFS (%)	Teller Area Total Cost ($/Day)	T_Customer Wait Time (Minutes)	Net Profit ($/Day)
Basic	2	1	0%	350.929	17.988	-
MFS	2	1	36.5%	165.657	4.91	16.041

DX software was used for locating the sweet spot area with multiple responses that satisfies the constraints listed in table (5.36) and help to find the combination of input factor values that *optimizes* responses in order to achieve the required goals.

Table 5.36: Constraints and goals to be achieved for a normal day type

Name	Goal	Lower Limit	Upper Limit
PT (Number)	is in range	1	3
TT (Number)	is in range	0	2
MFS (%)	is equal to 36.50	20	60
Teller Area Total Cost ($/Day)	minimize	112.47	1131.51
Customer Wait Time – Tellers Area (Minutes)	is in range	5	10
Net Profit ($/Day)	maximize	9.11	26.80

The output of DX shows that the stationary point of the fitted response surfaces **X_o = (PT, TT, MFS) = (1.87, 0, 36.5)** which yields predicted mean responses of **Y_o = (Y1, Y2, Y3) = (122.82, 7.67, 15.92)** a maximum desirability in the experimental region as shown in table (5.37) with a solution desirability of **85.3%.**

Table 5.37: The DX optimization process output for normal day constraints and goals

Solution Number	PT (Number)	TT (Number)	MFS (%)	Y1: Teller Area Total Cost ($/Day)	Y2: T_Customer Wait Time (Minutes)	Y3: Net Profit ($/Day)	Solution Desirability (%)
1	***1.87***	***0***	***36.5***	***122.82***	***7.67***	***15.92***	***85.3***
2	1.85	0	36.5	123.39	7.91	15.92	85.2
3	1.72	0	36.5	128.57	9.85	15.92	84.6
4	1.22	1.99	36.5	197.88	8.57	15.92	69.1

Desirability is an objective function that ranges from zero outside of the limits to one at the goal (Statease, n.d.). Its value is completely dependent on how closely the lower and upper limits are set relative to the actual optimum. The goal of optimization is to find a *good* set of conditions that will meet all the goals, not to get to a desirability value of **100%**. Desirability is simply a mathematical method to find the optimum. If we take the combination of nearest integer values of **PT** and **TT** as **X = (PT, TT, MFS) = (2, 0, 36.5)**, the output responses will be **Y = (Y1, Y2, Y3) = (119.23, 6.01, 15.92)** which is very close to $\mathbf{Y_o}$ as **X** is very close to $\mathbf{X_o}$ and lays within the solution desirability region as shown in Fig. (5.17) which leads us to conclude that **X** is the optimal solution for a normal day configuration.

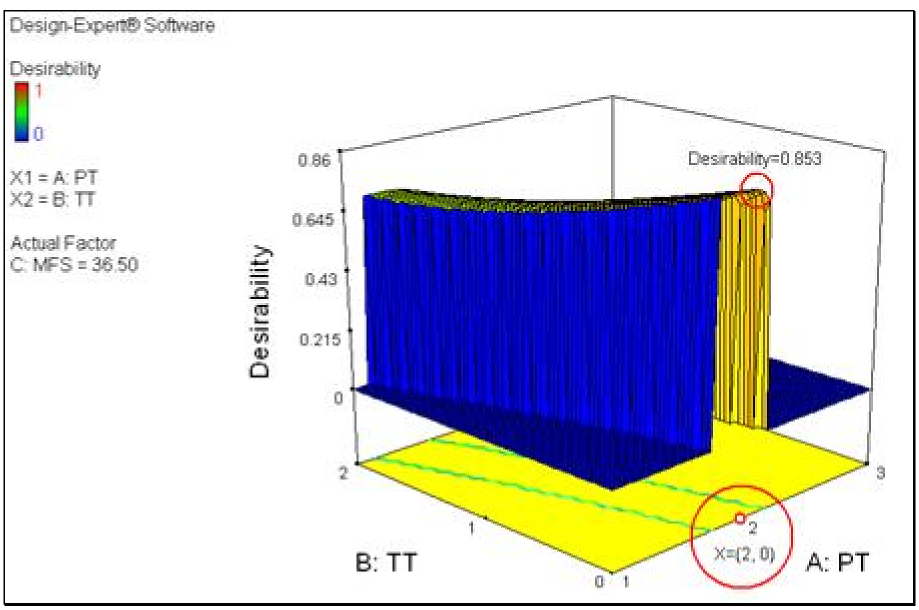


Figure 5.17: Desirability plot of normal day solutions

The simulation model of the considered combinations of input factor values is then run and the results are given in table (5.38). It is noted that simulation model responses are very close to meta-model *predicted* responses, which is a secondary validation step for the meta-models.

Table 5.38: Comparing meta-model to simulation model responses for a normal day

Model Type	PT (Number)	TT (Number)	MFS (%)	Tellers Channel Total Cost ($/Day)	Tellers Channel Customer Wait Time (Minutes)	Net Profit ($/Day)
Meta-Model (Regression)	2	0	36.5	119.23	6.01	15.92
Simulation	2	0	36.5	122.62	5.00	16.03

Figures (5.18), (5.19), and (5.20) shows the response surface plots of the tellers area total cost, customers waiting time, and net profit responses respectively at the level of **36.5%** of customers are using MFS. These plots confirms the results of DX optimization output for the optimal solution as the lowest cost of tellers area seems to be achieved at **2** permanent tellers only with a waiting time between **5** and **10** minutes. Figure (5.20) explains only the amount of net profit that might be generated at this level of MFS usage which is constant at all points since net profit response is a function of MFS usage factor only as can be seen from model equation (5.3).

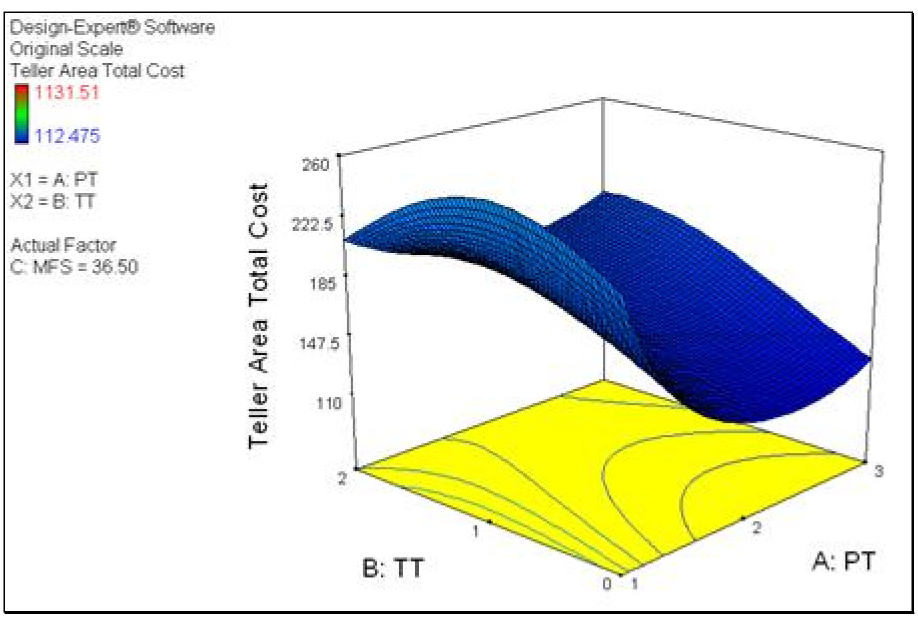


Figure 5.18: Total cost response of tellers channel during normal day type

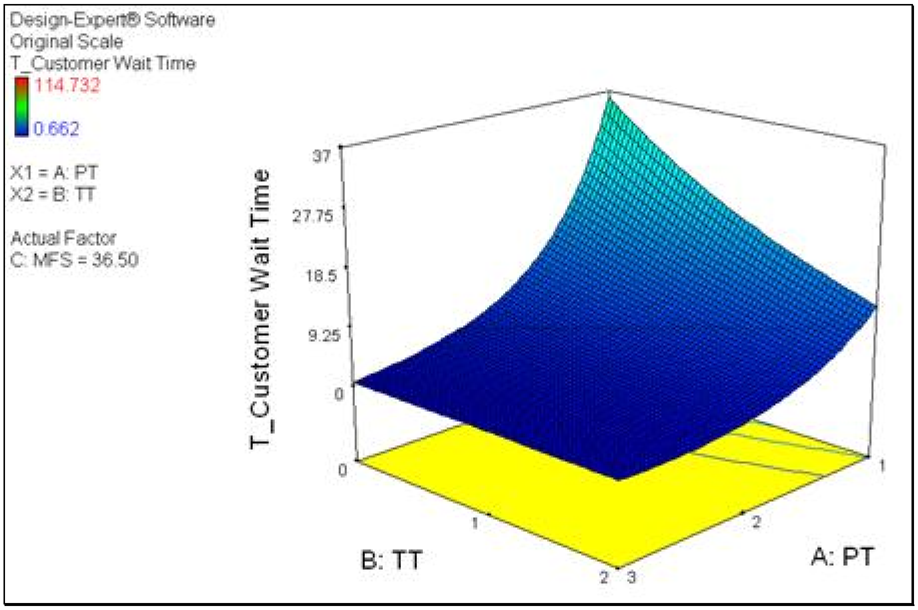


Figure 5.19: Customers waiting time response of tellers channel during normal day type

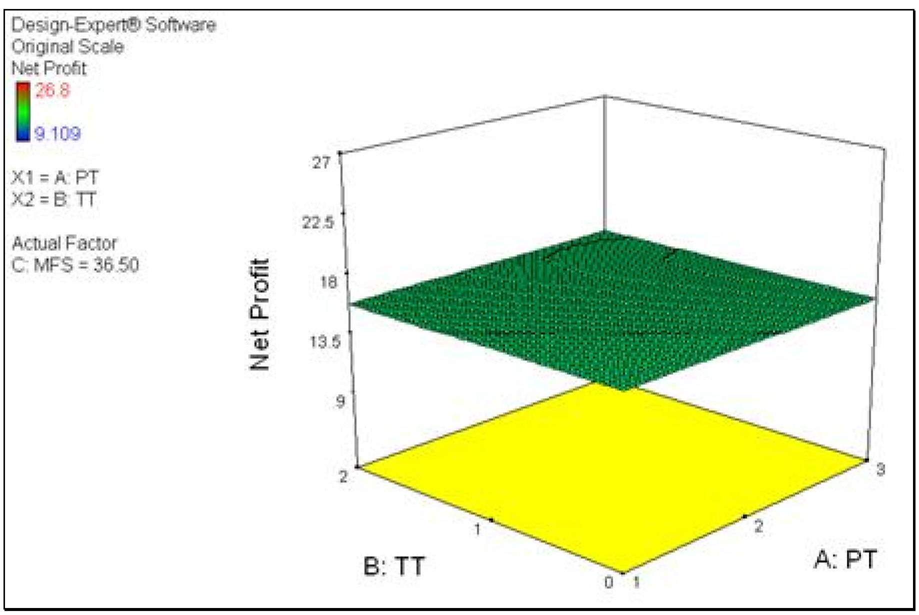


Figure 5.20: Net profit response that might be generated during normal days

5.4.2. Analyzing the Rush Day Configuration

The responses of the basic simulation model were compared to the MFS-based simulation model responses. The results shown in table (5.39) indicates that the **36.5%** of MFS early adopters will reduce customers waiting time in the tellers area to

(10.82 minutes) on average with a total cost of **(487.30 $/Day)**, which is much less than the total cost of tellers area without using MFS **(1735.47 $/Day)**. In addition, ATM service delivery channel cost might reach**(76.08 $/Day)** with an average service time of **(3.52 minutes)** which is again much less than current basic configuration. At this level of MFS usage, there is a possibility to generate **(38.01 $/Day)** net profit from the current customers base during rush days.

Table 5.39: Comparing basic and MFS-based models for the current rush day configuration

Simulation Model	PT (Number)	TT (Number)	MFS (%)	Teller Area Total Cost ($/Day)	T_Customer Wait Time (Minutes)	ATM Area Total Cost ($/Day)	ATM Customer Wait Time (Minutes)	Net Profit ($/Day)
Basic	4	1	0%	1735.47	43.03	486.52	26.33	-
MFS	4	1	36.5%	487.30	10.82	76.03	3.52	38.01

DX software was used for locating the sweet spot area with multiple responses that satisfies the constraints listed in table (5.40) and help to find the combination of input factor values that optimizes responses in order to achieve the required goals.

Table 5.40: Constraints and goals to be achieved for a rush day type

Name	Goal	Lower Limit	Upper Limit
PT (Number)	is in range	3	5
TT (Number)	is in range	0	2
MFS (%)	is equal to 36.50	20	60
Teller Area Total Cost ($/Day)	minimize	214.26	2562.28
Customer Wait Time – Tellers Area (Minutes)	is target = 10	10	15
ATM Area Total Cost ($/Day)	minimize	17.78	249.24
Customer Wait Time – ATM Area (Minutes)	is in range	0.29	13.23
Net Profit ($/Day)	maximize	20.59	62.42

The output of DX shows that the stationary point of the fitted response surfaces X_o **= (PT, TT, MFS) = (3.99, 0, 36.5)** which yields predicted mean responses of Y_o **= (Y1, Y2, Y3, Y4, Y5) = (449.43, 9.99, 65.04, 3.17, 37.10)** a maximum in the experimental region as shown in table (5.41) with a solution desirability of **86.865%.**

Table 5.41: The DX optimization process output for a rush day constraints and goals

Solution Number	X1: PT (Number)	X2: TT (Number)	X3: MFS (%)	Y1: Tellers Area Total Cost ($/Day)	Y2: Tellers Area Customer Wait time (Minutes)	Y3: ATM Area Total Cost ($/Day)	Y4: ATM Area Customer Wait Time (Minutes)	Y5: Net Profit ($/Day)	Solution Desirability (%)
1	***3.99***	***0***	***36.5***	***449.43***	***9.99***	***65.04***	***3.17***	***37.10***	***86.865***
2	3.99	0	36.5	450.62	9.99	65.04	3.17	37.10	86.861
3	3.99	0.12	36.5	452.21	10.00	65.04	3.17	37.10	86.857
4	3.99	0.13	36.5	452.41	9.99	65.04	3.17	37.10	86.851
5	3.99	0.25	36.5	455.03	10.00	65.04	3.17	37.10	86.843
6	3.99	0.57	36.5	462.41	10.00	65.04	3.17	37.10	86.814
7	3.99	1.55	36.5	484.96	9.99	65.04	3.17	37.10	86.725
8	3.99	1.74	36.5	489.48	10.00	65.04	3.17	37.10	86.701
9	3.99	1.82	36.5	491.34	9.99	65.04	3.17	37.10	86.690

If we take the combination of nearest integer values of **PT** and **TT** as **X = (PT, TT, MFS) = (4, 0, 36.5)**, the output responses will be **Y = (Y1, Y2, Y3, Y4, Y5) = (447.70, 9.93, 65.04, 3.17, 37.10)** which is very close to $\mathbf{Y_o}$ as **X** is very close to $\mathbf{X_o}$ and lays within the solution desirability region as shown in Fig. (5.21) which leads us to conclude that **X** is the optimal solution for a rush day configuration.

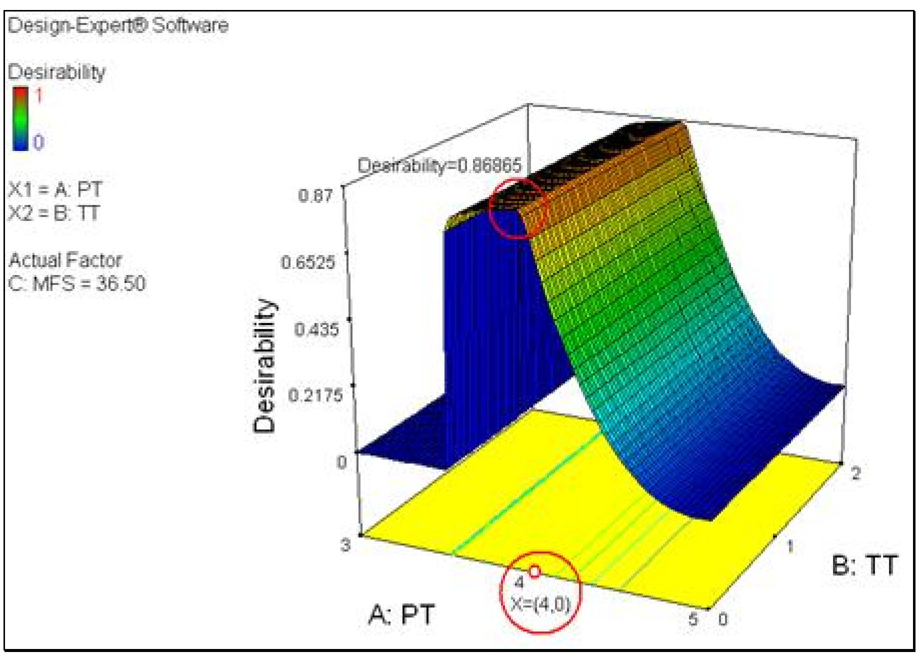


Figure 5.21: Desirability plot of rush day solutions

The simulation model of the considered combinations of input factor values is then run and the results are given in table (5.42). It is noted that simulation model responses are close to meta-model responses, which is a secondary validation step for the meta-models of the rush day configuration.

Table 5.42: Comparing meta-model to simulation model responses for a rush day

Model Type	PT (Number)	TT (Number)	MFS (%)	Tellers Channel Total Cost ($/Day)	Teller Channel Wait Time (Minutes)	ATM Channel Total Cost ($/Day)	ATM Channel Wait Time (Minutes)	Net Profit ($/Day)
Meta-Model (Regression)	4	0	36.5	447.70	9.93	65.04	3.17	37.10
Simulation	4	0	36.5	499.03	13.20	69.50	3.15	38.04

Figures (5.22), (5.23), (5.24), (5.25), and (5.26) shows the response surface plots of the tellers area total cost and customers waiting time, ATM area total cost and customers waiting time, and net profit responses respectively at the level of **36.5%** of customers are using MFS. These plots confirms the results of DX optimization output for the optimal solution as the lowest cost of tellers area seems to be achieved at **4** permanent tellers only with a waiting time between **5** and **15** minutes.

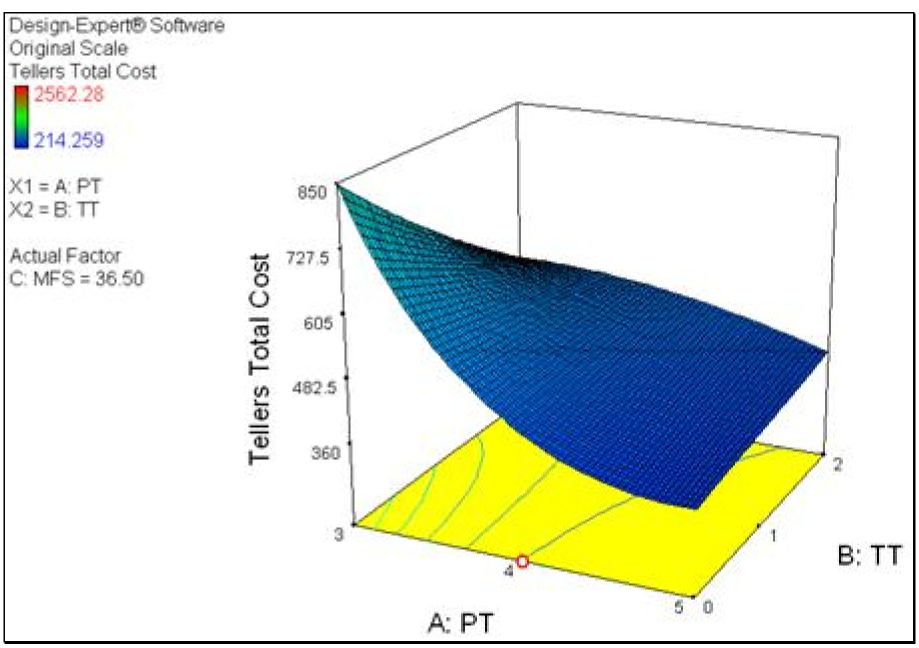


Figure 5.22: Total cost response of tellers channel during rush day type

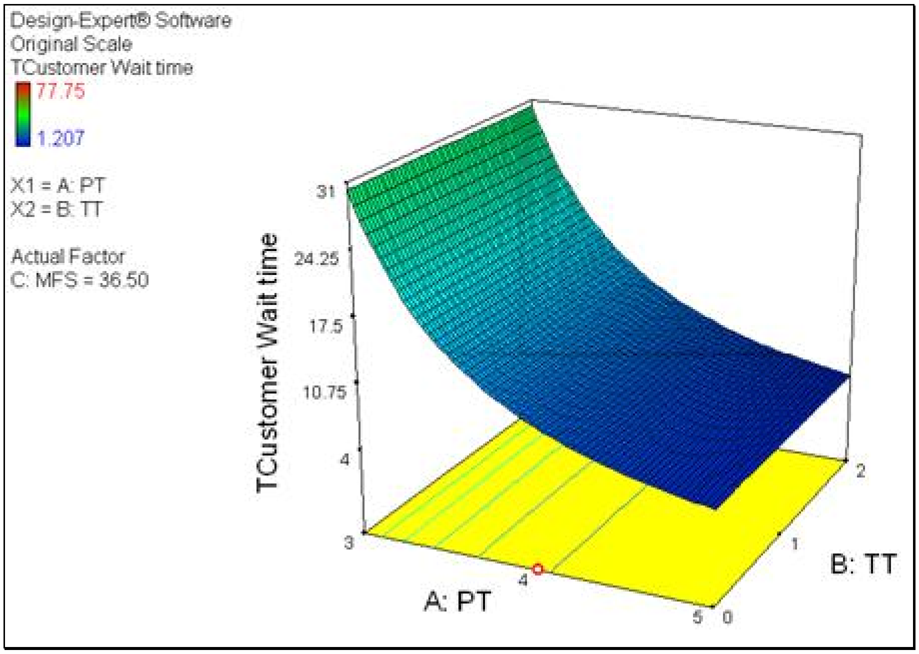


Figure 5.23: Customers waiting time response of tellers channel during rush day type

Figures (5.24), (5.25), and (5.26) explains that ATM channel total cost, ATM channel customers waiting time, and MFS net profit responses is constant at all points since these responses are a function of MFS usage factor only as can be seen from model equations (5.6), (5.7), and (5.8).

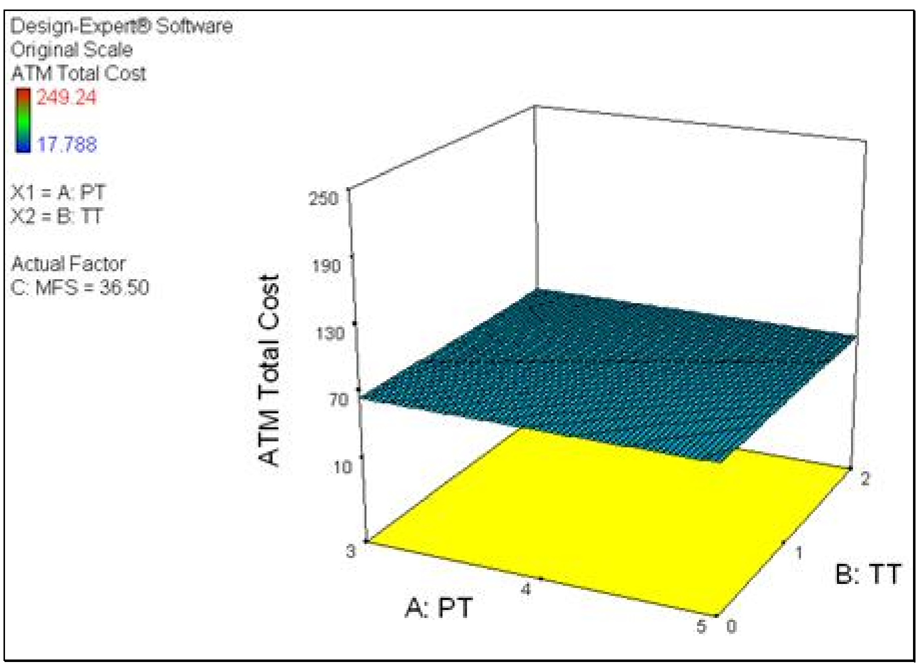


Figure 5.24: Total cost response of ATM channel during rush day type

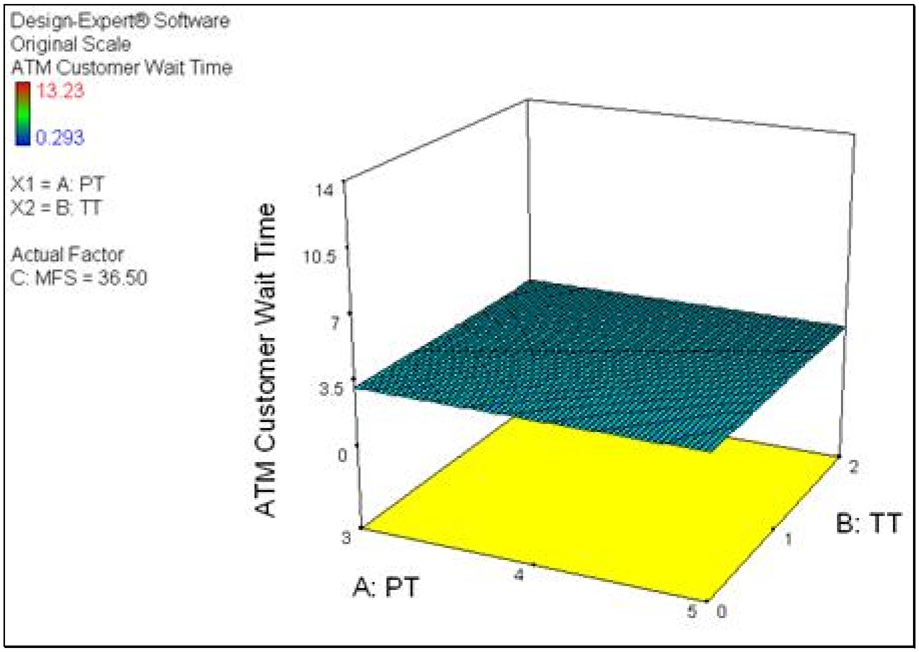


Figure 5.25: Customers waiting time response of ATM channel during rush day type

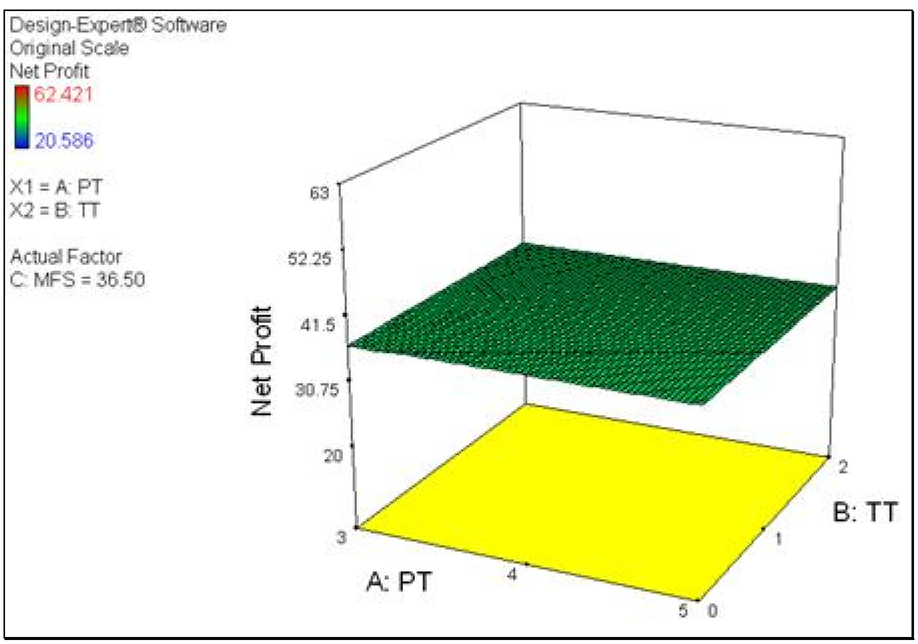


Figure 5.26: Net profit response that might be generated during rush days

5.5. CONCLUSION

The comparison for the predicted responses estimated from the regression models to the simulated responses obtained from the simulation experiment shows that these responses are close enough to accept the use of regression models for approximating the simulated responses. By using RSM as an optimization technique for the simulation experiment at the level of **36.5%** of customers is willing to use MFS, the study concluded that:

- § During Normal Days: Providing **2** permanent tellers with solution desirability of **85.30%** will help to achieve the required goals and constraints listed in table (5.36).
- § During Rush Days: It has also be shown that providing 4 permanent tellers with a solution desirability of **86.86%** will lead to the required goals and constraints listed in table (5.40).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

This chapter consists of the following sections:

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. INTORDUCTION

The main objective of this research aims to evaluate banking servicing opportunities via cell phones as an opportunity for branchless banking operations that may reduce the cost of the delivered services, improve customer satisfaction, and probably develop new sources for revenue. This chapter will consolidate the main results of the previous chapters in the light of research problem and objectives. Research recommendations will be directed towards promoting the adoption and implementation of MFS in Palestine.

6.2. CONCLUSIONS

Banking will no longer be constrained to conventional service channels. Mobile Financial Services (MFS) are new phenomena in the world of M-Commerce which helps customers to interact with a bank via a mobile device and makes banking virtually anywhere on a real-time basis a reality. MFS can be divided into two sub-categories: *Mobile Payment (M-Payment)* and *Mobile Banking (M-Banking)*. The advantage for the customers lies in the fact that they does not need to carry cash. Therefore, MFS can be seen as a promising M-Commerce application.

If implemented proficiently, MFS can help financial institutions and banks in Palestine to improve customer acquisition and customer retention, reduce total service costs for costly branch offices by migrating simple transactions away from these branches.

This study has shown how MFS may affect PIB operations in Khanyounis branch during normal and rush days. The simulation has been valuable in providing a flexible environment in which to model PIB for Khanyounis branch and gather information about the arrival patterns and key performance indicators which were necessary for running the simulation experiment and applying RSM as an optimization technique. The RSM is used to find the optimum levels of the considered factors to ensure a well-designed physical system.

By simulating the behavior of the queuing systems in the bank for both types of days at the level of **36.5%** of customers are willing to use MFS, the study concluded that:

- During Normal Days: Providing **2** permanent tellers with solution desirability of **85.30%** will help to achieve the minimum average of customers waiting time **(**6.01 **Minutes)** for serving customers within **5** to **10** minutes at a total average cost for tellers service channel of **(**119.23 **$/Day)**, which is less than half of the total average cost for tellers area without using MFS, in addition for eliminating the need for temporary tellers during day hours to be ready. At this level of MFS usage, there is an opportunity to generate a maximum of **(15.92 $/Day)** net profit from the *current* customers base.

- During Rush Days: It has also be shown that providing 4 permanent tellers with a solution desirability of **86.86%** will lead to the required minimum average of customers waiting time **(**9.93 **Minutes)** as to serve customers within **10** to **15** minutes at a total average cost for tellers service channel of **(**447.70 **$/Day)**, which is much less than the total average cost for tellers area without using MFS **(**1735.47 **$/Day)**, in addition for eliminating the need for a temporary tellers during day hours to be ready. At this level of MFS usage, the total average cost and waiting time for ATM service channel will be reduced to **(**65.04 **$/Day)** and **(**3.17 **Minutes)** respectively which is again much less than the average cost and wait time for ATM area without using MFS. In addition, this level of MFS usage will allow for an opportunity of a maximum of **(37.10 $/Day)** net profit that might be generated from the *current* customers base.

Good utilization of MFS will help to find new methods for payments and money withdrawals as to overcome the difficulties appeared in Gaza Strip area resulting from the limitations for supplying Israeli Shekels, US Dollars and Jordanian Dinars to the Palestinian banks which were used for day-to-day transactions and caused many difficulties for both customers and banks. It is important for Palestinian banks to learn from successful stories were applied around the world.

In conclusion, MFS is offering several benefits and added value to banks and customers alike. Mobile operators value M-Commerce applications much. Because through M-Commerce the network created by the operators can be benefited to the maximum limit. Banks in Palestine must be aware of this race especially that some of the foreign banks in Palestine already established partnership relations with mobile operators to offer MFS outside Palestine. Moreover customers' perception of MFS as a new innovation will affect the rate of adoption. Many innovations require a lengthy period of many years from the time when they become available to the time when they are widely adopted. Therefore, a common problem for many banks is how to speed up the rate of diffusion of MFS. The challenge for banking sector in Palestine is not to get unbanked to the bank, but to get the bank to the unbanked.

6.3. RECOMMENDATIONS

Mobile phones hold great potential to become a common way of conducting financial transactions on a global scale in the near future. Therefore, our recommendations aim to promote a regulatory balance to foster an enabling environment for MFS in Palestine. These recommendations are:

- Palestinian banks need to have a vision for successful implementation of MFS with smaller pilot projects so they can gain experience with MFS and build support for change across the bank. Also, they need to measure and monitor results on a regular basis in order to ensure that they maintain world class performance levels given that **46%** of the banks in Palestine do not have quantified measures to ensure that they have achieved their strategic goals and **26.32%** do not have formal IT investment evaluation instructions (El-Kourd, 2007).

- Palestinian banks must establish MFS that works across all Palestinian cellphone networks and with any cellphone model in order to provide mobile accounts for customers. This will result in expanding their customer base into unbanked customers that may not live in urban areas, or may not have access to branches; therefore it is important to pay considerable attention to MFS application interface and content to suit the targeted segments.

- The Palestinian Monetary Authority is challenged to create an enabling environment for the sustainable growth of MFS. This includes the development of a new set of effective regulations and laws that will supports innovations, mitigates risks that threaten its development and encourage Palestinian banks to implement competitive MFS, taking into considerations the difficulties appeared in Gaza Strip area for supplying Israeli Shekels, US Dollars and Jordanian Dinars to the Palestinian banks for day-to-day transactions which caused many difficulties for both customers and banks.

6.4. FUTURE RESEARCH STUDIES

Further research could focus on and go deeper into investigating the customers' behavior to reveal some of the complexities of technology adoption that can be applicable to MFS. The aim is to gain some insight into the possible determinants of success or failure in MFS adoption among consumers in Palestine. This study will be of a great value for any pilot project as it will help banks to market MFS properly and speed up the adoption process.

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APPENDIX (A):

BANKING SECTOR OVERVIEW IN PALESTINE

The development of the banking sector in Palestine was affected dramatically by the political circumstances that Palestine went through. Before 1948, there were many banks working Palestine, the most famous one was the Arab Bank that was established in 1930 in Jerusalem and had many branches. In the period between 1948 and 1967, there were two bank systems in Palestine; the West Bank followed the Jordanian Banking system while Gaza Strip followed the Egyptian Banking System. Most of the working banks in Gaza Strip and West Bank had to stop their activities between 1967 and 1993 due to Israeli occupation. After signing Paris protocol on Economic Relation between Palestine National Authority (PNA) and Israel in 1994 many political and economical changes took place (El-Kourd, 2007).

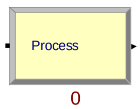
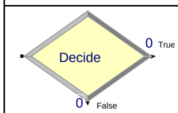
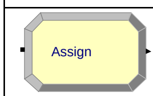
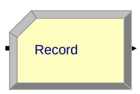
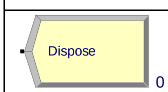
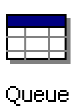
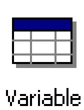
Currently, there are 21 banks operating in Palestine through a network of more than 180 branches and representative offices. Of this total, there are eleven foreign banks that comprise of eight Jordanian and two Egyptian banks, in addition to one branch for the HSBC. Three of the banks operating in Palestine are Islamic and the remaining are commercial non-Islamic banks.

The Palestinian banking sector is well-regulated and operates in an efficient and effective manner. Banks are governed by and fully-adhered to the Banking Law No (2) of 2002 and its explanatory instructions. In addition, banks comply with the best international banking practices, particularly, the Core Principles of Banking Supervision and its methodology, principles of good corporate governance, Basel I accord, and work is underway to apply the revised international capital framework or Basel II accord.

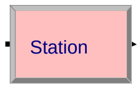
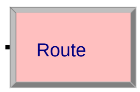
APPENDIX (B):

Main modules of Arena Simulation templates used in this study

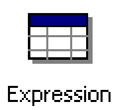
- Basic Process Panel

Block	Description
	This module is intended as the starting point for entities in a simulation model. Entities are created using schedule or based on a time between arrivals. Entities then leave the module to begin processing through the system.
	This module is intended as the main processing method on the simulation. Options for seizing and releasing resource constraints are available. Additionally, there is the option to use a "submodel" and specify hierarchical user-defined logic. The process time is allocated to the entity and may be considered to be value added, non-value added, transfer, wait, or other. The associated cost will be added to the appropriate category.
	This module allows for decision-making processes in the system. It includes options to make decisions based on one or more conditions or based on one or more probabilities. Conditions can be based on attribute values, variable value, the entity type, or an expression.
	This module is used for assigning new values to variables, entity attributes, entity types, entity pictures, or other system variables. Multiple assignments can be made with a single Assign module.
	This module is used to collect statistics in the simulation model. Various types of observational statistics are available, including time between exits through the module, entity statistics (time, costing, etc.), and general observations, (from some time stamp to the current simulation time). A count type of statistic is available as well. Tally and Counter sets can also be specified.
	This module is intended as the ending point for entities in a simulation model. Entity statistics may be recorded before the entity is disposed.
	This data module defines the various entity types and their initial picture values in a simulation. Initial costing information and holding costs are also defined for the entity.
	This data module may be utilized to change the ranking rule for a specified queue. The default ranking rule for all queues is First In, First Out unless otherwise specified in this module. There is an additional field that allows the queue to be defined as shared.
	This data module defines the resources in the simulation system, including costing information and resource availability. Resources may have a fixed capacity that does not vary over the simulation run or may operate based on a schedule. Resource failures and states can also be specified in this module.
	This data module is used to define a variable's dimension and initial value(s). Variables can be referenced in other modules (e.g., the Decide module), can be reassigned a new value with the Assign module, and can be used in any expression.

- Advanced Transfer Panel

Block	Description
	The Station module defines a station (or a set of stations) corresponding to a physical or logical location where processing occurs. If the Station module defines a station set, it is effectively defining multiple processing locations. The station (or each station within the defined set) has a matching Activity Area that is used to report all times and costs accrued by the entities in this station. This Activity Area's name is the same as the station. If a parent Activity Area is defined, then it also accrues any times and costs by the entities in this station.
	The Route module transfers an entity to a specified station or the next station in the station visitation sequence defined for the entity. A delay time to transfer to the next station may be defined. When an entity enters the Route module, its Station attribute (Entity.Station) is set to the destination station. The entity is then sent to the destination station, using the route time specified. If the station destination is entered as By Sequence, the next station is determined by the entity's sequence and step within the set (defined by special-purpose attributes Entity.Sequence and Entity.Jobstep, respectively).

- Advanced Process Panel

Block	Description
	The Expression module defines expressions and their associated values. Expressions are referenced in the model by using their name. Expressions can optionally be specified as one- or two-dimensional arrays. An expression value may be formed using combinations of integers, real numbers, symbol names, statistical distributions (e.g., NORM(10,2)), arithmetic operators (e.g., +, *), parentheses, logical operators, (e.g., .GT. or >), attributes, and variables. An expression value may be referenced in another expression, but recursive calls to the same expression are not allowed.
	The Failure module is designed for use with resources. When a failure occurs, the entire resource (regardless of its capacity) is failed. Failures are designed to be used with single capacity resources or with multiple-capacity resources whose individual resource units all fail at the same time.

APPENDIX (C)

Sample Inter-Arrival Data Collection Form

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
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APPENDIX (D)

Change Point Analyzer Software Overview

Change-Point Analyzer (CPA) is a shareware software package for analyzing time ordered data to determine whether a change has taken place. It detects multiple changes and provides both confidence levels and confidence intervals for each change. The results are clearly displayed in table form and supplemented by easy to interpret plots. It can be used with all types of data: pass/fail, individual values, averages, ranges, standard deviations, normal, abnormal and ill-behaved data. It can be used to trend complaints, inventory turns, sales, particulate counts and just about anything else.

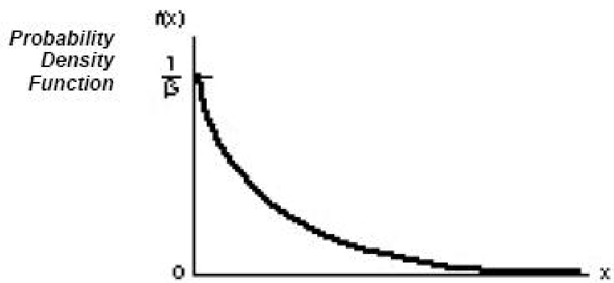
CPA is an important problem solving tool which can be used to complement real-time control charts. Analyzing control charting data using CPA will help to better isolate the time of a change, help to identify more subtle changes missed by the control chart, and expose false detections. When performing a one-time analysis on historical data, a change-point analysis is preferred to control charting, especially when dealing with large data sets.

CPA Software trial version for 30 day can be downloaded from:
http://www.variation.com/cpa/index.html

APPENDIX (E)

Probability distributions used in this study

Exponential(β)   EXPONENTIAL(Mean) or EXPO(Mean)



$$f(x) = \begin{cases} \frac{1}{\beta} e^{-x/\beta} & \text{for } x > 0 \\ 0 & \text{otherwise} \end{cases}$$

Parameters The mean (β) specified as a positive real number.

Range $[0, +\infty)$

Mean β

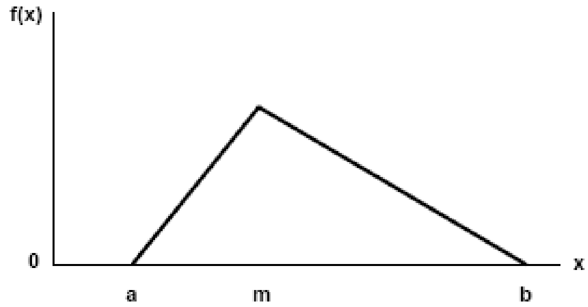
Variance β^2

Applications This distribution is often used to model inter-event times in random arrival and break-down processes, but it is generally inappropriate for modeling process delay times.

In Arena's Create module, the Schedule option automatically samples from an exponential distribution with a mean that changes according to the defined schedule. This is particularly useful in service applications, such as retail business or call centers, where the volume of customers changes throughout the day.

Triangular(*a, m, b*) TRIANGULAR(Min, Mode, Max) or TRIA(Min, Mode, Max)

Probability Density Function



$$f(x) = \begin{cases} \dfrac{2(x-a)}{(m-a)(b-a)} & \text{for } a \le x \le m \\ \dfrac{2(b-x)}{(b-m)(b-a)} & \text{for } m \le x \le b \\ 0 & \text{otherwise} \end{cases}$$

Parameters The minimum (a), mode (m), and maximum (b) values for the distribution specified as real numbers with $a < m < b$.

Range $[a, b]$

Mean $(a + m + b)/3$

Variance $(a^2 + m^2 + b^2 - ma - ab - mb)/18$

Applications The triangular distribution is commonly used in situations in which the exact form of the distribution is not known, but estimates (or guesses) for the minimum, maximum, and most likely values are available. The triangular distribution is easier to use and explain than other distributions that may be used in this situation (e.g., the beta distribution).

APPENDIX (F)

Design Expert Software Overview

Design Expert (DX) is statistical design of experiments (DOE) software. It performs multilevel factorial screening designs to help finding the critical factors that lead to breakthrough improvements. DX use response surface methods (RSM) to optimize processes and display optimum performance with rotatable 3D plots to help visualizing response surface, explore the 2D contours and predict responses. The sweet spot where all requirements are met can be found via the program's numerical optimization function, which finds the most desirable factor settings for multiple responses simultaneously.

Design Expert Software trial version for 45 day can be downloaded from:
http://www.statease.com/