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Adoption of Bonded-cellular Technology

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ADOPTION OF BONDED-CELLULAR TECHNOLOGY

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ABSTRACT

This study analyzed four determinant factors attributed to the acceptance of Bonded Cellular (BC) technology and applies the tenants of Diffusion of Innovation and Technology Acceptance Models.

BC “bonds” available cellular channels and transmits a multiplexed signal to a broadcaster.

This study will advance the understanding of factors that may impact the acceptance of BC at the management level.

Research Questions

1. Can behavioral intention (BI) to adopt BC tools be predicted by using an independent variable representing Perceived Ease-Of-Use (PEOU)?
2. Can behavioral intention (BI) to adopt BC tools be predicted by using an independent variable representing Perceived Usefulness (PU)?
3. Can behavioral intention (BI) to adopt BC tools be predicted by using an independent variable representing the Relative Advantage (RA)?
4. Can behavioral intention (BI) to adopt BC tools be predicted by using an independent variable representing Compatibility with existing operations (COMP)?

Null Hypotheses

1. H01:B1=0. There is no correlation between the (PEOU) intention to adopt BC.
2. H02:B2=0. There is no correlation between the (PU) and intention to adopt BC.

3. H03:B3=0. There is no correlation between (RA) and intention to adopt BC.

4. H04:B4=0. There is no correlation between (COMP) and intention to adopt BC.

Adoption of BC technology is the dependent variable, behavioral intent (BI).

An Internal Review Board approved Qualtrics questionnaire was disseminated to a targeted population comprised of TV technology and media production managers. The 32 carefully constructed Likert-Scaled questions explore a manager's current familiarity, current usage, anticipated plans and time-frames regarding the adoption of BC technology. The survey results were tabulated using IBM SPSS statistical Linear Regression analysis models that correlates aspects of DOI and TAM to examine the independent variables (IV) to arrive at a determination of the factors contributing to the behavioral intent (BI) to adopt BC technology.

PREFACE

My interest in television began in the early 1980s with the launch of Music Television (MTV), the invention of digital video effects (DVE) and other newly introduced video recording formats such as; 1-inch Type-C and Beta SP tape.

I was fortunate to work as a video engineer with many television stations, SONY Corporation of America and RCA. This professional background provided the engineering foundation and interest about the recent subject of Bonded-Cellular television transmission technology for TV remote production.

With the help of my dissertation committee, the goal for this original research is to contribute to the body of knowledge about the subject and to highlight previous work with citations and proper acknowledgment, while conducting the research in an ethical manner prescribed by the Institutional Review Board of Indiana State University.

This study may be of interest to television technology managers, decision makers and technology investors that are considering using Bonded Cellular video transmission systems within their organizations.

ACKNOWLEDGMENTS

I want to express my deep gratitude to Dr. Xiaolong Li as my dissertation chair, and Dr. Jared Wuerzburger for joining the committee at a late stage, Thanks to Dr. Mehran Shahhosseini for his guidance and timely feedback, and Dr. Andrew du Fresne for mentorship and support. I also wish to thank Marti Mix, Mary (Mebby) Griffy and Mary Drzycimski-Finn for keeping me organized and on track, with their outstanding professionalism and commitment.

Finally, I would like to remember my mother Karen Phipps for instilling within me a love of education and thank my father, Gary Phipps, for imparting the stoic importance of hard work and perseverance. Finally, I would like to let my wife, Kathleen, know that her love and support made it possible to accomplish this goal while demonstrating the best of human qualities as an example to our children, Ben and Sara. I appreciate my entire family for their unwavering support throughout my academic journey.

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CHAPTER 1

INTRODUCTION

This paper explores the critical success factors required for Bonded Cellular (BC) video technology and applies core tenants of technological adoption and diffusion models as defined in *Communication Technology: The New Media in Society* (Rogers, 1986) and *Diffusion of Innovation* (Rogers, 1995) and technology acceptance models (TAMs) as defined by Fred Davis (1986).

BC is a method of transmitting video over cellular data service that allows television broadcasters and news agencies the ability to deliver “live” High-Definition (HD), 4K or higher resolution television content from remote locations around the world. Bonded Cellular, (as its name implies) “bonds” together a multitude of available cellphone data channels (ranging from 2-14 available channels) depending on the bandwidth demands of the content and transmits a multiplexed HD video camera signal back to the broadcast facility over commercial cellular service networks. BC, as a product category that had not been invented 10 years ago and had just a handful of customers five years ago, is now a major path for broadcast remotes (Kovacs, 2017, p. 18)

Diffusion of Innovation (DOI) and Technology Acceptance Modeling (TAM) are well defined precepts with wide application and citation for the study of technology adoption. The concept of DOI dates back to 1903 when French sociologist, Gabriel Tarde first delved into original diffusion research creating the well-known, S-shaped diffusion curve. Gabriel Tarde, a French judge and one of the forefathers of sociology and social psychology, observed certain generalizations about the diffusion of innovations that he called “the laws of imitation,” and this became the title of his influential book, published in 1903. He observed that the rate of “imitation” or adoption of a new idea usually followed an S-shaped curve over time. Everett M. Rogers recognized Tarde as the first author on diffusion theory research (Odijk, 2012). The S-curve illustrates time on the x-axis and adoption on the y-axis.

Rogers utilized a similar S-shaped curve to describe the adoption rate of innovations which shows that innovations that diffused rapidly have a very steep trajectory, whereas, slow diffusion can be illustrated with a gradual sloping S-curve.

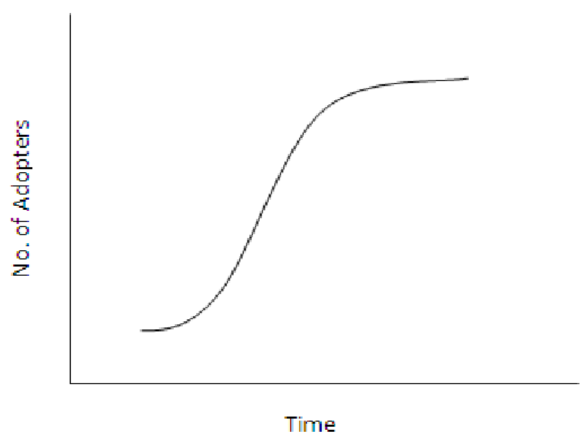


Figure 1-1 Basic Form of S-shaped Adoption Curve

Adoption and diffusion research have become an important tool for understanding the rate of adoption in a multitude of scientific, technological, sociological disciplines and even agricultural seed diffusion. The introduction of any new communications technology can be also illustrated with the use of Rogers’ DOI and Davis’s TAM principles to enhance understanding.

The introduction of BC video transmission technology is no exception and adoption among technology managers and the adoption of BC may be predicted with the use of these models.

Traditionally, High-Definition (HD) video required high data rates and large amounts of bandwidth within a channel to transmit “Live” video images from a TV crew that is “on location” back to the studio via a microwave Electronic News Gathering (ENG), or via Satellite News Gathering (SNG).

Broadcast technology managers now have another option for transmitting live HD video content back to the station with the use of BC systems. These systems essentially, combine (or bond) the bandwidth of many cellular phone data channels into a synchronized, high data capacity data system that can transmit live video from any location that has 3G/4G connectivity (and soon to be introduced 5G cellular services). Technology Managers should be made aware that there are many benefits, but also some drawbacks to using such a system for live, mission critical, TV broadcasts. This research study aims to reveal industry trends regarding the adoption or rejection of BC technology by technology managers and the economic, technical and workflow implications within the live mobile video industries. Relevant technologies also include; cellular transmission services, coupled with video encoding technologies that are central to providing BC options to technology managers.

BC service is comprised of systems that integrate several traditional video signal standards of MPEG, HEVC and H.264 or H.265, and other evolving data compression algorithms, along with several types of data connectivity, including; 3G/4G LTE, Wi-Fi, Ethernet, as well as traditional C-Band and Ka-Band satellite. BC technology must also be seamlessly integrated into the traditional workflow of a busy television station production environment and must provide easy set-up for engineers and operators while providing integration into an existing broadcasting infrastructure designed for remote news gathering. Cellular live shots have come a long way. Camera makers targeting their wares at news departments are building cellular live shot wherewithal in their equipment, and some companies that pioneered modern cellular live shot technologies are using cellular wireless for more than just transporting news stories (Johnston, 2016).

Statement of Problem

In 2011, BC had moved from an innovator only technology into the early stages of adoption (Robinson, 2012).

The intent of this study is to advance the understanding of factors impacting the acceptance and usage of BC technology at the management level prior to adoption, and identify the likely factors that impact a decision for the successful adoption of the innovation within an organization. More specifically, the problem of this study was to determine if the identified factors would have a significant impact upon the decision to adopt BC by broadcast technology managers that may be considering the replacement of traditional ENG and SNG transmission technologies. The study will provide insight into the question if technology managers have plans to migrate live video mobile video platforms to BC systems or continue to utilize their existing remote video services.

Research Questions

The paper will be directed towards television engineering technology managers, broadcast operations managers and electronic media professionals. The intent of this research is to investigate four specific factors that may impact a technology manager's decision to adopt BC technology. Insights from this study can also assist in the analysis of industry and manufacturing trends ranging from traditional microwave communication equipment providers (ENG) and satellite communications service providers.

1. Can a technology leader's behavioral intention (BI) to adopt BC tools for remote broadcast be predicted by using an independent variable representing perceived ease-of-use (PEOU)?
2. Can a technology leader's behavioral intention (BI) to adopt BC tools for remote broadcast be predicted by using an independent variable representing perceived usefulness (PU)?
3. Can a technology leader's behavioral intention (BI) to adopt BC tools for remote broadcast be predicted by using an independent variable representing the relative advantage (RA)?
4. Can a technology leader's behavioral intention (BI) to adopt BC tools for remote broadcast be predicted by using an independent variable representing Compatibility (COMP)?

Null Hypotheses

H01:B1=0. There is no correlation between the perceived ease-of-use (PEOU) and a technology leader's intention to adopt Bonded Cellular systems.

H02:B2=0. There is no correlation between the perceived usefulness (PU) and a technology leader's intention to adopt Bonded Cellular systems.

H03:B3=0. There is no correlation between the perceived Relative Advantage (RA) and a technology leader's intention to adopt Bonded Cellular systems.

H04:B4=0. There is no correlation between the perceived Compatibility (COMP) and a technology leader's intention to adopt Bonded Cellular systems.

With the stated method that adoption is represented as the dependent variable, behavioral intent (BI). Perceived ease of use (PEOU), perceived usefulness (PU), relative advantage (RA), and compatibility (COMP) are the independent variable.

Possible Additional Research Questions for Future Studies

1. Does adoption of BC technology “fit” other models of Innovation Diffusion and Adoption and Technology Acceptance Models by Rogers, Davis or others?
2. How can “A Model of Stages in the Innovation-Decision Process” (Rogers, 1986) be applied to the adoption of BC?
3. Diffusion is the Process by Which (1) an Innovation (2) Is Communicated through certain Channels(3) Over Time (4) Among the Members of Social System (Rogers, 1986). How are these components relevant to the adoption of Bonded Cellular technology?
4. What technologies have made BC a capable technology positioned to possibly replace current transmission technologies?
5. What are the current and future pathways for innovation with the development of BC technologies?
6. What are the implications of future advances and innovations, such as 5G that may affect BC technologies?
7. How can technology managers further identify and leverage the benefits of Bonded Cellular systems?
8. What are the challenges and potential risks of utilizing BC systems?
9. What economic implications and business pressures does Bonded Cellular present to current ENG and SNG service providers’ manufacturers?

Statement of Purpose

This research is being done to identify the implications of four specific factors that may influence the decision to adopt BC live mobile video technology. A technology manager may recognize benefits but may also identify challenges for not adopting BC technology. For example, BC may not work well in very crowded venues where a large population is simultaneously using cellular phone data service that competes with the BC transmission. Many live sporting and entertainment events are broadcast from venues with extremely high cell usage. Also, in extreme weather emergencies, cellular service may be interrupted or unavailable. A BC service may not work under these circumstances, just when broadcast coverage is needed the most! Will technology managers be willing to jeopardize losing their ability to report “breaking” news while using BC under these extreme circumstances, while their competitors are able to get the shot for important news stories by using proven ENG or SNG methods?

Statement of Need

A study from the Radio Television News Directors Association (RTNDA) / Hofstra University finds that the consolidation of TV newsroom operations has slowed and local news continues to run on a record number of stations. Among the report’s take-aways is the quantity of local TV News is at an all-time high (Eggerton, 2018). The results of the RTNDA survey demonstrates that there is renewed growth of local TV news programming and that the competitive marketplace is actively utilizing live television transmission technology, like BC, to reach their audience.

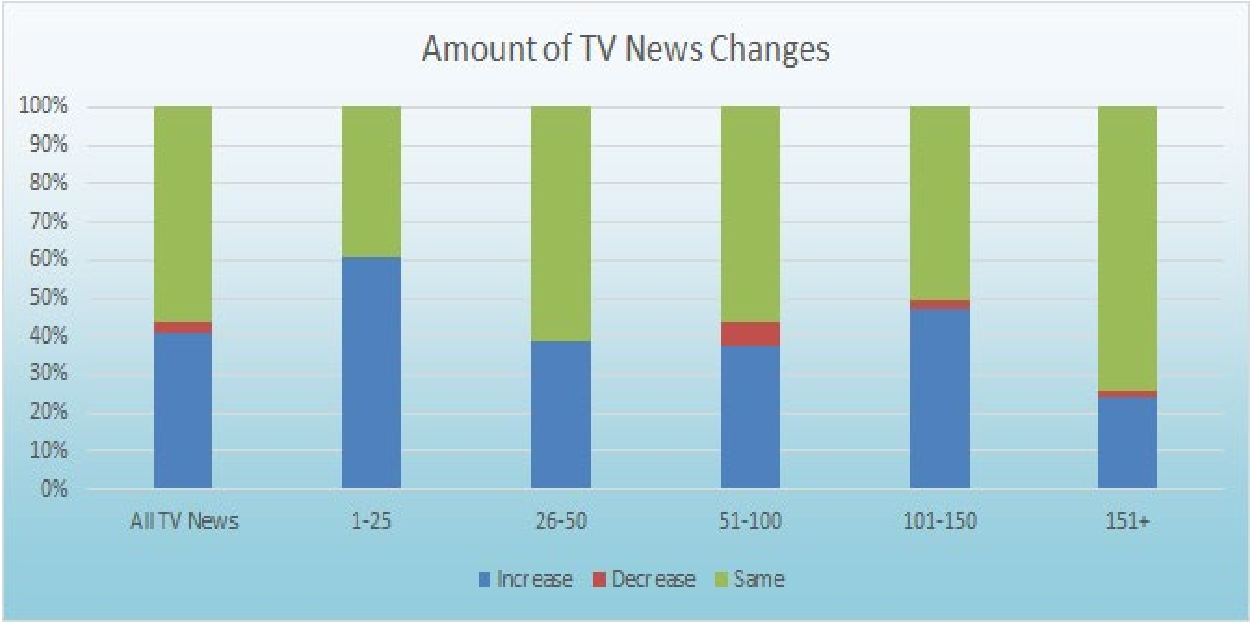
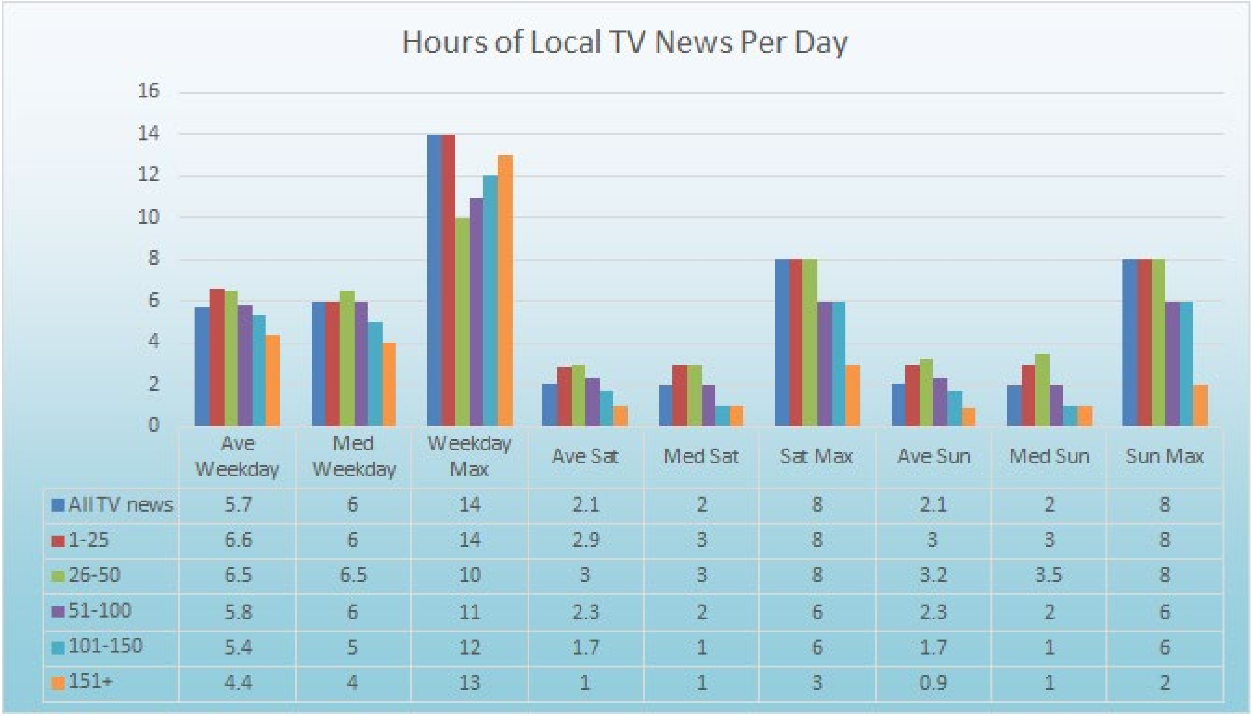


Figure 1-2 Amount of TV News Changes (Papper, 2017)

The amount of local news for TV hit a new, record high. The average amount of weekday news set a new, all-time high at 5.7 hours… up 12 minutes from the previous record set in 2012 and tied just last year. But the median weekday amount of 6 hours broke the old record (2016) by half an hour. Once again, the increases were pretty much across the board. With rare exception, almost every weekday number rose from a year ago (Papper, 2017).



	Ave Weekday	Med Weekday	Weekday Max	Ave Sat	Med Sat	Sat Max	Ave Sun	Med Sun	Sun Max
All TV news	5.7	6	14	2.1	2	8	2.1	2	8
1-25	6.6	6	14	2.9	3	8	3	3	8
26-50	6.5	6.5	10	3	3	8	3.2	3.5	8
51-100	5.8	6	11	2.3	2	6	2.3	2	6
101-150	5.4	5	12	1.7	1	6	1.7	1	6
151+	4.4	4	13	1	1	3	0.9	1	2

Figure 1-3 Hours of Local News per Day (Papper, 2017)

Quantitative research is need to assist technology managers and news directors with the task of committing resources, facilities, infrastructure and staffing required with the adoption of a new technology platform, such as, BC. Research can help illustrate what technologies are poised for growth or currently being utilized for live remote TV broadcasting. Also, equipment manufacturers and service providers can utilize the research information to assist with strategic business planning and trends analysis. Although the topic of cellphone and mobile video adoption and usage is a prolific topic for academic research, there is little academic literature available on the specific topic of the adoption of BC for the live remote TV broadcasting and streaming industries.

Statement of Assumptions

A. TV stations currently use some manner of technology to produce Live video remote broadcasts, including microwave (ENG), satellite (SNG), BC, or Wi-Fi.

B. Disruptive technologies or restrictive Federal Communications Commission (FCC) policies will not be introduced within the timeframe of the research.

Statement of Limitations

A. Survey results may be skewed by unscrupulous parties that may influence the survey input.

B. Exposure to recent Trade / Press articles may influence technology managers as they are completing the surveys.

C. BC and 5G cellular technologies are rapidly developing with a highly dynamic rate of advancement that may present disruptive advances that are difficult to anticipate. This study will limit the scope of investigation within the limits of current 4G cellular capabilities and the known potentialities of 5G cellular deployment.

Statement of Methodology

The data was collected via a Qualtrics online survey instrument administered to a targeted sample population drawn from the U.S. television engineering and management industry. The target population consisted of decision makers with experience and knowledge of the TV broadcast industry as described in the demographics portion of the survey results.

The descriptive statistics will be summarized from the sample characteristics of the population demographics.

KMO and Bartlett's Sampling Adequacy Test

The Kaiser-Meyer-Olkin (KMO) statistic is a measure of sampling adequacy. A KMO and Bartlett's Test of Sphericity will be conducted to determine if the data results are suitable for factor analysis According to James Gaskin, a KMO score greater than .7 is desirable (2015).

Communalities Testing

The Extracted Communalities will be calculated to determine to Factor loading for each component and determine its suitability analysis.

Total Variances of Factors Test

The total variance will be calculated to determine Eigenvalues for each factor. Eigenvalues represent the explanation of the total variances of the factors. Generally, only eigenvalues greater than 1 should be considered factors. The data will be examined to determine if they meet these criteria.

Pattern Matrix Test

For convergent validity, it is desirable to find results above 0.5, as shown in Table 4-9. The values should average above 0.72 (Gaskin, 2015). The results meet this criterion.

Factor (Component) Correlations Tests

To avoid shared variance, there should be no factor correlations greater than 0.7 (Gaskin, 2015). The results will be calculated and inspected to see whether the factors are distinct and uncorrelated and meet the requirements of discriminant validity.

Cronbach's Alpha Reliability Testing

Internal consistency reliability for each of the variables will be assessed using Cronbach's alpha testing for all four reliability coefficients.

Rejection or Acceptance of the Null Hypothesis

The results and findings in the study have will determine if the research questions predict that Perceived Ease of Use (PEOU), Perceived Usefulness (PU), Relative Advantage (RA) and

Compatibility with existing workflows and norms (COMP) have a linear relationship to the behavioral intent (BI) to adopt Bonded Cellular technology. The research questions will be answered whether the null hypotheses are to be rejected or accepted.

Collection of Data

A key component to conducting successful research is the collection of data, including a thorough Review of Literature, (ROL) of the current existing knowledge base pertaining to the research subject. Preparing a comprehensive ROL allows one to fully review the ideas, concepts, historical perspectives, disagreements and conclusions that have been published to date.

A Qualtrics questionnaire survey was developed and disseminated to a targeted population comprised of technology managers within the various groups of television station market sizes and local affiliations. The survey is comprised of 31 carefully crafted questions that explore a manager's current familiarity, current usage and anticipated plans regarding BC mobile video acquisition. Sample questions will include 1-24 month timelines regarding anticipated needs, budgetary considerations and operation workflow models. The survey results are tabulated using the appropriate IBM SPSS 26 statistical analysis techniques described in greater detail in chapter 3.

Statement of Terminology

AC	Alternating Current	HD	High Definition
AP	Access Point	BS	Base Station
BC	Bonded-Cellular	ANOVA	Analysis of Variance
ENG	Electronic News Gathering	ROL	Review of Literature
SNG	Satellite News Gathering	3G,4G,5G	Third, Fourth, Fifth Generation
MPEG	Motion Picture Expert Group		

GSM	Global System for Mobile
LTE	Long Term Evolution
PSTN	Public Switched Telephone Network
H0:	Null Hypothesis
SDI	Serial Digital Interface
HEVC	High-Efficiency Video Coding (H.264 / H.265)
UMA	Unlicensed Mobile Access
GNA	Generic Network Access
CDMA	Code-Division Multiple Access
TDMA	Time-Division Multiple Access
FDMA	Frequency-Division Multiple Access
OFDMA	Orthogonal Frequency Division Multiple Access
QAM	Quadrature Amplitude Modulation
VoIP	Voice Over Interne Protocol
BER	Bit Error Rate
IP	Internet Protocol
DTF	Discrete Fourier Transform
S/NR	Signal to Noise Ratio

CHAPTER 2

REVIEW OF RELATED LITERATURE

In Chapter 1, the topic for study of the Diffusion and Adoption of BC was introduced and the breadth of the research questions and statement of the problem were established. Chapter 2 presents and integrates relevant manuscripts, peer-reviewed texts, articles and journals published research related to the study of BC technology, Adoption of Innovation, and Electronic Communications.

The review of related research content is offered to provide the necessary context in which to better understand and evaluate the historical and current state of the BC industry and the conceptual framework constructed for this study.

Overview of Technology

In the endeavor to improve the circumstances of our lives and exert control over the conditions of our environment, we deploy the full power of our intellect to create tools that yield beneficial actions on our behalf. We are the creators of tools that ply leverage over our environment and amplify our capabilities.

One of the most characteristic features of technology is the fact that it is undergoing constant change. Technology never stands still, never reaches a steady-state equilibrium (Braun, 1998).

Tools and knowledge combine into 'technology' and becomes the conduit from which our minds and resolve intersect with the physical world; the use of technology has become a defining characteristic of what makes us human.

The study of technology is important not just for its own sake, but for what it tells us about the kinds of society's we make for ourselves (Volti, 2009, p. 15). One tends to consider the word – technology, as being referential to a dedicated tool or machine, designed for a specific task. A closer look at the definition reveals a deeper association as to how we leverage technology to fulfil our bidding.

Technology is a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome (Rogers, 1986, p. 12).

It is true that the creation and use of technology is often directed with the specific purpose of solving a explicit problem. It is with purpose and intent that solutions are crafted from the available materials and knowledge that is accessible at any given moment in time.

Ernest Braun defines technology as the "ways and means by which humans produce purposeful material artifacts and effects." Alternatively, he suggests we may define technology as the material artifacts used to achieve some practical human purpose and the knowledge needed to produce and operate such artifacts (1998, p. 9). What Braun refers to as material artifacts are more commonly known as *hardware.* Material artifacts may be a steel bar that is used as a lever to amplify human strength to move a rock, or a super computer to amplify human intelligence to solve complex equations in the blink of an eye.

However, the use of prescribed technology to solve a problem may often reveal new avenues that may also be in need of a heretofore unresolved set of problems or set of circumstances, thus opening a chasm of novel conundrums in need of new problem-solving attention. Hopefully, that is where human judgment has the discernment to make wise and ethical choices on issues in need of technological *solutions*.

We use technology for better or for worse, and it is the task of technology management to tilt the balance toward the better (Braun, 1998, p. 5). Braun's use of the term "technology management" suggests that humans act as the agents, i.e. as technologists that can dispatch a solution to a problem that requires a technological solution. However, with the proliferation of Artificial Intelligence (AI) systems, the practice of engaging a human technologist may not always be an underlying supposition.

Reliance on technology is as old as humanity itself. Whatever evils have accompanied the use of particular technologies, it is pointless to indict technology as being somehow "unnatural" (Volti, 2009, p. 4). Rudi Volti further explains that our past as well as our future as a species is inextricably linked to our capacity to shape our existence through the invention and application of implements and techniques that allow us to transcend our meager physical endowments (2009, p. 4).

In 1831 Jacob Bigelow published *Elements of Technology*, the first book in English with the word "technology" in its title (Volti, 2009, p. 4). As Bigelow defined it, technology consisted of "the principals, processes, and nomenclatures of the more conspicuous arts, particularly those which involve applications of science (Volti, 2009, p. 4).

It has nearly become an epistemological certainty the technology will continue to transform, improve and modify in the wake of the rapidly evolving technological age in which we find ourselves. Moore's Law, exponential expansion of scientific knowledge and compounding AI advances, all give testament to the supposition that technological advancement may be unending. Technological development is more than the other random accumulation of tools, techniques, and organizational forms. Underlining the process is a set of attitudes and orientations that are collectively described as "rational" (Volti, 2009, p. 14).

Braun postulates that there are two major forces pushing technology toward change. One is the internal logic of science and technology. Technology is never so perfect that it could not be improved, in new knowledge brings with it new technological possibilities (1998, p. 13).

As mentioned previously, with new knowledge also comes the understanding that there are always more problems that are in need of a new technological solution and so on. The marketplace rewards problem-solvers. Individuals and enterprises are in the business of providing a solution to someone's problem for which they are willing to exchange their capitol and become a customer. If there were no problems to be solved, there would be no need to hire anyone to resolve the disrupting issue in the first place. This exchange of capitol for solutions gets to the quick of Braun's second force that compels technology forward, that being economic. Technology is a crucial weapon in the relentless quest for economic growth. New technologies and new products on the market expand economic activity; improved efficiency of production increases wealth, provided society can absorb it without increases in unemployment (1998, p. 13).

Implications for Communication Research

All communication technology extends the human senses, especially hearing and seeing. Such extensions allow an individual to reach out in space and time and thus obtain information that would not otherwise be available (Rogers, 1986).

Embedded in every tool is an ideological bias, a predisposition to construct the world as one thing rather than another, to value one thing over another, to amplify any sense or skill or attitude more loudly than the other (Postman, 1993, p. 14).

This is what Marshall McLuhan meant by his famous aphorism "The medium is the message." This is also what Marx meant when he said, "Technology discloses man's mode of dealing with nature" and creates the "conditions of intercourse" by which we relate to each other. It is what Wittgenstein meant when, in referring to our most fundamental technology, he said that language is not merely a vehicle of thought but also the driver (Postman, 1993, p. 14).

The development of technology has stimulated the belief that progress is a natural part of human life. At the same time, the progress of development of technology has itself been the product of a distinctive set of cultural values and mental processes that are characterized by a rational approach to the world and how it is to be controlled (Volti, 2009, p. 13).

The new communication technologies have elevated the field of communication research to a high level of importance in human society. Public and private policy issues swirl around the results of research being conducted on new technologies: international competition and trade conflicts in high technology; that transition from an industrial society to an information society; and growing concern with socio-economic and gender inequalities, unemployment, and other social problems that result from the impacts of the new communication technologies (Rogers, 1986, p. 7).

Communication technology has had a very strong impact on the nature of scholarly research on human communication. The issues studied by communication scientists over the past 40 years have been affected by the changing nature of communication (Rogers, 1986, p. 3).

When technology is seen as a combination of devices, skills, and organizational structures, it becomes natural to think of it as a system. For an individual technology to operate effectively more is required than the invention of a particular piece of hardware; it has to be supported by other elements that are systematically interconnected (Volti, 2009, p. 5).

As Charles Horten Cooley wrote in 1909, “By communication is here meant the mechanism through which human relations develop – all the symbols of the mind, together with the meanings of conveying them through space and preserving them in time” (Peters, 1999, p. 9).

Electronic Communications Technology

The key technology underlying all the other new communication technologies is electronics. Electronics technology these days allows us to build virtually any kind of communication device that one might wish, at a price (Rogers, 1986).

Telecommunications has been defined as a technology concerned with communicating from a distance, and we can categorize it in various ways. It includes mechanical communication and electrical communication because telecommunications have been developed from mechanical to electrical using increasingly more sophisticated electrical systems. Our main concern here is electrical and bidirectional linking communication (Anttalainen, 2015, p. 2).

A history of communications with the first major technical undertaking using electricity is considered to have started with the commercial telegraph service by William Cook in England in 1839 and by Samuel Morris in the United States in 1844 (Miao, 2007, p. 1).

The invention of the telegraph was not just a communication device with technological implications; it should be revered as a seminal inflection point of human advancement and cognition.

Neil Postman describes the presumed close connection between information, intelligence, reason, and usefulness began to lose its legitimacy toward the mid-19th century with the invention of the telegraph. His description points out that prior to the telegraph, information could be moved only as fast as a train could travel: about 35 miles per hour. Prior to the telegraph, information was sought as part of the process of understanding and solving particular problems and prior to the telegraph, information tended to be of local interest. Telegraphy changed all of this and instigated the second stage of the information revolution (Postman, 1993, p. 67).

The telegraph enabled much more than the speedy transmission of information; it removed the constraints of information from its physical wrapping and physical displacement of space and time. The telegraph changed how humans send, receive and interact with information. It is the first instance of immediate transmission of information.

The most important element of the telegraph was its instantaneous operation across longer distances. Telegraph was the first technology to provide the transmission of information data over communication channels. Thus, it led to many fundamental advances in the field of signal processing and communications (Miao, 2007, p. 1).

The telegraph removed space as an inevitable constraint on the movement of information, and, for the first time, transportation and communication disengaged from each other (Postman, 1993, p. 67).

In the United States, the telegraph erased state lines, collapsed regions, and, by wrapping the continent in an information grid, created the possibility of a unified nation-state. But more than this, telegraphy created the idea of context-free information -- that is, the idea that the value of information need not be tied to any function it might serve in social and political decision-making and action (Postman, 1993, p. 67).

Postman argues that the information transmitted by telegraph now defines and inculcates the modern view of information.

The next major development in communications is the telephone, which was a direct outgrowth of increasing the message handling capacity of telegraph lines. In 1870, Joseph

Stearns and Thomas Edison demonstrated reliable communication systems for the simultaneous transmission of two and four telegraphic signals on a single wire. Meanwhile, in 1875, Alexander Graham Bell in the United States both invented practical telephones that could be used to transmit human speech over a single wire, there by leading to telephone for local wireline services (Miao, 2007, p. 2).

Telecommunications Networks make up the most complicated equipment in the world. Let us think of the telephone network, which includes over seven billion fixed and cellular telephone subscriptions with universal access. When any of these telephones request a call, the telephone network is able to establish a connection to any other telephone in the world. The Internet, the global Computer Network, is used by some three billion users and the number of devices connected to it is increasing rapidly. This gives us a view of the complexity of the global Telecommunications Network no other system in the world exceeds the complexity of telecommunications networks (Anttalainen, 2015, p. 2).

Digital Wireless Communications Technology

The advancement of radio is another major milestone of the development of modern wireless communications. Electromagnetic propagation had first been discovered in a mathematical formula by James Clerk Maxwell in 1860. In 1888, Heinrich Hertz demonstrated the generation and detection of the electromagnetic radiation in numerous experiments. Several years later, Marconi introduced wireless signal instruments to transmit signals over distances of several 100 miles in 1896 this led to widespread advances in Wireless Communications (Miao, 2007, p. 2).

That the expression “radio communication” as used in this act means any system of electrical communication by telegraphy or telephony without the aid of any wire connecting the points from and at which the radio-grams, signals, or other communications are sent or received. United States radio act 1912 (Peters, 1999, p. 276).

A communication channel is the means by which messages get from one individual to another. Mass media channels are more effective in creating knowledge of innovations, whereas interpersonal channels are more effective in forming, and in changing, attitudes toward a new idea, and thus in directly influence and the decision two adopt or reject a new idea (Rogers, 1986, p. 118).

Transmission

Transmission is the process of transporting information between endpoints of a system or a network. Transmission systems use three basic media for information transfer from one to another: copper, fiber-optic cables and radio waves. In a Telecommunications Network the transmission systems interconnect elements that provide services such as exchanges and these transmission systems altogether are called the transmission or transport network (Anttalainen, 2015, p. 20).

A brief overview of a few definitions describing signal transmission are in order.

Transmitter

The transmitter processes the input signal and produces a transmitted signal suitable to the characteristics of a transmission channel. The signal processing for transmission often involves encoding and modulation. In the case of optical transmission, the conversion from an electrical signal format to an optical one is carried out in the transmitter (Anttalainen, 2015, p. 157).

The transmission channel is an electrical medium that bridges the distance from the source to the destination. It may be a pair of wires, a coaxial cable, a radio wave, or an optical fiber. Every channel introduces some amount of transmission loss or attenuation and, therefore, the transmitted power progressively decreases with increasing distance. Loss over the channel is undesirable since it reduces signal strength at the receiver, making reception more sensitive to noise and other disturbances (Anttalainen, 2015, p. 158).

Receiver

A receiver operates on an output signal from the channel in preparation for delivery to the transducer at the destination. Receiver operations include filtering to take away out-of-band noise, amplification to compensate for transmission lost, equalizing to compensate for distortion, and demodulation and decoding to reverse the signal processing performed at the transmitter (Anttalainen, 2015, p. 158).

Spectrum of a Transmitted Symbol

Digital information is a sequence of symbols and each symbol represents a set of bits or, in the binary case, one bit. These symbols are transmitted as electrical signals. Electrical communications signals are time-varying quantities such as voltage or current. Although a signal physically exists in the time-domain, we can also represent it in the frequency domain where we view the signal as consisting of sinusoidal components at various frequencies. This frequency-domain description is called the spectrum (Anttalainen, 2015, p. 159).

Any physical signal can be expressed in both domains. In the time domain, we draw the amplitude along the time taxes and in the frequency domain we draw the amplitude, and phase-shift, along the frequency axis. Although both of them give a perfect description of the signal, both presentations are needed for easier understanding of different phenomena. The time the main signal is the sum of the spectral sinusoidal components. Fourier analysis gives the mathematical connection between the time – and frequency – domain descriptions (Anttalainen, 2015, p. 159).

Propagation of Radio Waves

One of the most important transmission media is free space or open air where the high – frequency radio-waves can propagate. They do not usually need any guiding.

Most radius systems of today operate well above 100 MHZ where the radio wave travels a direct path from the transmitting antenna to the receiving antenna. This propagation mode is called line-of-site (LOS) propagation. The power of a radio wave is reduced with distance. The attenuation of a radio wave, free-space loss, on the LOS path is due to the spherical dispersion of the radio-wave. Here we assumed that both antennas are isotropic antennas, which radiate to and received from all directions equally. The transmitted power from an isotropic antenna is distributed over a spherical surface and the radiated power per unit area decreases in proportion to the square of the radius.

Nyquist Theory

Harry Nyquist was an important contributor in the history of communications and did important work on thermal noise known as the Johnson-Nyquist noise, the stability of feedback amplifiers, and information theory. In 1927, Nyquist discovered that the number of independent pulses, which could be put through a telegraph channel per unit time, is limited to twice the bandwidth of the communication channel. His early theoretical work laid the foundations for later advances by Claude Shannon. In 1948, the publications of Claude Shannon established the mathematical foundations to reliably transmit the information content of a source over a communication channel with basic limits on the maximum rate. This gave rise to a new field called information theory. These results are essentially a combination of what is known as the Nyquist–Shannon sampling theorem.

The late 1940s was probably the single grandest moment in the century's confrontation with communication. One source was the excitement around information theory (originally in fact known as communication theory). Information theory developed from what might be called the information and practice of telecommunications, specifically from research on telephony at Bell laboratories starting in the 1920s and on cryptography during the war (Peters, 1999, p. 22).

The mathematical theory of communications during the late 1940s were also years of important scholarly work in communication science. At MIT, the mathematician Norberto Weiner published, *Cybernetics, Or Control and Communication in the Animal and the Machine*, (1948). Two years later, Weiner wrote a nontechnical companion volume that also became a best seller called *The Human Use of Human Beings: Cybernetics and Society* (1950) (Rogers, 1986, p. 83).

Perhaps even more influential in the rise of communication science was a small book by Claude E. Shannon, an electrical engineer at Bell Labs, and Warren Weaver of the Rockefeller Foundation in New York. *The Mathematical Theory of Communication* (1949) proposed a general model of communication accompanied by a series of mathematical theorems about the engineering aspects of communication. This simple model was accepted with enthusiasm by communication scholars, and was to influence their research for the decades that followed (Rogers, 1986, p. 83).

Shannon and Weaver's theory was published at the time when communication researchers were emerging from the ghetto of trade-school education, and straining for the intellectual respect of their academic colleagues (Berlo, 1977, p. 16)

Information theory offered a means by which communication scholars could gain academic respectability (Rogers, 1986, p. 84).

Shannon's Information Theory

Without doubt, the Shannon and Weaver (1949) paradigm was the single most important turning point in the history of communication science (Rogers, 1986, p. 85).

Within four years, *The Mathematical Theory of Communications.* sold 6000 copies in hardback and by 1985 over 32,000 paperback copies have been sold, and the book continues to sell well (Rogers, 1986, p. 86).

As Weaver emphasized, "Information must not be confused with meaning" (Rogers, 1986, p. 87).

Although the idea of quantitative measure of information has been around for a while, the person who held everything together into what is now called information theory was Claude Elwood Shannon, an electrical engineer at Bell Labs. Shannon defined a quantity called "self-information" (Sayood, 2006, p. 13).

Shannon's *Mathematical Theory of Communication* (1948) was many things to many people. It gave scientists a fascinating account of information in terms of the old thermodynamic favorite, entropy, gave AT&T a technical definition of signal redundancy and hence a recipe for "shaving" frequencies in order to fit more calls on one line, and gave American intellectual life a vocabulary well suited to the country's newly confirmed status as military and political world leader (Peters, 1999, p. 23).

Shannon's theory prescribed the boundaries and the nomenclature onto which information and communications could to adhere.

Such a distinction helps put the subjectivity of human communication into Shannon's model. Certainly, Shannon and Weaver realized that the encoding of messages into signals, and their later decoding, was a subjective process when human beings were involved (Rogers, 1986, p. 87).

The Impact of Shannon's Theory

However, Shannon's model could not really be tested by scholars of human communication. It had too many component parts, linked in too many complex ways. The model mainly served as a sensitizing function, alerting scholars to dimensions of communication that they otherwise might not have appreciated. Shannon's theorems, derived from his model, could have been tested by communication scientists. This, however, they did not do, mainly because they could not understand them.

Entropy is the degree of uncertainty or disorganization of a system. Claude Shannon suggested that the amount of information could be measured by the logarithm of the number of available choices, with the logarithm calculated to the base 2, rather than to the more usual base 10. Thus, the unit of information is a "bit" (a word first suggested by the statistician John W. Tukey as a condensation of "binary digit") (Rogers, 1986, p. 90).

One of the many contributions of Shannon was that he showed that if the experiment is a source that puts out symbols Ai from a set A, then the entropy is a measure of the average number of binary symbols needed to code the output of the source. Shannon showed that the best that a lossless compression scheme can do is to encode the output of a source with an average number of bits equal to the entropy of the source (Sayood, 2006, p. 16).

"Information" became a substantive and communication theory became an account of meaning as well as of channel capacity. Indeed, the theory may have seemed so exciting because it made it something already quite familiar in war, bureaucracy, and everyday life into a concept of science and technology. Information was no longer raw data, military logistics, or phone numbers; it was the principle of the universe's intelligibility (Peters, 1999, p. 23).

Information theory provides answers to two fundamental questions in communication theory:

1. What is the ultimate data compression?
2. What is the ultimate transmission rate of communication in terms of the channel capacity?

The communications engineer aims to optimize his design for an efficient communication system, taking into account various competing goals. Ideally, the designer proceeds with an eye toward a system with the highest data rate possible and a minimal bit error rate, using minimal power and spectrum. In so doing, the designer endeavors to offer reliable service to as many users as possible, with as minimal interference and as high reliability and quality as possible. The engineer also aims for minimal complexity and cost. These goals are a tall order in the face of technology replete with fierce competition (Abate, 2009, p. 72).

Data (Information) Compression

Data compression involves identifying models for the many different types of structures that exist in different types of data and then using these models, perhaps along with the perceptual framework in which these data will be used, to obtain a compact representation of the data. These structures can be in the form of patterns that we can recognize simply by plotting the data, or they might be statistical structures that require a more mathematical approach to comprehend (Sayood, 2006, p. 20).

Most BC products today rely on H.264 encoding, which is well established as an efficient means of compression and data reduction. However, the next generation of television encoding - HEVC/H.265, is even more efficient than its predecessor H.246, and therefore requires even less bandwidth for the same quality of delivered video. What does that mean for BC systems (Kovacs, 2017, p. 18)?

All bonded cellular live shot systems utilized some form of compression, but not all of them use the same version of compression. According to Chris Crump, senior director of sales for Comerex in Devon's, MA. The version of H.264 Comerex implements, "takes advantage of all the profiles within H.264's specification. And so, within our device, you can create a customized profile" (Kovacs, 2017, p. 18).

Data compression algorithms are used in these standards to reduce the number of bits required to represent an image, a video sequence or music. In brief, data compression is the art and science of representing information in a compact form. These compact representations are created by identifying and using structures that exist in the data. Data can be characters in a text file, numbers that are samples of a speech or image waveforms, or sequences of numbers that are generated by other processes. The reason we need data compression is that more and more of the information that we generate and use is in digital form, in the form of numbers represented by bytes of data (Sayood, 2006, p. 1).

Video compression in the Cell-mux devices is performed by either a Digital Signal Processor (DSP) or Field Programmable Gate Array (FPGA) chip, which is dedicated to the task and uses less power than the alternative, which is a software or CPU based encoder. Note that CPU encoding is highly configurable, while DSP, which is cheaper and uses less power, is relatively inflexible. While H.264 is dominant largely because the codecs are now relatively mature. Several new devices have introduced H.265 encoding. H.265 is more CPU intensive, but it is designed to produce more compression and lower bit rates at a quality equivalent to H.264. In bandwidth constrained environments, such as backhaul, H.265 could introduce increased quality from deeper in the field. Devices might produce adaptive bit rate (ABR) or variable bit rate (VBR) in coding options (Robinson, 2014).

When we speak of compression technique or compression algorithm, we are actually referring to two algorithms. There is the compression algorithm that takes an input X and generates a representation Xc that requires fewer bits, and there is a reconstruction algorithm that operates on the compression representation Xc to generate the reconstruction Y (Sayood, 2006, p. 3).

Evolution of Cellular (Mobile) Systems

During the second half of 2016, Americans reached an important mile-stone in the history of cellular communications: It was the first time that the majority of homes owned only wireless phones. According to the Centers for Disease Control, 51 percent of American homes owned at least one cellphone and did not use a landline (Friedman, 2017, p. 1).

With the massive growth of cell phone adoption and usage and the plethora of apps leading to countless innovations, it's difficult to imagine a time when the notion of communicating with each other via "radio telephones", as opposed to telephone landlines was ridiculed.

Herbert Hoover, United States secretary of commerce in 1923 once quipped, "The use of the radio telephone for communication between single individuals, as in the case of the ordinary telephone, is a perfectly hopeless notion. Obviously, if 10,000,000 subscribers are crying through the air for their mates, they will never make a junction" (Peters, 1999, p. 277).

Cell Site Definitions

The very fundamental idea of cellular technology, at least when it was first conceptualized, pivots around the idea that by reducing the transmit power and as a result, reducing the service area, the reuse of a frequency again and again, is possible and helps increase capacity and conserve the premium spectrum. However, different applications require different transmit power and sizes of cell sites (Abate, 2009, p. 49).

Cellular telephony is designed to provide communications between two moving units, called mobile stations (MS), or between one mobile unit and one stationary unit, often called a land unit. A service provider must be able to locate and track the caller, assign a channel to the caller, and transfer the channel from base station (BS) to another BS as the caller moves out of range. To make this tracking possible, each cellular service area is divided into small regions called cells. Each cell contains an antenna and is controlled by a solar or AC powered network station (Forouzan, 2007, p. 467).

With so much of America dependent upon cellular connections, individuals and businesses alike understand the frustration of weak cell signals, dropped calls, or being unable to get online.

Just as the technology of smartphones has evolved, so too have the solutions for keeping the masses connected.

Whether using cellphones for personal or business purposes, consumers have come to expect five-bar, reliable service. Fortunately, cellular network engineers have developed numerous solutions to meet modern cellular connectivity needs. Whether in remote areas or inside structures made of “signal-sapping” building materials, there are a variety of choices to solve the lack of cellular signal and constant dropped calls (Friedman, 2017, p. 1).

Cellular phone networks have begun incorporating the use of multiple network access as a part of their overall architecture. This is best evidenced in the launch of unlicensed mobile access (UMA) now called the generic network access (GNA). This permits the users to switch automatically to Wi-Fi for VoIP calls or broadband Internet whenever in the area of coverage of such hot-spots. It is particularly convenient to use if Wi-Fi connectivity is available. The calls meant for the cell phones are automatically diverted to the network, saving on more expensive usage of network or better reception in many areas where the cellular signals are weak (Kumar, 2008, p. 11).

Definition of Cell Sizes

Macro cells are for outdoor and in-vehicle applications. The cell site locations are usually on towers, buildings, or water tanks. The coverage radii is a range from 1K to 30 KM. Pico cells, are for coverage of localized regions. This might include airport terminals, train stations, office complexes, or college campuses. Micro cells and pico-cells can be used as a means of signal re-transmission of macro cells into a confined area, such as a conference hall or a particular floor in a building. A good example of a micro-cell is a Wi-Fi hotspot in a Starbucks store, where the clients share the signal. Micro cell radii are between 200 and 2000 meters, while picocells are between 4 to 200 meters. A femtocell is the smallest in radius of coverage and is comparably or analogous to a Wi-Fi home router antenna range inside a residence (Abate, 2009, p. 50).

Cell size is not fixed and can be increased or decreased depending on the population of the area. The typical radius of a cell is between one to twelve miles. High-density areas require more, geographically smaller cells to meet traffic demands than do low-density areas. Once determined, cell size is optimized to prevent the interference of adjacent cell signals. The transmission tower of each cell is kept low to prevent its signal from interfering with those of other cells (Forouzan, 2007, p. 467).

Using smaller cell sites can increase capacity as well as transmit power while increasing switching activity on a account of frequent hand-off. Another downside to reduction of cell radii is the increased complication of the E911 application used to locate subscribers in an event of emergency (Abate, 2009, p. 50).

Using a signal meter is the most effective way to test for signal frequency, bandwidth, and strength down to the decibel-milliwatt (dBm) not the “bar.” Signal meters read the signal level for all frequency ranges and bands in order to test for any carrier and make sure the signal will work for all users (Friedman, 2017, p. 7).

In cellular or mobile networks, user terminals are connected to the network via a radio path that provides users with global mobility. The network consists of small cells controlled by base stations (BS) that behave as access points (AP) to the network. The key idea of cellular systems is that with the help of the cell structure we can overcome the problem of limited radio capacity. The network is divided into cells, allocates frequency channels to cells and controls the transmission power of both the base station and mobile station so that frequencies can be reused in nearby cells (Anttalainen, 2015, p. 219).

Structure of a cellular network instead of covering an entire geographical area with high power fixed radio stations, the way older generation radio systems did, the area of a cellular network is divided into small cells, only a few kilometers or less across.

The major reason for this is that the total maximum transmission capacity per cell is fixed (depends on used technology.) Areas where subscriber density is high are covered by smaller cells then areas where subscriber density is low. Places such as shopping malls may have several

BSs to provide good enough indoor coverage and capacity. The power of BSs and mobile devices is lower for smaller cell size. Typically, the cells overlap each other to provide higher reliability.

For a longtime the major application for wireless communications was speech. Radio telephones have been around for many decades but the capacity of these systems has been very limited. These networks consisted of only a few base stations (BS) with which mobile units communicate, and each BS covers a large geographical area. The number of simultaneous calls inside the area covered by one BS was restricted to the number of channels available for this BS. Therefore, the capacity of these systems was low and the radio telephone service was available only for professionals (Anttalainen, 2015, p. 311).

First-Generation (1G)

During the 1970s, the development of digital switching and information technologies made modern cellular telephone systems feasible. The cellular principle offered a solution to the capacity problem. Different analog cellular standards were developed in Europe, the United States, and Japan and they became available in the first half of the 1980s. These systems are often referred to as the first generation (1G) cellular systems.

Cellular networks such as Global System for Mobile Communications (GSM) were originally designed to offer mobile voice services. Later these new cellular technologies were optimized to carry data services such as Internet access. The possibility of high-speed internet access that is not tied to cable and one place has made these cellular solutions increasingly popular. Also in many developing countries where there is no copper cable infrastructure in place, cellular networks have become the main Internet access technology for private subscribers (Anttalainen, 2015, p. 22).

Second-generation (2G)

To provide higher quality, less noise prone mobile voice communications, the second generation of the cellular phone network was developed. While the first generation was designed for analog voice communication, the second generation was mainly designed for digitized voice (Forouzan, 2007, p. 470).

The development of the second–generation (2G) digital mobile networks began during the 1980s and different systems were developed by Europe, the United States and other countries. The European digital cellular system GSM was developed by the conference European Des hostess at telecommunications. The acronym GSM came originally from the standardization working team, but GSM is presently understood to mean Global System for Mobile Communications. The multiple access method used in GSM is a combination of Frequency-Division Multiple Access (FDMA) and Time-Division Multiple Access (TDMA), in which each frequency channel is divided into time slots for multiple users (Anttalainen, 2015, p. 312).

Code–Division Multiple Access (CDMA) technology was selected in the early 1990s to become the main 2G digital cellular standard in the United States. The main difference between CDMA and other technologies discussed previously is that on the radio path it does not use either FDMA or TDMA. Instead, the mobiles share the same wide frequency band all the time and the users are separated with the help of a unique code for each user. This unique code is used to spread the signal over a wide frequency band and to detect the desired signal at the receiving end (Anttalainen, 2015, p. 312).

Third-generation (3G)

The third-generation (3G) of cellular telephony refers to a combination of technologies that provide a variety of services. The third-generation provides both digital data and voice communication. Using a small portable device, a person is able to talk to anyone else in the world with a voice quality similar to that of the existing fixed telephone network. A person can download and watch a movie, can download and listen to music, can surf the Internet or play games, can have a video conference, and can do much more. One of the interesting characteristics of a 3G system is that the portable device is always connected; you do not need to dial a number two connect to the Internet (Forouzan, 2007, p. 477).

The main forces behind the development of the 3G systems has been driven by the 2G system's low-performance data services, incompatible services in different parts of the world, and lack of capacity. In the 1990s, the ITU started a project to develop a future global 3G system, which is known today as International Mobile Telecommunication (IMT)-2000. The goal of IMT 2000 was to be a global system for 3G mobile communications. Many problems prevented the achievement of a mutual understanding among countries regarding this system. As a consequence, a common understanding about a detailed implementation for this technology was not achieved and IMT 2000 did not specify a global compatible technology. It instead acts as an umbrella for compatible services provided by different underlying technologies (Anttalainen, 2015, p. 312).

The blueprint defines some criteria for 3G technology as outlined below:

*Voice quality comparable to that of existing public telephone network.

*Data rate of 144 KBPS for access in a moving vehicle, 384 KBPS for walking pedestrians, and 2MPS for the stationary user's office or home.

*Support for packet switched and circuit switched data services.

*A band of 2 GHZ.

*Bandwidths of 2 MHZ.

*Interface to the Internet. The main goal of 3G cellular telephony is to provide universal personal communication (Forouzan, 2007, p. 477).

The actual 3G standardization work based on GSM technology was done by the third-generation partnership project (3GPP), which is a collaboration among groups of telecommunications associations. The original scope of 3GPP has been extended to include, in addition to the evolution of 3G, the evolution of GSM and 4G Long-Term Evolution (LTE) (Anttalainen, 2015, p. 313).

3GPP Standardization Areas

The 3GPP is a partnership project of a number of standards bodies, which are setting standards for 3G cellular mobile services and long-term evolution technologies (LTE). The 3GPP release include standards for encoding, decoding of audio, video, graphics, and data, as well as call control procedures and cell phones and user devices (Kumar, 2008, p. 59).

As previously stated, the 2G and 3G public land mobile networks (PLMN) are widely used for voice services and in many countries, they have replaced traditional fixed lines. 2G networks such as GSM and IS – 95 (CDMA1) were originally designed for voice – centric services and they still offer a competitive solution in that area. However, when customers require more data-centric services and higher data speeds, 3G and 4G networks offer a much better solution. The original 3G networks, UMTS and CDMA2000, provided a solution that worked well both with the traditional circuit–switched public switched telephone network (PSTN) networks and packet – switched Data Networks. The latest enhancements in 3G, however, have been mainly targeted to increase the offered data speeds. 4G networks based on long-term evolution (LTE) technology were designed from the beginning for various data services and they have no direct circuit–switched interfaces to PSTN (Anttalainen, 2015, p. 26).

Multimode cellular phones, which are able to switch among different wireless cellular standards, are growing much faster than single mode phones. Technology innovation is accelerating to bring the ability of the multimode cellular phones to interface with other Wireless Network Services. This creates seamless wireless connectivity between the wireless cellular and Wireless Networks standards, thereby rapidly meeting demand for wireless internet connectivity. Signal processing and digital communications (Miao, 2007, p. 3).

Most of the mobile phones support more than one technology and they can be used for voice calls and Data Services like web browsing. Many of the phones include a GPS global positioning system receiver and with the help of that they are able to offer location – based services like navigation (Anttalainen, 2015, p. 26).

Long Term Evolution (LTE) 4G / 5G

Cellular telephony is now in its fourth generation with the fifth on the horizon (Forouzan, 2007, p. 470). An entirely new radio platform technology and a GSM evolutionary path beyond 3G, long term evolution LTE is a standard under development by 3GPP. The GSM evolutionary path of LTE is beyond 3G, and it is widely considered the 4G for GSM /WCDMA networks. LTE achieves high peak data rates in wide spectrum bandwidth as a result of using OFDMA. It is believed that LTE technology will serve as a foundation for of the GSM evolution path of 4G the main benefits of LTE can be summed up as:

*IP, packet-based network that lowers latency and cost.

*Flexibility of deployment spectrum as well as the scalability of bandwidth, which allows operators to tailor their network deployment strategies to fit their available spectrum resources (Abate, 2009, p. 265).

LTE is a completely new mobile network solution and it has no common network elements with GSM or WCDMA with the exception the home subscriber server (HSS) database.

One of the major changes in the LTE network is that it was designed to carry only internet protocol (IP) packets. This simplified the network architecture and protocols used, but it also introduced some challenges such as how to support voice servers. Because the majority of the traffic carried over mobile networks and other networks is IP packets, this decision was well justified. Because the LTE is purely an IP based solution, an enhanced quality of service (QoS) mechanism is required to be able to support various real-time applications (Anttalainen, 2015, p. 342).

In LTE this uplink challenge has been solved by modifying orthogonal frequency division multiplex access (OFDMA) multiplex and in such a way that the sub-carriers allocated for one device are no longer independent from each other. This type of multiplexing schema is called single–carrier frequency division multiple access (SC-FDMA). The user data is first fed into a single carrier quadrature amplitude modulation (QAM) modulator, which forms time-domain symbols based on the user data and selected QAM modulation. These time – domain symbols are then taken into serial to parallel conversion and fed to a discreet Fourier transform (DFT), which calculates the spectrum of the time – domain signal. Now this spectrum can be carried over a transmitter at selected sub-carriers. This SC – FDMA process reduces the variation of the signal strength and improves the power efficiency of the transmitter. It also allows the system to allocate different sub-carriers to different users. The uplink data rate for one user can be changed by changing the single-carrier QAM modulation scheme (if channel quality allows) or the number of allocated sub carriers in OFDM a multiplexing. These changes can be made in one-millisecond resolutions, same as for the downlink transmission (Anttalainen, 2015, p. 345).

Perhaps a significant advantage that LTE will enjoy when it becomes fully realized, is leveraging on the more than 2.5 billion existing subscribers in the GSM / UMTS evolution of technologies, thus tipping the balance of the economies of scale. This means that infrastructure and service costs can be significantly lower on account of mass production. As a case in point, in the United States, both AT&T and Verizon have chosen LTE as their vehicle for the 4G and 5G migration (Abate, 2009, p. 268).

In LTE neighboring cells may also use the same carrier frequency, but some carriers and their power levels are allocated to mobile devices in such a way that they do not interfere with each other (Anttalainen, 2015, p. 317).

Modern cellular networks use an adaptive modulation encoding scheme, which means that the signal to noise (S/N) ratio is high, the system selects as high in modulation scheme as possible and uses as few bits as possible for error recovery. In small cells the attenuation of the signal is lower compared to large cells, resulting in a higher S/N ratio and higher data rates. Because the total capacity of one BS is shared by the users connected to it, smaller cells mean fewer users and more capacity per user (Anttalainen, 2015, p. 317).

Although current 4G technology would seem perfect for BC occasional television broadcast remotes, a 5G standard is in development. It promises to have more efficient spectrum usage and to serve more users with faster data speeds from each cell site. But it is important to remember that these are built for consumers and BC vendors are optimizing these networks for professional video applications. We've heard this same story through the years that 3G is going to be fast enough, LTE is going to give us plenty of speed for video, and so on. But as cellular networks get better, the demand for more bandwidth and reliability continues to grow because we keep filling the capacity (Kovacs, 2017, p. 18).

To address the so-called 1000× mobile data challenge, researchers have started investigating the next generation of cellular networks. Compared to 4G networks, the next generation of cellular networks are envisioned to achieve 1000 times the system capacity (Khan, et al., 2014, p. 37).

Cellular Radio Principles

One of the main challenges in radio communication is the limited frequency band available for this service. Cellular networks provide a solution for this by using the same frequencies in multiple areas, that is, cells, inside the network. A cell can be defined as a geographical area covered by Base Station (BS) where the signal quality is strong enough for communication between a mobile device and the BS. This principle of frequency reuse with the help of a cellular network structure was invented at Bell laboratories during the 1960s. The technical development of the radio frequency (RF) control, the microprocessor, and the software technologies made cellular networks feasible by the end of the 1970s (Anttalainen, 2015, p. 314).

As pointed out previously, the main objective of a communication network is to enhance coverage and capacity, while minimizing interferences in its various forms and eliminating or filtering out the effects of noise. Meeting capacity demand by increasing spectrum is not a luxury that most carriers have on account of its scarcity and cost. Antenna diversity, especially receive diversity techniques – based on putting two antennas sufficiently apart -have been around for a while and have proved very useful in shoring up faded received signals or improving SNR. Signals fade because of a variety of reasons, not the least of which is interference (Abate, 2009, p. 137).

Multiple Input Multiple Output Antenna

Traditionally, we lower transmit power, tilt, or use sectored antennas to alleviate interference and improve SNR. Unfortunately, more needs to be done. Multi-path propagation is, on account of reflections or alternate paths along the way, unless mitigated, can create interference challenges (Abate, 2009, p. 137).

Digital communication systems based on MIMO channel have recently emerged as one of the most important technical breakthroughs for wireless communications. A communication link of which a transmitter and a receiver are equipped with multiple antenna elements is considered a MIMO system.

The idea behind MIMO systems is to use space-time signal processing in which the dimension of digital communication data is complemented with the spatial dimensions by using the multiple spatial distributed antennas. The MIMO systems are capable of turning multi-path propagation into a benefit for the user. This is because the MIMO systems are able to provide spatial diversity, time diversity, and frequency diversity by coherently combining the use of the transmitter antennas at one end and the receiver antennas at the other end. Thereby, enhancing wireless transmission over the MIMO channel which improves the channel capacity and the quality of bit error rate BER (Abate, 2009, p. 118).

With the advent of multiple-input-multiple-output (MIMO) antennas, an additional degree of freedom became available as a tool to improve SNR. As a matter of fact, the very idea of using multiple antennas, in both transmit and receive sides, to intentionally create additional multipaths is used as a back door to improve SNR (Abate, 2009, p. 137).

The Physical Radio Interface (Concept of BC)

First, we need to be clear on some definitions: channel bonding refers to Cell-mux devices which include video encoding, and not simple channel bonding link aggregators which can work to create a single high-capacity Layer 3 Network, but with no video intelligence. While it might seem pedantic two separate different classes of device out like this, it is this reckless misuse of the terms “channel bonding” that has left many people unaware of why TV engineers hit major work flow problems in the field (Robinson, 2014)

To provide cellular systems with additional spectral resources, the wireless industry is considering the aggregation of frequency carriers in licensed, unlicensed, and shared access (SA) bands. Focus is placed upon reliable carrier aggregation/channel bonding (CA/CB) techniques, in which when CA/CB between the licensed, unlicensed, and SA carriers is performed, the licensed carrier is used for the primary and secondary carriers, and the unlicensed and SA carriers operate as additional secondary carriers (Khan, et al., 2014, p. 37).

The physical down link radio interface of LTE is based on OFDM such as in WLAN and WiMax. The used bandwidth is divided into 15 KHZ sub carriers and they are allocated to users based on the need and the overall load of the network. To keep the needed signaling for resource allocations reasonable, a block of some carriers and symbols is always allocated to users. If a user needs more capacity, they may get several of these resource blocks for a certain period of time. In the time-domain the resource allocation may be changed in one milli-second periods, that is, after two resource blocks (Anttalainen, 2015, p. 343).

Bonded Cellular for TV Broadcast

As TV broadcasters seek to expand their remote news gathering capabilities without breaking their budgets, many are increasingly looking to BC systems to supplement their ENG services. It is easy to understand why. BC systems, which allowed news crews to transmit signals from news sites via IP -are becoming more robust, with more options and more powerful transmission capabilities (Butts, 2015, p. 2).

Cellular live shots have come a long way. Camera makers targeting their wares at news departments are building cellular live shot wherewithal into their equipment, and some companies that pioneered modern cellular live shot technologies are using cellular wireless for more than just transporting news stories.

“Our user behavior has moved way beyond its use as a news gathering tool,” said Paul Shen, CEO of TVU networks in mountain view, CA. “We’ve begun to see this technology used regularly as a transmission means for various different programs. That’s a fundamental paradigm shift.”

Cell-mux (another term for BC) technology is usually an option where either time or location determines that a satellite link cannot be provided, and as such the typical Cell-mux use case is a fallback option usually limited to video workflows that require back-haul of video from ad-hoc locations. Typically, this is the case for sports, news, or security applications. This might be a live shot for linear insertion into a broadcast feed, or it could be file based for post-production insertion into an editorial workflow. The sources are usually Serial Digital Interface video (SDI) or similar, and the target workflow either expects the source delivered is a digital IP based workflow or will require that the video be converted back into SDI as it completes the path back to the studio (Robinson, 2014).

Since breaking into the market, a half decade ago, these (BC) packages- which often allow for “one-man band” news crews to cover breaking news, have quickly adopted to new advances in cellular technology to take advantage of faster links and more capabilities.

Companies have adopted to such technologies as statistical multiplexing (stat-muxing) to aggregate signals; they are also integrating social media feeds and redesigning antennas. Hybrid BC systems take the best of both worlds, IP and microwave, to improve signal reception in particularly out of the way places. It is these types of advances that are allowing news crews to operate in more locations than ever before (Butts, 2015, p. 2).

BC signal routing is comprised of multiple SIM cards, each representing a discrete data path. However, by adding some relatively simple intelligence at both ends of the data path, multiple paths can be aggregated together. In a packet video environment, a multiplexer can be used to break up the video stream, sending bits of video down one path and other bits down another path, to achieve a throughput several times greater than the single path maximum of 384 kilobits per second. Solid broadcast quality video at around 1.5 MBPS or even greater can then be sent live over a group of cellular data networks (Robinson, 2012).

Latency, the delay between the capture of a live shot in the field and its play out to the anchors in the studio moments to seconds later, is a maddening problem that can make a broadcast hard to watch. Though using a single cellular modem eliminates the latency inducing processing time, the challenge is to provide sufficient bandwidth to enable quality video and audio for the live shot. Long before bonded cellular technology hit the live news scene, microwave and satellite delivery was firmly established. Stations that have invested heavily in infrastructure for those legacy technologies are looking to integrate bonded cellular as another tool in the ENG toolbox (Johnston, 2013, p. 44).

In 2011, cellular multiplex had moved from an innovator only technology into the early stages of adoption. In 1991, an event would occur, and local observers would contact either the police or the local media. Phone calls, telegrams, faxes, and possibly bulletin board systems and email would start to notify local representatives of news agencies. They would mobilize reporters and outside broadcast uplink trucks from local depots. Given the portability of the technology required, radio reporters would probably get online first using public switched telephone network and integrated services digital network codecs to get the first reports flowing. As the TV crews arrived and got set up, pictures would start to appear via satellite, being downlink and fed into scheduled playout on TV broadcast channels. Only a really significant event would justify the thousands of dollars for reporters and TV satellite uplink to provide "live" coverage. All in all, as far as the end consumer was concerned, news was something that evolved on a 24-hour basis; only really dramatic events received live coverage; and all content would be played out only if it achieved high-quality production standards (Robinson, 2012).

Satellite is, however, more expensive and requires either a self-alignment system built into a vehicle (limiting its portability) or a skilled engineer to align the dish. Satellite is a more "ad-hoc" than fiber, but considerably less "ad-hoc" than BC. So, where portability and time to live are the key performance indicators, BC will be the best choice (Robinson, 2012).

By 2001, the Internet had arrived. RSS, e-mail, and push technologies used by local observers accelerated the notification process since more of the general public was versed in the technology and could notify the news agencies directly. Indeed, trend-based searching had emerged, and alerts could spot news as it developed and mobilize the technical teams much faster. Once mobilized, the reporters and contributors would still need to travel to the event and link-up. Despite webcasts technology's ability to deliver reasonably good quality images to the TV news companies, its use was very nascent. Some low-quality footage would occasionally make it to broadcast from camera phones or "handy-cams", but all in all, the TV broadcast industry still viewed any video content that was not produced to a very high production standard, with caution The general public still relied primarily on TV broadcast news media as the earliest sources for breaking news (Robinson, 2012).

However, this scenario does not mean that a network topology such as BC will replace or supplant existing TV broadcasting infra-structures. During the same time, there is a need to recognize that the existing networks for broadcasting, Internet and cellular mobile need to coexist for a long time. Terms such as disruptive technology do not mean that is the end of digital TV or HDTV. In fact, the screen size is of no critical importance. What it means is that the days of linear programming in its present manifestation may be limited. It is more than likely to undergo a metamorphosis into interactive, on demand and push broadcasting methodologies. Networks will, therefore, continue to operate in a multi technology environment. This requires network architectures that facilitate multiple networks to operate together (Kumar, 2008, p. 15).

It is important to remember that such systems are not replacing the traditional ENG-work-flow, but are positioned as an added capability to expand ENG functionality. And as these systems become more powerful, yet more lightweight and more cost efficient, we should see higher adoption across the board (Butts, 2015, p. 2).

By 2011, the landscape had changed completely. Twitter was the technology that breaks the news. Disintermediating the entire news workflow of a decade earlier, the local observers themselves can communicate directly to the audience. As soon as the event occurs, observers can shoot from their phones, and these ‘tweets’ can include images. This low bit rate general packet radio service or 3G stream gets the story to the audience at the same speed that it formally took to notify the news agencies that the story existed. As soon as twitter has announced the event, we see links to uploaded videos, shot on smart phones and published on sharing sites such as YouTube. In 2011, There may have been a scattering of capable users who are familiar with live streaming services such as Ustream or LiveStream and have a smartphone app that enables them to stream the events live (Robinson, 2012).

Still, there is a demand for quality in broadcast media, and mobile/smart phone live video streaming is usually limited by the uplink capabilities of the smartphone's connectivity. Typically, this means that the single data stream enabled by a smartphone's SIM card is a limiting factor, maximizing throughput at anywhere between 64 KBPS and 384 KBPS on a typical 3G network, and only then if the user is near a cell mast to get a stable, clean signal (Robinson, 2012).

LiveU is one of a number of BC vendors whose technology multiplexes multiple 3G, 4G, or Wi-Fi data channels in order to create a constant link with sufficient bandwidth to send SD or HD images back to the studio. These vendors are hoping to disrupt the broadcast ENG and contribution markets. Proponents of the technology say that it brings radical change to ENG applications because it is quick to setup, and does not require (traditional) broadcasters to deploy an expensive and time consuming, ENG van to cover breaking news events (Zaller, 2012).

LiveU is considered to be the first early innovator for BC and the company has announced at the 2018 National Association of Broadcasters (NAB) annual convention the ability to scan and aggregate spectrum using satellite, cellular and wi-fi bandwidth simultaneously to adaptively choose the most robust combination of all spectrum to create a robust signal path.

Anyone with a cell phone knows that a good connection is not always a sure thing, so manufacturers like Ontario, Canada, Dejero created the live + booster to work around that reality. Live + booster is a vehicle mounted unit with an array of up to 12 high gain antennas to improve performance. Paired with live + go box or 2020 transmitter, the live + booster is an alternative to satellite or microwave systems that may be blocked by weather or line of sight obstructions. JVC recently launched a vehicle mounted system that incorporates diversity antennas to establish a high reliability channel with BC (Kovacs, 2017, p. 18).

Bonded cellular is a technology that each station or network will use in a slightly different way, and even a single broadcaster will have several methods in which to deploy the technology. This calls for packaging the basic technology in diverse ways (Johnston, 2013, p. 44).

Each vendor has its own proprietary way of enabling its BC. To get an idea of how this has evolved, let us look at link aggregation control protocol (LACP), which is an established standard and has been around for many years. Each vendor's proprietary link aggregation system presents different APIs and interfaces, but the underlying principles are much the same. In terms of reliability, this process is mission critical. Errors here can have widespread negative effects, so this piece of software must be written properly and is the crux of the BC's unique capability to maximize reliability (Robinson, 2014)

In theory, at the camera/encoding, there is no limit to the quality that can be filmed, encoded, multiplexed, and sent over the cellular Data Network. However, limits do exist in the cellular networks themselves. A typical cellular mast has from 3 to 9, T1 lines connected to it. Since each of these T1 lines is 1.5 MBPS, it is easy to see how even a couple of BCs that live in the same area will saturate the mobile network backhaul, and contention for the limited bandwidth could cause problems for all data services on that cell. In some limited cases, cellular operators will allow BC users to pay for a premium class of service, but this is still very rare and expensive, and it requires planning, which would negate all of the opportunity that BC presents for breaking news (Robinson, 2012).

Accordingly, even the most extreme, unexpected, and remote events are finding their ways to audiences live, in a way that was never before possible because of the scarcity and cost of the technology that could provide the bandwidth required to stream live video. Video footage documenting events is now widely available before the traditional news agency has just about digested what has happened and begun to react! In fact, the agency itself is more or less regulated to being in the audience. This is transformational (Robinson, 2012).

The problem of predicting the future is more difficult with technology that is experiencing rapid change. Management must be able to predict discontinuities, which occur when one technology threatens to replace another (Khalil, 2000, p. 254).

In essence, we try to imagine different plausible futures and to assess the interaction of our technology with its environment in each case. We imagined different plausible changes in the social and natural environment, as well as different development pads for the technology we are introducing. The problem of forecasting is not to know the future, but to obtain a range of likely future situations. This gives us some guidance on what actions we need to take at the present and how we might adjust our actions to the unfolding future situation (Braun, 1998, p. 110).

The first thing live shot equipment providers point out is not to expect any miracles around the corner. “I don’t see them rolling out 5G or something, or suddenly be able to offer us 100 MBPS/ 4G link,” said john Landman, vice president of sales for Terradeck, the developer of IP based wireless video technology, based in Irvine, CA. That said, there have been network improvements, with wireless providers touting 4G LTE for wireless communication of high-speed data for mobile phones. The advantage of 4G is that you are basically, particularly from a cellular uplink system standpoint, able to do more with less so you can use fewer modems but the bandwidth is just as strong (Butts, 2015, p. 3).

The ‘killer app’ has the ability to reach a wider range of cells than those in immediate proximity, since doing so insurers that you can broadcast at the center of the action, but you do not have to contend with all the other network activity that such an event is likely to produce. Devices that lack that capability will, at that critical moment, fail. They are not ideal for mission critical content workflows.

What will become of the thousands of microwave remote trucks operated by broadcasters across the country? Can BC systems do everything a traditional ENG truck can do, without the need to get an FCC license for microwave operations? Not exactly. Microwave has its niche where cellular coverage has not been deployed or in the rare situations of a severely congested environment - although those situations are becoming less common, as the cellular infrastructure continues to improve. BC, as product category that had not been invented 10 years ago and had just a handful of customers five years ago, is now a major path for broadcast remotes (Kovacs, 2017, p. 18).

However, the technology comes with a major potential downside. Broadcasters relying on BC are not always able to control the availability of wireless network bandwidth. In a crowded area, like a stadium, courtroom, or breaking news location, it may be difficult to gain access to sufficient bandwidth, resulting in severe image degradation. Several news organizations have experienced that problem at recent news events in Chicago and Denver (Zaller, 2012).

ENG crews that use cellular live shot gear in the field applaud or curse the cellular networks on which they rely, on a day to day basis. Can we get connected? Will the connection hold? The anecdotal evidence about what worked yesterday, did not work today. Designers and builders of the cellular live shot equipment that news crews are looking at not only the present, but into the future, assessing what new technology the cellular network operators will be rolling out. They've got to plan their next generation of products to work with tomorrow's networks as well (Butts, 2015, p. 3).

While weather is a significant factor affecting the use of cellular networks, live broadcasters must also contend with heavy traffic on those networks for voice and data communication, as crowds build around a breaking news story or sports venue (Johnston, 2013, p. 42).

To overcome these issues, some vendors, including LiveU, offer their products as part of a service bundle, which may also include dedicated cellular or Wi-Fi bandwidth. This helps users remove the risk and complexity associated with data roaming and crowded spectrum. It also benefits users by giving them the option of moving their technology costs from capitol expense (CapEx) to operational expense (OpEx) (Zaller, 2012, p. 2).

BC systems are no longer novelties reserved only for the most extreme shooting conditions. They now enjoy a growing pride of place in (nearly) every field video producer's toolbox and play an integral role in Electronic News gathering (ENG). At the 2014 World Cup one vendor reported that more than 200 of its units were used each week during peak times, with more than 40 TB of data delivered over the course of the entire event. Of course, no matter how popular BC solutions become, they'll never offer the same reliability as more 'tried and true' backhaul methods (Robinson, 2014, p. 1).

As telcos such as AT&T, Verizon, and Sprint and T-Mobile acquired more spectrum and implemented 4G technology, digital bandwidth that could be used for broadcast quality video increased. With two 4G connections pared to the camera, it is perfectly reasonable to get a transmission channel of 20 MBPS or greater – easily enough for a high-quality link, especially when using H.264 encoding. Compared to microwave trucks, BC has another big advantage: it has high-bandwidth return capability for cueing and Intercom Fold Back (IFB) built into the system. The big disadvantage of BC is that the digital link can vary widely from "lousy to great", an operator might anticipate getting 20 MBPS, but once in the field, find out that it will not go higher than 3 MBPS. As telcos continue to improve their systems and build additional 4G (and 5G) sites, getting higher speeds in the future is almost certain (Kovacs, 2017, p. 18).

Future Implications for BC

It is important to note, that for all of the benefits that cellular services offer traditional TV broadcasters, those broadcasters still view giant cellular companies with a cautious eye, as the giant telcos ply their considerable resources to pressure the FCC to push broadcasters to release more and more of their dedicated TV spectrum and turn it over to telco conglomerates, as in the case of the recent FCC TV Spectrum and Re-pack initiative.

Broadcasters have a wary relationship with telco companies, but reliable remote connections using BC products could change some attitudes among broadcasters. As more cell sites are rolled out and broadcaster friendly bandwidth becomes more available and reliable, routine ENG remotes will increasingly move to BC links. After all, what once needed a truck (and engineering staff) will now almost fit in a couple of vest pockets (Kovacs, 2017, p. 18).

The cellular industry – in the form of the big telcos – is not a great friend of broadcasters. For decades, broadcasters controlled a huge swath of spectrum that turned out to be ideal for telcos to press into cell phone service – lobbying, advertising and probably some old-fashioned arm twisting was involved in forcing broadcasters off that spectrum. To be fair, the telcos did pay a lot of money for it, but much of that money went to “Uncle Sam” and not the broadcasters (Kovacs, 2017, p. 18).

There could be several books written about the antagonistic relationship between TV broadcasters and telco providers, but the point is that some broadcasters grumble that the use of products and services that are sold under the name “Bonded-Cellular”, since cellular has been well, the enemy. A few people in the industry probably want to avoid the use of the word cellular, and certainly do not want to be seen “bonding” with it (Kovacs, 2017, p. 18).

Could BC Become Outdated by 5G Implementation?

The idea of “bonded” may be quickly becoming passé, as wireless network speeds ramp up the 4G wireless networks that are now common, and they theoretically have speeds as high as 100 MBPS. In practice one routinely gets 4G speeds of 15 - 20 MBPS at home and occasionally 42 MBPS on the road. With the advent of 5G, which promises greater spectral efficiency than 4G and theoretical wireless speeds up to 1 GBPS (giga-bits per second), the need for bonding multiple channels for a single feed is no longer necessary. There is scarce deployment of 5G currently, but the standard has been determined and rollout of 5G has begun in some large metropolitan test markets.

Even 15 MBPS with H.264 encoding results in a pretty good HD signal back at the studio, and some video industry manufacturers are building gear to make such bandwidth as reliable as possible (Kovacs, 2017, p. 18).

Adoption of Innovation

The diffusion of technology artifacts has been studied in the literature for a long time and from a variety of perspectives. One major perspective models the temporal pattern of diffusion, with the aim of explaining the observed shape and/or forecasting how the pattern will evolve in the future (Dutta, Puvvala, Roy, & Seetharaman, 2017).

A technological innovation, a new idea, or a new system is considered to be successful when it is a adopted by users and diffused through the user population. Diffusion is the process by which an innovation is communicated overtime, through certain channels, to members of a social system (Khalil, 2000, p. 90).

Here, the main research questions include: who adopts a new communication technology? Why do they adopt? What is the rate of adoption of a new technology? What will it likely be in the future? How could the rate of adoption be speeded up or slowed down? Are individuals or organizations that adopt new communication technology also likely to adopt other new communication technologies? Is there a key communication technology that triggers the adoption of other communication technologies (Rogers, 1986, p. 8)?

History of Diffusion of Innovation

Gabriel Tarde was a French judge, and he based many of his sociological observations on the human behavior that came before him in his courtroom. Tarde set forth a theory of imitation, that is, of how individuals work influenced by the behavior of others with whom they came in daily contact. These understandings about imitation provided a basis, 40 years later in the United States, for communication research on the diffusion of innovations (Rogers, 1986, p. 71).

Rogers defines Diffusion as the process by which an innovation is communicated through certain channels overtime among the members of social system. Tarde observed that the rate of adoption of a new idea usually followed S-shaped curve over time: at first, only a few individuals adopt a new idea, then the rate of adoption spurts as a large number of individuals accept the innovation, and, finally, the adoption rate slackens as only a few individuals are left to adopt. Astutely, Tarde recognized that the S – curve "took off" when the opinion leaders in a system adopted the new idea (Rogers, 1986, p. 73).

Diffusion of Innovation (DOI) theory explained that the innovation and adoption happened after going through several stages including understanding, persuasion, decision, implementation, and confirmation that led to the development of Rogers' (1995) S-shaped adoption curve of innovators, early adopters, early majority, late majority and laggards (Lai, 2017, p. 12).

The process of technological innovation is held to be of great importance and, hence, is the subject of much theoretical analysis. Theories of technological innovation concentrate on three aspects: the process of technological innovation and its various stages, the classification of innovations according to technological and economic criteria, and in the management of innovation (Braun, 1998, p. 14).

Managing technological innovation requires that an organization continue to introduce incremental innovations and forecast future changes in order to ensure continued existence in the face of discontinuous innovation (Khalil, 2000, p. 90).

BC communication technology is no different and vendors struggle to innovate the industry shifting to 5G standards, whilst battling stiff completion in the market.

Seeing technology as a system should help us to understand that technological change is closely connected with a variety of associated changes, and that the creation of a technological system may be fraught with tension and discomfort (Volti, 2009, p. 6).

Innovation of Communication Technologies

One of the two main areas of research with new communication technologies deals with how these innovations are adopted and implemented by users. The other main topic of research, the impacts of the technologies, is moot until adoption has occurred. Research on the adoption of the new media is based on a contemporary application of a, well researched theory with a long history, that of the DOI (Rogers, 1986, p. 116).

One pervasive presence in diffusion modeling has been the Rogers DOI model (1995) whose underlying mechanism is that of contagion, where actual adopters influence other potential adopters. Different parameters, such as propensity to innovate or imitate, modulate the diffusion. Numerous studies have used this classical model to understand large scale technology diffusion (Dutta, Puvvala, Roy, & Seetharaman, 2017, p. 28).

The term innovation is frequently used in the diffusion literature as being synonymous with technology. Adoption of a certain type of technology is usually based on the possible efficacy of that technology in solving a perceived problem. Information about an innovation reaches a potential adopter through communication channels. There are many channels for communicating new ideas to potential users, including interpersonal channels and mass media (Rogers, 1986, p. 118).

A communication channel is the means by which messages get from one individual to another. Mass media channels are more defective in creating knowledge of innovations, whereas interpersonal channels are more effective in forming, and in changing, attitudes toward a new idea, and thus in directly influence and the decision two adopt or reject a new idea (Rogers, 1986, p. 118).

Time is involved in diffusion in 1. the innovation – decision processes, 2. innovative nests, the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a social system, and 3. and innovations rate of adoption (Rogers, 1986, p. 118).

The decision to adopt an innovation by an individual or an organization takes a certain period of time and consists of several stages. It starts with gaining knowledge of the innovation, forming a favorable opinion about it, making the decision to adopt it, implementing the innovation, and following up on its performance. Innovative organizations that are considered technology leaders require a shorter time, than others to go through the innovation – decision process. Followers take longer to affect the same process, and laggards take much longer to make a decision for technology adoption (Khalil, 2000, p. 93).

Innovations that are perceived by individuals as having greater relative advantage (RA), compatibility, and less complexity and that can be tried in observed will be adopted more rapidly that other innovations (Khalil, 2000, p. 91). It is for this reason that this study incorporates Roger's theory of Relative Advantage (RA) and Relative Compatibility (COMP) as two of the four independent variables (IV) in this study.

The innovation-decision process is the mental process through which an individual or other decision-making unit passes from first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of the decision (Rogers, 1986, p. 118).

Technological innovation needs to be distinguished from invention. An invention is a novel technological idea that need never reach production or the market. A technological innovation is a new, or substantially improved, technology, or product or technology, that is offered for commercial transactions on the market (Braun, 1998, p. 14).

Forecasting Technology

Forecasting is an attempt to glean what affect different present actions and decisions might have upon the future. We try to gaze into the future in order to learn how to shape it in desirable ways (Braun, 1998, p. 109). The first step in technological planning is forecasting. Forecasting provides visions of the future that can be used to guide actions in the present in anticipation of future states (Khalil, 2000, p. 254).

If we are trying to introduce a new technology, we are bound to ask how likely it is to be successful in the marketplace and how it will interact with the world into which it will be introduced. How do we reconcile the paradox of our inability to know the future and our need to foresee the consequences of our actions upon the future (Braun, 1998, p. 109)? Those who forecast well can seize opportunities in a timely manner and thus reap the rewards of future changes. Technology forecasting (TF) is based on following established methodology to forecast the character a role of technological advancement (Khalil, 2000, p. 254).

Forecasting is the art of postulating a range of likely futures, enabling us to make a reasonably informed choice of actions affecting the future. What we regard as plausible is invariably strongly influenced by the present we know, though it may also be influenced by wishful, or fearful, thinking (Braun, 1998, p. 110).

Managing technological innovation requires that an organization continue to introduce incremental innovations and forecast future changes in order to ensure continued existence in the face of discontinuous innovation (Khalil, 2000, p. 90).

Method of Forecasting – Extrapolation

The method of extrapolation essentially consists of obtaining historical data and fitting a curve to them which extends into the future. The fundamental assumption of extrapolation is that things will continue as before (Braun, 1998, p. 111).

The S-curve of technology progress is a very useful model in technological forecasting (Khalil, 2000, p. 80).

The process of technological advance can be graphically portrayed according to the following diagram, in which the horizontal axis represents time and the vertical axis represents just about any aspect of technological advance (Volti, 2009, p. 9). Although there are inevitable fits and starts over time, the general trend can be depicted as a sinusoidal or S-shaped curve: (Volti, 2009, p. 9)

Note that at first, the curve rises rather slowly, inclines steeply in the middle, and then begins to slow down. That is, after an initial period of slow growth, the rate of advance accelerates, reaches a maximum, and then begin supersede at a slower pace, but never completely levels off. Although the rate of increase is smaller as the curve moves toward the right, this rate is applied two and increasingly larger base, so the actual edition is still substantial (Volti, 2009, p. 9).

The technologies improvement of performance follows the S-curve. On a technology performance parameter, Y-axis, is plotted against time, X-axis, the result resembles an S – shape diagram called the S-curve. Technological performance can be expressed in terms of any attribute, such as density, in the electronics industry number of transistors per chip, or aircraft speed in miles per hour (Khalil, 2000, p. 80).

Rogers points out that “implementation” is frequently the dependent variable (DV) in studies of the diffusion of new communication technologies, rather than adoption (Rogers, 1986, p. 122). Thus this study will designate the dependent variable (DV) as the “intention to adopt” or in other words, the intention to ‘implement’ BC technology as describer in-depth in Chapter 3.

Technology capabilities change over time, sometimes rapidly. Rogers describes an opinion leader as an individual able to influence other individuals’ attitudes or overt behavior informally in a desired way with relative frequency. The opinion leader embodies the norms of the system, the established behavior patterns for the members of a social system. If the norms of a system are favorable to an innovation, the opinion leaders are more likely to adopt it, and other individuals will tend to follow their lead (Rogers, 1986, p. 120).

In the case of communications technology, diffusion may occur very rapidly within the prescribed social system, as previously noted by Rogers. For example, analog to digital signal transmission, the introduction of CDMA or GSM standards for mobile telephones, are examples of such abrupt technology advances that affected diffusion. Second, consumer or user perceptions of the value proposition also evolve over time, especially when additional offerings become available through the technology such as in the case of e-commerce on the Internet or mobile value-added services in the case of smartphones. Third, regulations evolve and affect the interaction between technology and individuals, such as limits on the number of competing mobile carriers (Techatassanasoontorn & Kauffman, 2014)

In short, the drivers of the contagion process in technology settings may cause diffusion parameters to change over even relatively short periods of time (Dutta, Puvvala, Roy, & Seetharaman, 2017).

Technology Acceptance Model (TAM)

As with the examples previously discussed of Roger's DOI Theory, the related theory of Technology Acceptance Model (TAM) also plays a major role with the ever-increasing development of technology and its integration into users' private and professional life to arrive at a decision regarding the acceptance or rejection of a particular technology. A respectable amount of work dealing with the Technology Acceptance Model (TAM), from its first appearance more than a quarter of a century ago, clearly indicates a popularity of the model in the field of technology acceptance. Originated in the psychological theory of reasoned action and theory of planned behavior, TAM has evolved to become a key model in understanding predictors of human behavior toward potential acceptance or rejection of the technology (Marangunic & Granić, 2014).

TAM, as shown in Figure 2-1, was introduced by Davis in 1986 for his doctorate proposal. An adaptation of Theory of Reasonable Action, TAM is specifically tailored for modeling users' acceptance of information systems or technologies.

TAM model developed by Davis is the most used framework in predicting information technology adoption and argued that TAM should be able to analyze factors affecting adoption intentions beyond perceptions of convenience and usefulness. Though TAM had received much support, it focused on the effects of perceptions of the technology's usefulness and convenience on adoption intentions (Lai, 2017, p. 12).

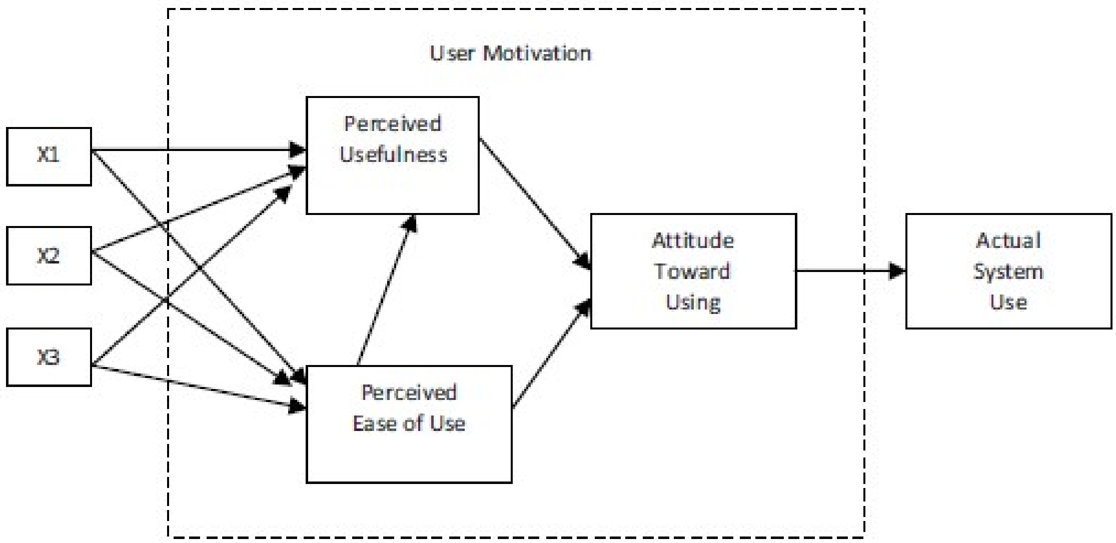


Figure 2-1 Original Technology Acceptance Model (Davis, 1986)

In 1989, Davis used TAM to explain computer usage behavior. The goal of Davis' (1989) TAM is to explain the general determinants of computer acceptance that lead to explaining users' behavior across a broad range of end-user computing technologies and user populations. The basic TAM model included and tested two specific beliefs: Perceived Usefulness (PU) and Perceived Ease of Use (PEU). Perceived Usefulness is defined as the potential user's subjective likelihood that the use of a certain will improve his/her action and Perceived Ease of Use refers to the degree to which the potential user expects the target system to be effortless. The belief of the person towards a system may be influenced by other factors referred to as external variables in TAM (Lai, 2017).

Davis hypothesized that the attitude of a user toward the system was a major determinant of whether the user will actually use or reject the system. The attitude of the user, in turn, was considered to be influenced by two major beliefs, Perceived Usefulness (PU) and Perceived Ease of Use, (PEOU) with the perceived ease of use having a direct influence on the perceived usefulness.

Davis defined Perceived Usefulness (PU) as the degree to which the person believes that using the particular system would enhance her/his job performance.

Whereas the Perceived Ease of Use (PEOU) is defined as the degree to which the person believes that using the particular system would be free of effort. Finally, both beliefs were hypothesized to be directly influenced by the system design characteristics.

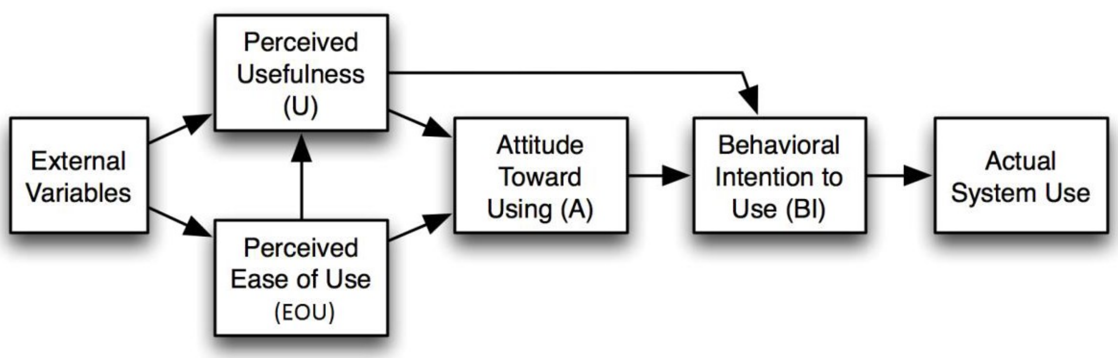


Figure 2-2 Technology Acceptance Model (TAM)

TAM became a dominant model in investigating factors affecting users' acceptance of the technology. The TAM presumes a mediating role of two variables called perceived ease of use and perceived usefulness in a complex relationship between system characteristics (external variables) and potential system usage. Derived from the psychology-based theory of reasonable action (TRA) and theory of planned behavior (TPB), TAM has taken a leading role in explaining users' behavior toward technology. Without understanding the origins, development, and modifications along with the limitations of the model, there can be no comprehensive and methodical research in the field (Marangunic & Granić, 2014).

Davis and his associates additionally found that attitude did not fully mediate the perceived usefulness and the perceived ease of use. Based on these complementary findings, a parsimonious TAM was suggested, which removed the attitude construct from the model.

Subsequent TAM development has included behavioral intention (BI) as a new variable, which was directly influenced by the perceived usefulness of the system. Davis and his colleagues suggested that there would be cases when, given the system which was perceived useful, an individual might form a strong behavioral intention to use the system without forming any attitude, thus giving rise to a modified version of TAM (Marangunic & Granić, 2014).

Therefore, this study will incorporate and correlate aspects of Roger's DOI and Davis's TAM to examine the previously described independent variables (IV) theorized by Rogers and Davis to arrive at a determination of the user behavioral intent (BI) to adopt BC technology as describe further in chapter 3.

CHAPTER 3

METHODS OF ANALYSIS

The general purpose of all research studies, except those that we call purely descriptive, is to look for relationships between variables (Gliner & Morgan, 2000, p. 62).

This chapter describes the analytical methods used in the conduction of the empirical study regarding the stated problem and specific research questions. Data acquired from an online survey conducted by Qualtrics was collected from a sample population of TV technology managers and engineering decision makers. Qualified email contacts that reached the desired target demographic within the United State were derived, with consent, from the Broadcast Education Association, (BEA) membership lists and the NAB/BEA National Job search contacts for Broadcast TV networks and Engineering. The survey research questions are carefully constructed to ascertain useful responses regarding the current usage or future plans of the intention to adopt BC technology.

Scientific and academic research is a vast field that is generally thought of as being developed from the origins of the scientific method. The method involves several steps or processes with the aim of arriving at a conclusion derived from the results of the research. Generally, the process is as follows: Hypothesis, definition, gathering of data, analysis, testing and interpretation and a conclusion.

If a hypothesis can NOT be disproven via the conclusion, then the hypothesis has survived another round of testing and may be accepted as a truth until the next research testing opportunity presents itself. It is also important to clearly state a hypothesis both in description and in formula. The hypotheses lay at the heart of any statistical research and are the cornerstone of what the research is all about! The hypothesis states, what exactly is trying to be proved or disproven within the scope of research. A properly constructed and defined hypothesis allows a researcher describe the assumptions being made that are relevant to the models that are employed in the research and validate those assumptions

Research must be conducted in a manner and method which incorporates integrity, honesty, and unwavering commitment to finding truth. Otherwise, research just becomes one more tool in the human intellectual arsenal of control and manipulation. Scientific and academic research must be rooted in dignity, ethics and a desire to reveal universal truths.

When scientists ask questions about any relationship that is in question for study, they need to set up an experiment to determine if there may be a correlation between those relationships.

One of the many roles of a technology manager is to supervise, guide and direct the proper administration of an institution's applied research teams, resources and assets. Practical decisions must be made as to the implementation of the institution's mission, goals and statement of purpose. These resources must be deployed in a manner that is ethical, honest and forthright and are closely aligned with the mission of the institution. That said, the prudent development of applied research and proper statistical testing can leverage institutional assets for growth into new markets, develop new product lines while increasing efficiencies with the goal of creating a better community and happier employees. Applied research is an offshoot of basic research, in which basic research is conducted for the discovery of how things work in our universe, or "knowledge for knowledge's sake. Research is inquiry or examination of a critical and exhaustive investigation aiming for the discovery of new facts and their correct interpretation" (D. P. Beach, personal communication, 2012).

Research Approach (Qualitative vs. Quantitative)

Quantitative data are said to be objective, which indicates that the behaviors are easily classified or quantified, either by the participants themselves or by the researcher. Quantitative or positivist researchers usually translate perceptions, feelings, and attitudes into numbers by using, for example, rating scales. Qualitative or construct researchers, on the other hand, usually do not tried to quantify such perceptions (Gliner & Morgan, 2000, p. 9).

Descriptive research, unlike experimental, is based on causality, and establishes only associations between variables (Limo, 2015, p. 41). The general purpose of all research studies, except those that we call purely descriptive, is to look for relationships between variables (Gliner & Morgan, 2000, p. 62). Unlike other methodologies, the quantitative approach also relies on deductive logic and seeks to test theories, identify variables, and relate these variables in terms of questions (Limo, 2015, p. 41).

This approach divides the research into three general types: experimental, individual differences, and descriptive. The first type of approach has an active independent variable, the second has an attribute independent variable, and the descriptive approach does not have an independent variable (Gliner & Morgan, 2000, p. 62).

Generally experimental research is associated with quantitative or otherwise known as positivist research, which is the research foundation employed for this study.

The intended audience of this study is targeted towards technology management and decision makers in broadcast television and live streaming professionals, including, engineers and media management. It is determined that a quantitative research approach is best suited for this study.

Research Design

The nature of this study determined that the best choice for the research design and methodology would be that of a positivist approach utilizing quantitative techniques. This investigation studies the determinants of adoption of BC technology among technology managers to help answer the stated research questions of this study.

The positivist approach to research is based upon the scientific method. Drew (1980) presents six steps to the research process (Gliner & Morgan, 2000, p. 23).

1. The first step involves the research question. This initial stage involves choosing a question that has the potential to work into a researchable project.
2. The second stage suggested by Drew (1980) involves developing hypothesis. Briefly, the research problem is directed into specific questions that are testable.
3. The third step is developing a research design that allows the investigator to test the hypothesis. The major focus of the research design is to allow the investigator to control or eliminate variables that are not of direct interest to the study. This allows the investigator to test or answer the research questions directly.
4. The fourth stage involves data collection and analysis. Data are collected in an unbiased and objective fashion. The data, which are usually quantitative numbers, are then analyzed by using statistics.

5. The fifth step involves making inferences or interpretations from the data. However, these interpretations must be based on the original hypothesis.
6. A statement is then that made as to whether the hypothesis is accepted or rejected (Gliner & Morgan, 2000, p. 23).

Determinant Variables (Descriptions)

The determinant independent variables (IV) of this study were selected from the theoretical foundations found in Roger's, Diffusion of Innovation (DOI) and Davis' Technology Acceptance Model (TAM) previously discussed in chapter two. The following four IV determinants were chosen for their specific relevance to the research questions of this study:

1. Relative Advantage (RA), as defined by Rogers (1995) is a variable that represents the potential advantages that would be associated with the adoption of the BC innovation.
2. Compatibility (COMP), as defined by Rogers (1995), is the extent to which BC is perceived to be consistent with existing values, past experiences and the needs of potential adopters.
3. Perceived Ease of Use (PEOU)
4. Perceived Usefulness (PU)

Survey Instrument

Surveys provide us with a methodology for asking people to tell us about themselves (Cozby, 2001, p. 104). A questionnaire is used to collect data subjects; it is referred to as a survey (Carper, 2015, p. 31). Surveys are helpful in providing data that represents a "snap-shot" of how people think and behave at a given moment in time. In addition, the survey method is also an important way for researchers to study relationships among variables and ways that attitudes and behaviors change over time (Cozby, 2001, p. 104). Analysis of the survey data will provide greater understanding about the selected determinants and their influence upon the behavioral intention to use BC among technology leaders.

Reliability, Consistency and Repeatability

It is important to establishing reliability in the methods and results obtained by this study to generate repeatability, and consistency. The proper implementation of the survey instrument will strive to ensure accuracy, generate consistent results, and reduce bias.

What is reliability? When a person is said to be reliable, we have certain conceptions about that person. For example, the person always shows up for meetings on time; therefore, he is a reliable person. When we use test or other instruments to measure outcomes, we also need to make sure that these instruments are reliable. Cronbach (1960) said that reliability “always refers to consistency throughout a series of measurements”. The importance of reliability for research methods cannot be overstated. If our outcome measure is not reliable, then we cannot accurately assess the results of our study (Gliner & Morgan, 2000, p. 310).

In order to establish statistical reliability, Cronbach’s alpha was utilized. Cronbach’s alpha determines the internal consistency or average correlation of items in a survey instrument to gauge its reliability (Limo, 2015). Cronbach’s alpha is a measure of reliability of scale in which the top half of the equation is simply the number of items (N) squared multiplied by the average covariance between items or the average of the off-diagonal elements in the variance covariance matrix. The bottom half on the equation shown below is the sum of all the elements in the variance-covariance matrix (Field, 2006)

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

Where:

α = Cronbach’s alpha

N = Number of items squared

$\bar{v}$ = Average variance of each component

$\bar{c}$ = The average of all covariances between the components across the current sample

This statistic was widely utilized for testing reliability in many technology adoption studies. The Cronbach’s alpha coefficients for the variable scores were evaluated using the guidelines where > 0.9 Excellent, > 0.8 Good, > 0.7 Acceptable, > 0.6 Questionable, > 0.5 Poor, < 0 .5 Unacceptable (Limo, 2015, p. 49).

Reliability is related to the consistency of item-level errors within a single factor. This indicates that the set of variables will consistently load on the same factor (Gaskin, 2015). An exploratory factor analysis will be conducted to obtain the value of Cronbach’s alpha for each factor. SPSS® used the following algorithm to calculate Cronbach’s alpha (Norušis, 2007):

Cronbach's alpha per dimension (s=1,...,p):

$$\alpha_s = m_w \left(\lambda_s^{1/2} - 1 \right) / \left(\lambda_s^{1/2} \left(m_w - 1 \right) \right)$$

Total Cronbach's alpha is

$$\alpha = m_w \left(\sum_s \lambda_s^{1/2} - 1 \right) / \sum_s \lambda_s^{1/2} \left(m_w - 1 \right)$$

with λs the sth diagonal element of Λ as computed in the orthonormalization step during the last iteration (Carper, 2015).

Validity

The current view of validity is that it is an evaluation of scores on a particular test and of how these scores will be interpreted. Validity, or, perhaps more importantly, the evaluation of validity, is concerned with the establishing evidence for the use of a particular instrument in a particular setting.

Although the correlation coefficient is most often used to describe a measurement reliability, there is no one type of statistic to describe measurement validity (Gliner & Morgan, 2000, p. 320).

However, Construct validity seeks to establish whether an inference can be made from the study's scale measures that correlate with the theorized constructs it purports to measure. Establishing construct validity ensures that the research instrument meets it purpose (Limo, 2015).

Constructs are hypothetical concepts that cannot be observed directly. Although we cannot observe a construct directly. Most (researchers) agree that these constructs exist through different observable behaviors. When applying construct validity to an instrument, there is a requirement that the construct that the instrument is measuring is guided by an underlying theory (Gliner & Morgan, 2000, p. 323).

Construct validity ensures that the survey questions have a link to the study objectives that examine the Behavioral Intentions (BI) to adopt Bonded Cellular (BC) technologies. The construct validity for this study will be established by utilizing factor analysis.

Data Analysis

The Data Analysis for this study will be completed in a three-phase procedure. First, the survey data is to be retrieved from the Qualtrics portal site onto a spreadsheet for preliminary review. The raw data will be examined for irregularities, discrepancies, response biases, and missing data. The second step involves preparation, cleaning, and coding of data for further analysis in the SPSS 26 software. Descriptive statistics will be generated for a description for the demographics of the sample population.

Percentages and frequencies and will be conducted for each of the respondents' responses. Means and standard deviations will be presented for each of the variables. The final step will be the correlation analysis, Cronbach's alpha, and linear regression analysis.

Factor Analysis

Factor analysis is a multivariate technique used for identifying whether the correlations between a set of variables stem from their relationship to one another or more latent variables in the data (Field, 2006). Factor analysis consists of many matrices that can be used to analyze, describe relationships, and examine patterns of correlations among variables (Tabachnick & Fidell, 2012).

This study will derive a correlation matrix in order to identify the amount of variability between the determinant variables and will examine if any relationships between the determinant variables, identify outliers, and any multi-collinearity exist.

Linear Correlation Statistics

The basis this study's hypothesis is to determine if there are linear relationships between perceived usefulness (PU), perceived ease of use (PEOU), relative advantage (RA) and Compatibility to existing work flow (COMP) and the behavioral intent to use BC broadcast transmission systems. The linear relationships of other variables will also be calculated for the purpose of observing the interactions within the entire model and will be presented in table form. Figure 3-1 shows a graphical representation for a model of the linear relationships between variables.

Statistical values of *R* square, *F* statistic, and *p* value are needed to establish linearity between two variables (Gaskin, 2015). SPSS® will be used to calculate these statistical values. The SPSS® Statistical Procedures Companion provides detail about the descriptions and calculations for these statistics (Norušis, 2007)

R-squared is the statistical measure of how close the data are to the fitted regression line. It is calculated by squaring the sum of the difference between the estimated values of the dependent variable minus the mean of the dependent variable (the regression sum of squares), divided by the sum of the difference between the actual values of the dependent variable minus the mean of the dependent variable (the total sum of squares) (Carper, 2015). Mathematically, the formula is as follows:

$$R2 = SSR / SST = \Sigma(\hat{y}i - \bar{y})2 / \Sigma(yi - \bar{y})2$$

The *F* statistic is the ratio of the two estimates of variance. A higher *F* statistic provides evidence against the null hypothesis. *F* statistic is calculated by dividing the between-groups mean square by the within-groups mean square (Carper, 2015). Mathematically, the formula is as follows:

$$F = \text{(mean square between groups)/(mean square within groups)}$$

Significance is determined by the *p* value. The *p* value represents the probability of the occurrence of a given event. A *p* value less than 0.05 is considered statistically significant (Carper, 2015). Mathematically, the formula is as follows:

$$p\text{-value} = 2 * P(TS > |ts| \mid H0 \text{ is true}) = 2*(1 - cdf(|ts|))$$

Where:

P is the probability of a random variable having a range of values.

TS is the random variable associated with the assumed distribution.

ts is the test statistic calculated from the sample.

cdf() is the cumulative density function of the assumed distribution.

The relevant criteria for establishing linearity between two variables is that the *p* value ("Sig") is less than .05 and that the *F* statistic is greater than the critical value of the *F* distribution (Gaskin, 2015). If the *F* statistic is significantly greater than the critical value, then a strong linear relationship was suggested (Carper, 2015).

The linear regressions in this study have the assumptions of linearity and homoscedasticity. Linearity assumes a straight-line relationship between the determinant variables and the criterion variable, intention to adopt BC technology. Homoscedasticity assumes that scores are normally distributed about the regression line.

F- Test

The *F* test will be used to assess whether the set of determinant variables collectively predicts intention to adopt BC technology. R-squared—the multiple correlation coefficient of determination—is to be reported and used to determine how much variance in intention to adopt BC technology is accounted for by the set of determinant variables.

Linear Regression

A linear regression will be conducted to assess if the independent variable predicted intention to adopt BC by way of the *F* test. R-squared is to be reported and used to determine how much variance in intention to adopt BC could be accounted for by the determinant variable.

The standard enter method will use and is appropriate as the theory did not sufficiently support a different method of entry. Determinant variables are to be evaluated on the basis what each determinant adds to the prediction of intention to adopt BC technology that is different from the predictability provided by the other determinant variables (Tabachnick & Fidell, 2012). The F test is used to assess whether the set of determinant variables collectively predicts intention to adopt BC technology. R-squared—the multiple correlation coefficient of determination will be reported and used to determine how much variance in intention to adopt BC technology can be accounted for by the set of determinate variables.

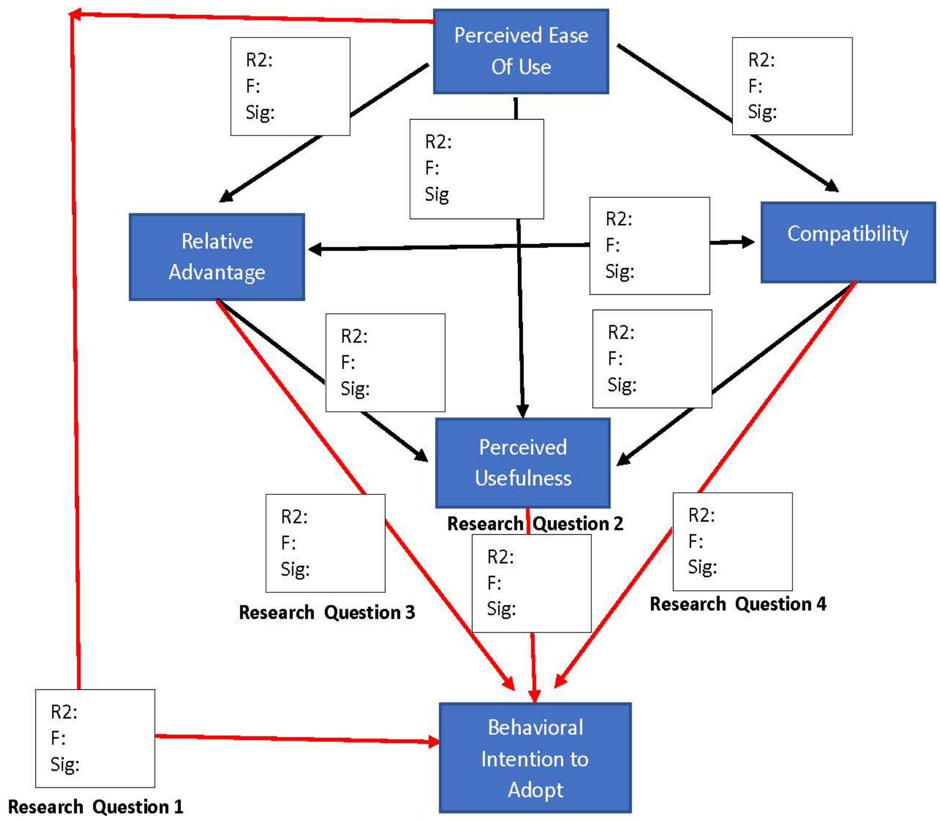


Figure 3-1 Linear Regression Model between Variables

Internal Review Board (IRB) Approval

In 1974 the department of health, education, and welfare published regulations on the protection of human subjects. It mandated that there be Institutional Review Boards (IRBs) at each research institution that accepted Federal funding to determine whether subjects are placed at risk, and if so, whether the benefits and importance of the knowledge to be gained so outweigh the risks that the subjects should be allowed to accept the risks (Gliner & Morgan, 2000, p. 33).

The guidelines also mandated that informed consent be obtained from participants in research. The principles of respect for participants, beneficence, and justice form the basis of appropriate human research. Voluntary informed consent by participants is required. The ethical principles of privacy are designed to ensure that the participants are free to choose how much to reveal and that what is revealed will be kept confidential. Various kinds of risks, psychological as well as physical, are to be mitigated. The design of this study is such that the integrity, respect, privacy and safety for the participants is held in high regard to the exacting standards of the IRB.

In order to comply with the ethical research guidelines for data collected from human subjects, an application has been filed and approved with the Indiana State University Institutional Review Board (IRB) as required for studies that involve human subjects. The IRB letter of waiver and approval is provided as an addendum (Appendix B).

Data Collection

The survey data was collected by use of an online web-based survey service portal provided by Indiana State University. Qualtrics was used as the means to collect the survey data. The use of Qualtrics fulfills the ethical concerns for privacy, security, and the dependable collection of data in a convenient platform that is easy for participants to use.

The participants received an e-mail from Qualtrics notifying them of the availability of the survey and provided them with a web link to the survey. Qualtrics automatically sent out two additional follow-up reminders to participants to encourage their engagement with the survey. The raw data results are only available to the researcher for privacy and security concerns. The use of Qualtrics allowed for the automated collection of survey data from participants at any time of day, which makes participation in the study convenient and appropriate. The collected data was gathered by means of a multi-stage plan, consisting of the following:

1. notification of participants,
2. downloading the raw data, and
3. importing the data into the Statistical Package for Social Sciences software (SPSS) version 26.

Chapter Summary

This chapter described the methodology, processes, and procedures that are to be used for this study. First, the research approach was described followed by design, and the rationale for choosing the methodology. This was followed by a description of the population sample, sample size, and survey instrument. Next ethical concerns were highlighted and the data collection methods for this research were outlined. This chapter also delved into how the reliability and validity for the study was established. Lastly, the steps used for the data analysis were described, and the chapter ended with a presentation of the study's regression analysis steps.

CHAPTER 4

DATA ANALYSIS

At its core statistical analysis uses the mathematics of probability and uncertainty to make inference about a population, based on a random sample from that population. Just about any question in science can be established as a question with regards to a relationship. Statistics can provide a tangible, repeatable method for determining an objective way to work towards an answer that reveals more information with regards to a relationship that is under study.

The field of Technology Management covers a broad spectrum of disciplines and activities that make use of many statistical analysis tools that are available to applied researchers. The competent use of statistics can provide valuable insights and reveal hidden patterns that may be otherwise locked within the unobservable parameters.

John Freund and Benjamin Perles observed that our society now utilizes statistics for nearly every human activity and social enterprise. Freund and Perles are concerned that the improper employment of the use of statistics could pose grave, negative consequences if not dispensed in a responsible, honest and forthright manner. Freund and Perles observe,

> Attempts have been made to treat ALL problems of statistical inference within the framework of a unified theory called decision theory, which, so to speak, covers everything from cradle to grave. One main feature of this theory is that we must account for all the consequences that can arise when we base decisions on statistical data. This

> poses serious problems, because it is difficult, if not impossible, to put a cash value on the consequences of one's actions. For instance, how can we put a cash value on the consequences of the decision of whether or not to market a new medication, especially if the wrong decision may well involve the loss of human lives? (Freund & Perles, 1999, p. 9)

This gets us to the very (ethical) heart of the proper use of statistics and applied research in the field of Technology Management. "Applied research is designed to solve *practical problems* of the modern world, rather than to acquire knowledge for knowledge's sake. One might say that the goal of the applied scientist is to *improve the human condition*" (Lawrence Berkeley National Laboratory, 2012).

With that definition in mind, it should be our goal as researchers to solve the practical problems within Technical Management by conducting applied research that is purposeful, efficient and productive in creating products and solutions for our customers while benefiting our stakeholders and the global community where we work and live. It may be easy to discount the distinction between good and bad statistics with a sigh of indifference. Numbers are just numbers, right? As the oft quoted Gregg Easterbrook penned, "Torture the numbers long enough and they'll confess to anything" (2012). However, it is not just an issue of the transmogrification of data to represent a particular viewpoint or outcome. The use of important statistical data can have real life implications that can impact society, individuals and entire industries!

Statistical Testing and analysis offer the academic researcher, powerful, repeatable and objective standards for revealing conclusions based on properly obtained data sets. Statistical tools are available to aid the researcher to get at the truth of discovery by utilizing powerful statistical techniques. However, researchers (and the population in general) should also maintain a "wary eye" towards just accepting conclusions that are espoused with the unsubstantiated claims of statistical results. As, Henry Clay wrote, "Statistics are no substitute for judgment" (n.d.).

Results

This chapter presents the results and statistical analysis of the survey results of this study. The survey, adapted from well-established TAM surveys, was conducted in November 2019. A total of 599 television and media technology managers, engineers, executives and University media educators, received the survey via Qualtrics email. The qualified email list was comprised of email contacts provided by the 2019 Broadcast Education Association (BEA) membership roll and the 2019 National Association of Broadcasters (NAB) Job Fair for Television Engineering and Management contacts.

There were 24 surveys initiated, of which response data from a range of 21 to 24 were used within the study, depending upon the research question and the data cleaning requirements. This represents a return rate of 4%. The responses were screened for unengaged participants, outliers, and missing data. SPSS® was used to analyze the data for linearity, exploratory factor analysis, and structural equation modeling. Any anomalies that were found are discussed in this chapter.

Data Screening

The standard deviation of the participants' responses ranged from 0.95 to 2.12. A visual observation of those responses concluded that the participants had made an intentional effort to respond in that way. As such, only one survey was partially discarded due to lack of full completion and engagement.

Descriptive Statistics

This section describes the descriptive statistics. Figure 4-1 and Table 4-1 show the demographic characteristics of the current study. The target participant was a TV technology manager, engineer or executive. Among the 24 responses, 15 (62%) hold roles at the operations engineer level or higher.

Q4 - Please indicate what best describes your position within your organization.

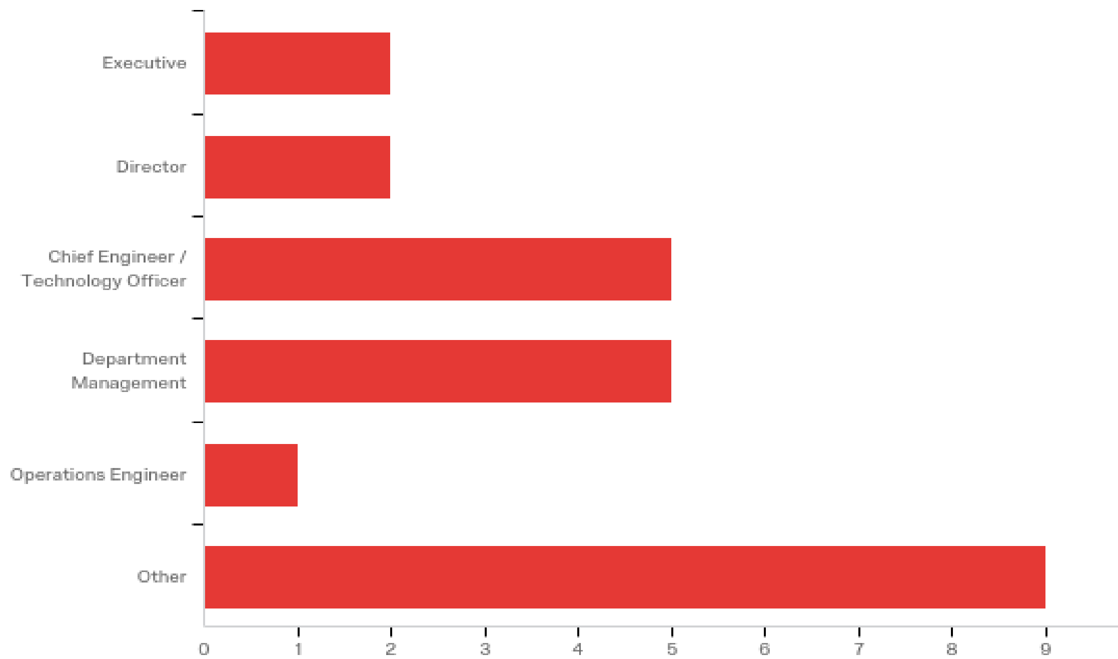


Figure 4-1 Role Demographics

Table 4-1 Role Demographics

#	Answer	%	Count
1	Executive	8.33%	2
2	Director	8.33%	2
3	Chief Engineer / Technology Officer	20.83%	5
4	Department Management	20.83%	5
5	Operations Engineer	4.17%	1
6	Other	37.50%	9
	Total	100%	24

The years of experience illustrated a very interesting and curious revelation about the demographics of the TV industry and may, in itself, initiate a topic for future study. The results in Figure 4-2 and Table 4-2 show that 19 of the 24 (nearly 80%) of respondents had 10 years or more in the TV industry experience and that no one had less than 5 years of experience, which may either represent an opportunity for a need for new television engineers or the overall decline of an industry that cannot attract new talent.

Q3 - Please indicate the number of years of your industry experience.

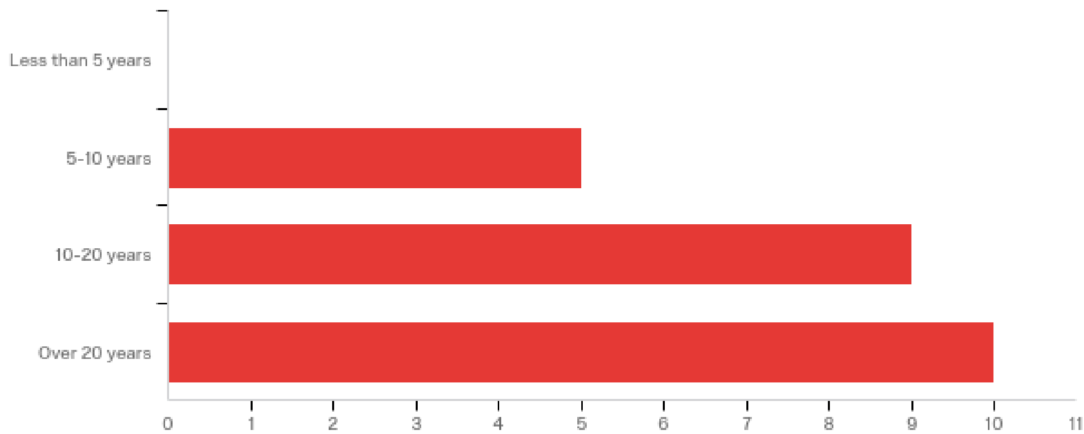


Figure 4-2 Experience Demographics

#	Answer	%	Count
1	Less than 5 years	0.00%	0
2	5-10 years	20.83%	5
3	10-20 years	37.50%	9
4	Over 20 years	41.67%	10
	Total	100%	24

Q1 - Is your organization using any Bonded Cellular (BC) broadcasting technology today?

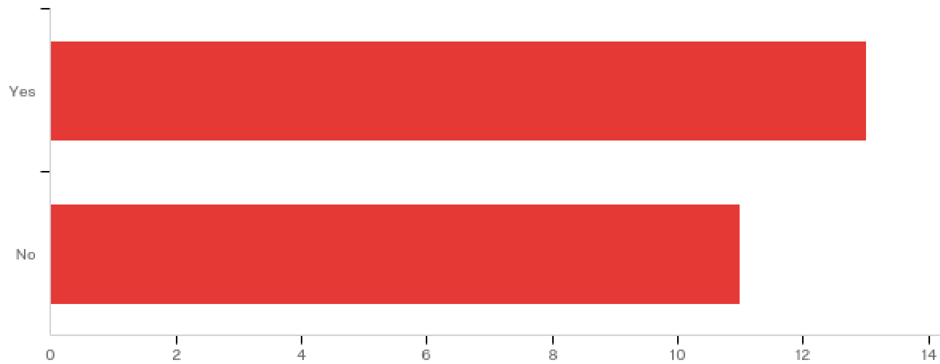


Figure 4-3 Current Use of Bonded Cellular (BC) Broadcasting Technology

Table 4-3 Current Use of Bonded Cellular (BC) Broadcasting Technology

#	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	1.00	2.00	1.46	0.50	0.25	24

#	Answer	%	Count
1	Yes	54.17%	13
2	No	45.83%	11
	Total	100%	24

Q2 - What is your company's primary communication industry sector?

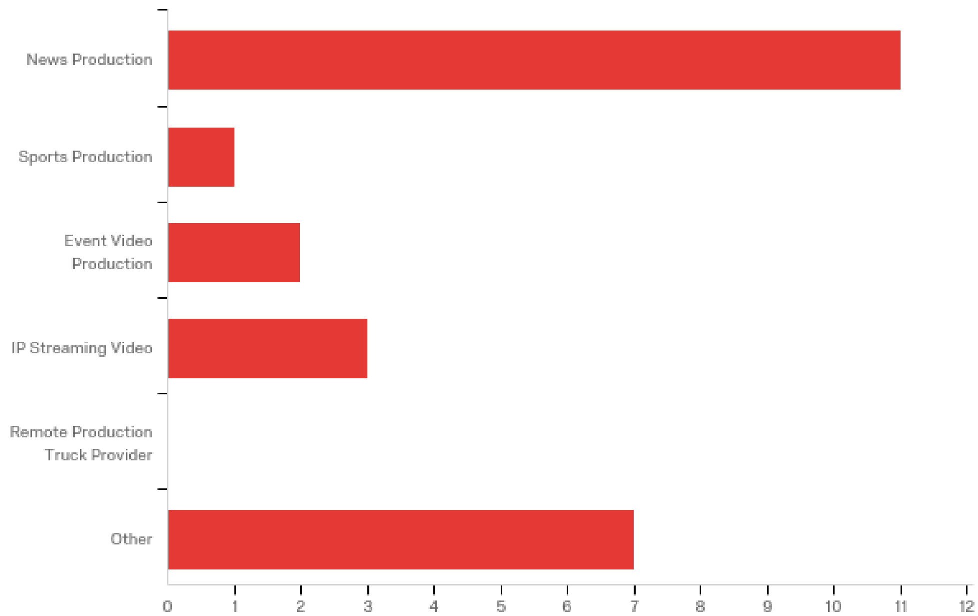


Figure 4-4 Company's Primary Communication Industry Sector

Table 4-4 Company's Primary Communication Industry Sector

#	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	1	6	3.04	2.15	4.62	24

#	Answer	%	Count
1	News Production	45.83%	11
2	Sports Production	4.17%	1
3	Event Video Production	8.33%	2
4	IP Streaming Video	12.50%	3
5	Remote Production Truck Provider	0.00%	0
6	Other	29.17%	7
	Total	100%	24

Table 4-5 Descriptive Statistics for Independent Variables–Exploratory Factor Analysis

Perceived Ease of Use (PEOU)								
PEOU	*Survey*	*N*	Missing	Minimum	Maximum	Mean	Std. Deviation	Variance
Q1_1	Q-6	23	0	1	6	2.48	1.25	1.55
Q1_2	Q-7	23	0	2	7	2.57	1.17	1.38
Q1_3	Q-8	23	0	1	7	2.7	1.2	1.43
Q1_4	Q-9	23	0	1	7	2.57	1.17	1.38
Q1_5	Q-10	23	0	1	5	2.3	1	0.99
Q1_6	Q-11	23	0	1	6	2.39	1.09	1.19

Perceived Usefulness (PU)								
PU	*Survey*	*N*	Missing	Minimum	Maximum	Mean	Std. Deviation	Variance
Q2_1	Q-12	22	0	1	7	2.18	1.5	2.24
Q2_2	Q-13	22	0	1	7	3	1.35	1.82
Q2_3	Q-14	22	0	1	7	2.77	1.47	2.18
Q2_4	Q-15	22	0	1	7	2.86	1.39	1.94
Q2_5	Q-16	21	0	1	7	2.62	1.4	1.95
Q2_6	Q-17	22	0	1	7	2.45	1.3	1.7

Relative Advantage (RA)								
RA	*Survey*	*N*	Missing	Minimum	Maximum	Mean	Std. Deviation	Variance
Q3_1	Q-18	22	0	1	7	3.18	1.59	2.51
Q3_2	Q-19	22	0	1	4	2.23	0.95*	0.9
Q3_3	Q-20	22	0	1	7	2.95	1.19	1.41
Q3_4	Q-21	22	0	1	7	2.5	1.34	1.8
Q3_5	Q-22	22	0	1	7	2.77	1.28	1.63

Compatibility (COMP)								
COMP	*Survey*	*N*	Missing	Minimum	Maximum	Mean	Std. Deviation	Variance
Q4_1	Q-23	22	0	1	7	2.95	1.49	2.23
Q4_2	Q-24	22	0	1	7	3	1.62	2.64
Q4_3	Q-25	22	0	1	7	3.59	1.8	3.24
Q4_4	Q-26	22	0	1	7	2.77	1.91	3.63
Q4_5	Q-27	22	0	1	7	2.86	1.89	3.57
Q4_6	Q-28	22	0	1	7	2.55	1.8	3.25
Q4_7	Q-29	21	0	1	7	3.1	1.6	2.56

Table 4-5, cont. Descriptive Statistics for Independent Variables–Exploratory Factor Analysis

Behavior Intent to Adopt (BI)								
BI	*Survey*	*N*	Missing	Minimum	Maximum	Mean	Std. Deviation	Variance
Q5_1	Q-30	22	0	1	7	3.36	2.12*	4.5
Q5_2	Q-31	22	0	1	5	2.95	1.8	3.23

*denotes lowest Std. Deviation
**denotes highest Std. Deviation
Range is 0.95-2.12

Tests for Sampling Adequacy

The Kaiser-Meyer-Olkin (KMO) statistic is a measure of sampling adequacy. Values close to 1.0 indicate that the factor analysis may be useful with the data. Values less than 0.50 indicate that a factor analysis would not be useful. Bartlett's test of sphericity tests to ensure that the correlation matrix is suitable for factor analysis when the significance level is less than 0.05.

SPSS® calculates these values and populates the table. As such, it is not necessary to calculate them manually. For reference, according to Norušis (2007) the algorithms used by SPSS® are as follows:

The KMO is calculated as follows:

$$KMO_j = \frac{\sum_{i \neq j} r_{ij}^2}{\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} a_{ij}^{2*}} \qquad KMO = \frac{\sum_{i \neq j} \sum r_{ij}^2}{\sum_{i \neq j} \sum r_{ij}^2 + \sum_{i \neq j} \sum a_{ij}^{2*}}$$

Where:

*a*ij* is the anti-image correlation coefficient.

The chi-square value for Bartlett's test of sphericity is calculated as follows:

$$\chi^2 = -\left(W - 1 - \frac{2p+5}{6} \right) \log |\mathbf{R}|$$

with $p(p-1)/2$ degrees of freedom.

Table 4-6 shows the results of a KMO and Bartlett's test. According to Gaskin (2015), a KMO score greater than .7 is desirable. The survey results were higher at .725. Thus, the data were suitable for factor analysis. A significance less than 0.5 is needed to consider the result significant (Gaskin, 2015). The survey results were significant at .000.

Table 4-6 KMO and Bartlett's Test

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.725
Bartlett's Test of Sphericity	Approx. Chi-Square	264.104
	Df	66
	Sig.	.000

Communalities

Communalities for variables are shown in Table 4-7. SPSS® iterates to find a solution for communalities and factor loadings. With each iteration i, the communalities from the preceding iteration are placed on the diagonal of R, and the resulting R is denoted by Ri. Eigen analysis is performed on Ri and the new communality of variable j is estimated by the following (Norušis, 2007):

$$h_{j(i)} = \sum_{j=1}^{m} |\gamma_{k(i)}| \, \omega_{jk(i)}^2$$

Factor loadings are obtained by the following:

$$\Lambda_{m(i)} = \Omega_{m(i)} \Gamma_{m(i)}^{1/2}$$

SPSS® continued iterations until the maximum number is reached or until the maximum change in the communality estimates is less than the convergence criterion. All communalities were above the desired threshold of 0.3, as shown in Table 4-7. Additionally, many of the values are approaching 1.0, which is an indication that the extracted components represent the variables well (Norušis, 2007).

Table 4-7 Communalities

Communalities

	Initial	Extraction
Q1-1 (PEoU)	1.000	.773
Q1-2 (PEoU)	1.000	.880
Q1-3 (PEoU)	1.000	.883
Q2-1 (PU)	1.000	.836
Q2-2 (PU)	1.000	.809
Q2-3 (PU)	1.000	.848
Q3-1 (RA)	1.000	.509
Q3-2 (RA)	1.000	.663
Q3-3 (RA)	1.000	.728
Q4-1 (COMP)	1.000	.903
Q4-2 (COMP)	1.000	.862
Q4-3 (COMP)	1.000	.714

Extraction Method: Principal Component Analysis.

Total Variances of Factors

Table 4-8 shows details about the total variance. Eigenvalues represent the explanation of the total variances of the factors. Generally, only eigenvalues greater than 1 should be considered factors. There are three factors with values greater than 1 and a fourth factor that was included because of an eigenvalue of 0.999 with a rounding threshold of 1.0.

The eigenvalues in Table 4-8 were computed by SPSS® using the QL method published by Wilkinson and Reinsch in 1971 (Norušis, 2007).

Table 4-8 Total Variance Explained

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings [a]
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	17.424	67.015	67.015	17.424	67.015	67.015	14.187
2	2.294	8.825	75.84	2.294	8.825	75.84	12.821
3	1.711	6.582	82.421	1.711	6.582	82.421	9.317
4	0.999	3.844	86.265	0.999	3.844	86.265	10.363
5	0.806	3.101	89.366				
6	0.599	2.304	91.67				
7	0.459	1.767	93.437				
8	0.423	1.626	95.063				
9	0.373	1.434	96.496				
10	0.263	1.011	97.508				
11	0.192	0.737	98.245				
12	0.148	0.57	98.815				
13	0.102	0.391	99.206				
14	0.053	0.203	99.409				
15	0.047	0.182	99.591				
16	0.043	0.165	99.756				
17	0.035	0.134	99.89				
18	0.018	0.069	99.96				
19	0.01	0.039	99.999				
20	0	0.001	100				
21	5.26E-16	2.02E-15	100				
22	4.49E-16	1.73E-15	100				
23	3.74E-16	1.44E-15	100				
24	-4.64E-17	-1.79E-16	100				
25	-3.06E-16	-1.18E-15	100				
26	-6.61E-16	-2.54E-15	100				

Extraction Method: Principal Component Analysis.
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

The Eigenvalues section of Table 4-8 shows the variance explained by the initial solution. Three factors in the initial solution have eigenvalues greater than 1 with the previously noted fourth factor having a value of 0.999. The total eigenvalues of the four factors account for 86.2% of the variability in the original variables. The “Extraction Sums of Squared Loadings” section shows the variance explained by the extracted factors before rotation.

The Rotation Sums of Squared Loadings section of Table 4-8 shows the variance explained by the extracted factors after rotation. The rotated factor model made significant adjustments to the factors from the unrotated factors. The unrotated extraction matches the initial eigenvalues. As such, the unrotated factors also indicated 86.2% of the variance is a better indicator of the variance associated with these factors.

The Scree Plot in Figure 4-5 provides a graphic visualization of the relevant Eigenvalues for the data points presented in the Total Variance Explained of the four prominent factor components.

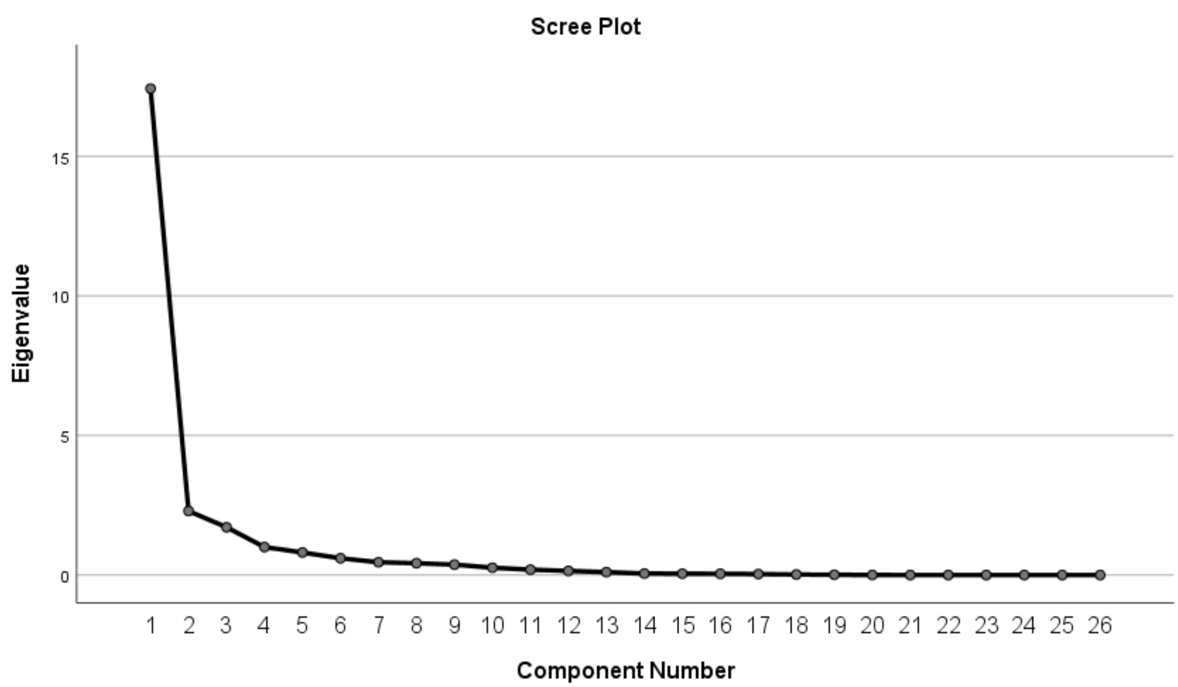


Figure 4-5 Scree Plot

Pattern Matrix

SPSS® uses the following algorithm to calculate the factors in the pattern matrix, as shown in Table 4-9:

$$\mathbf{F}_m = \mathbf{S}\Omega_m(\Lambda_m - I_m)\Lambda_m^{-1/2}$$

Where:

Ωm and *Λm* correspond to the m eigenvalues greater than 1.

For convergent validity, it is desirable to find results above 0.5, as shown in Table 4-9. The values should average above 0.72 (Gaskin, 2015). The results meet this criterion.

For discriminant validity, cross-loadings should be greater than the desired 0.2. The results met this criterion. However, the variables are not loading significantly to one factor. Therefore, the factor correlation matrix must be used to confirm discriminant validity (Gaskin, 2015).

Table 4-9 Pattern Matrix

Pattern Matrix[a]

	Component			
	1	2	3	4
Q10_1	.996			
Q25_1	.921			
Q24_1	.895			
Q23_1	.845			
Q7_1	.798			
Q11_1	.744			
Q6_1	.658			
Q29_1	.631			
Q20_1	.593			
Q8_1	.548			
Q9_1	.542			
Q28_1	.502			
Q15_1		1.008		
Q16_1		.906		
Q13_1		.882		
Q14_1		.804		
Q27_1		.557		
Q31			.916	
Q30_1			.817	
Q18_1			.649	
Q26_1			.589	
Q22_1				.676
Q21_1				.560
Q17_1				.526
Q19_1				.513
Q12_1				.486

Extraction Method: Principal Component Analysis.
Rotation Method: Promax with Kaiser Normalization.[A]
a. Rotation converged in 8 iterations.

Factor (Component) Correlations

To avoid shared variance, there should be no factor correlations greater than 0.7 (Gaskin, 2015). The results in Table 4-10 show that the factor correlations are all significantly lower than 0.7, which indicated that the factors are distinct and uncorrelated and meet the requirements of discriminant validity.

Table 4-10 Component Correlation Matrix

Component Correlation Matrix

Component	1	2	3	4
1	1.000	.604	.507	.550
2	.604	1.000	.497	.531
3	.507	.497	1.000	.463
4	.550	.531	.463	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Promax with Kaiser Normalization.

Reliability Statistics

Reliability is related to the consistency of item-level errors within a single factor. This indicates that the set of variables will consistently load on the same factor (Gaskin, 2015). An exploratory factor analysis was conducted to obtain the value of Cronbach's alpha for each of the four factor components. The values are above the required value of 0.7. Thus, the results are considered reliable (see Tables 4-11 through 4-16).

SPSS® used the following algorithm to calculate Cronbach's alpha (Norušis, 2007):

Cronbach's alpha per dimension (s=1,...,p):

$$\alpha_s = m_w \left(\lambda_s^{1/2} - 1 \right) / \left(\lambda_s^{1/2} \left(m_w - 1 \right) \right)$$

Total Cronbach's alpha is

$$\alpha = m_w \left(\sum_s \lambda_s^{1/2} - 1 \right) / \sum_s \lambda_s^{1/2} \left(m_w - 1 \right)$$

with λs the sth diagonal element of Λ as computed in the orthonormalization step during the last iteration.

Table 4-11 Reliability Test for FACTOR 1 Perceived Ease of Use (PEOU)

Reliability Statistics

Cronbach's Alpha	N of Items
.968	12

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q10_1	30.17	180.819	.935	.964
Q25_1	28.91	168.564	.729	.970
Q24_1	29.45	166.373	.873	.964
Q23_1	29.55	168.441	.919	.963
Q7_1	29.88	176.056	.917	.963
Q11_1	30.07	177.694	.945	.963
Q6_1	29.98	176.170	.852	.965
Q29_1	29.41	171.986	.786	.966
Q20_1	29.50	179.124	.804	.966
Q8_1	29.79	177.063	.855	.965
Q9_1	29.88	177.295	.875	.964
Q28_1	29.90	165.434	.803	.967

Table 4-12 Reliability Test for FACTOR 2 Perceived Usefulness (PU)

Reliability Statistics

Cronbach's Alpha	N of Items
.940	5

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q15_1	11.21	30.917	.877	.920
Q16_1	11.52	29.861	.919	.912
Q13_1	11.12	31.041	.864	.922
Q14_1	11.36	29.838	.855	.922
Q27_1	11.26	27.133	.755	.953

Table 4-13 Reliability Test for FACTOR 3 Relative Advantage (RA)

Reliability Statistics

Cronbach's Alpha	N of Items
.913	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q31	9.63	25.267	.877	.862
Q30_1	9.14	24.408	.750	.912
Q18_1	9.34	29.075	.772	.902
Q26_1	9.79	24.725	.844	.872

Table 4-14 Reliability Test for FACTOR 4 Compatibility (COMP)

Reliability Statistics

Cronbach's Alpha	N of Items
.952	5

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q22_1	9.48	22.056	.863	.942
Q21_1	9.76	20.900	.920	.932
Q17_1	9.86	21.481	.893	.937
Q19_1	10.00	25.455	.830	.954
Q12_1	10.05	19.952	.896	.939

Table 4-15 Reliability Test for Dependent Variable Behavior Intent to Adopt (BI)

Reliability Statistics

Cronbach's Alpha	N of Items
.881	2

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q30_1	3.00	3.333	.797	.
Q31	3.49	4.524	.797	.

Table 4-16 Summary Table

TAM /DOI Factor	Cronbach's Alpha	*N* of Items
Perceived Ease of Use (PEOU)	0.968	12
Perceived Usefulness (PU)	0.940	5
Relative Advantage (RA)	0.913	4
Compatibility (COMP)	0.952	5
Behavioral Intent (BI)	0.881	2

Linear Correlation Statistics

The basis of the current study's hypothesis was to determine if there is a linear relationship between Perceived Ease of Use (PEOU), Perceived Usefulness (PU), Relative Advantage (RA) or Compatibility (COMP) and the Behavioral Intent (BI) to adopt bonded cellular TV technology tools amongst TV/media technology managers. The linear relationships of other variables were also calculated for the purpose of observing the interactions for the entire model (see Table 4-38).

Statistical values of *R* square, *F* statistic, and *p* value are needed to establish linearity between two variables (Gaskin, 2015). SPSS® was used to calculate these statistical values. As such, these values were not calculated manually. The SPSS® Statistical Procedures Companion provides detail about the descriptions and calculations for these statistics (Norušis, 2007). These are discussed in chapter 3 in detail, but are also reviewed here as reference for additional background and convenience.

R-squared is the statistical measure of how close the data are to the fitted regression line. It is calculated by squaring the sum of the difference between the estimated values of the dependent variable minus the mean of the dependent variable (the regression sum of squares), divided by the sum of the difference between the actual values of the dependent variable minus the mean of the dependent variable (the total sum of squares). Mathematically, the formula is as follows:

$$R2 = SSR / SST = \Sigma(\hat{y}i - \bar{y})2 / \Sigma(yi - \bar{y})2$$

The *F* statistic is the ratio of the two estimates of variance. A higher *F* statistic provides evidence against the null hypothesis. *F* statistic is calculated by dividing the between-groups mean square by the within-groups mean square. Mathematically, the formula is as follows:

$$F = \text{(mean square between groups)} / \text{(mean square within groups)}$$

Significance is determined by the *p* value. The *p* value represents the probability of the occurrence of a given event. A *p* value less than 0.05 is considered statistically significant. Mathematically, the formula is as follows:

$$p\text{-value} = 2 * P(TS > |ts| \mid H0 \text{ is true}) = 2*(1-cdf(|ts|))$$

Where:

P is the probability of a random variable having a range of values.

TS is the random variable associated with the assumed distribution.

ts is the test statistic calculated from the sample.

cdf() is the cumulative density function of the assumed distribution.

The relevant criteria for establishing linearity between two variables is that the *p* value ("Sig") is less than .05 and that the *F* statistic is greater than the critical value of the *F* distribution (Gaskin, 2015).

In this case, the alpha is 0.10, df1=1, and df2=21; the critical value for the *F* statistic is 2.96 (Cozby, 2001) as determined by the look-up table for finding critical values for F. If the *F* statistic is significantly greater than the critical value, then a strong linear relationship was suggested.

The relationship between Perceived Ease of Use (PEOU) and Behavioral Intent (BI) to adopt is significant with a *p* value of 0.006 (see Tables 4-17 and 4-18 and Figures 4-6 and 4-7). The model indicates that nearly 31% of the variance is explained by this model and the *F* statistic of 9.288 is greater than the critical value of the *F* statistic. The results of this analysis are directly relevant to Research Question 1 (RQ-1).

Table 4-17 Linear Correlation Statistics between PEOU and BI – Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.554[a]	.307	.274	1.56609

a. Predictors: (Constant), AVE_PEOU

b. Dependent Variable: AVE_BI

Table 4-18 Linear Correlation Statistics between PEOU and BI – ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.780	1	22.780	9.288	.006[b]
	Residual	51.505	21	2.453		
	Total	74.286	22			

a. Dependent Variable: AVE_BI

b. Predictors: (Constant), AVE_PEOU

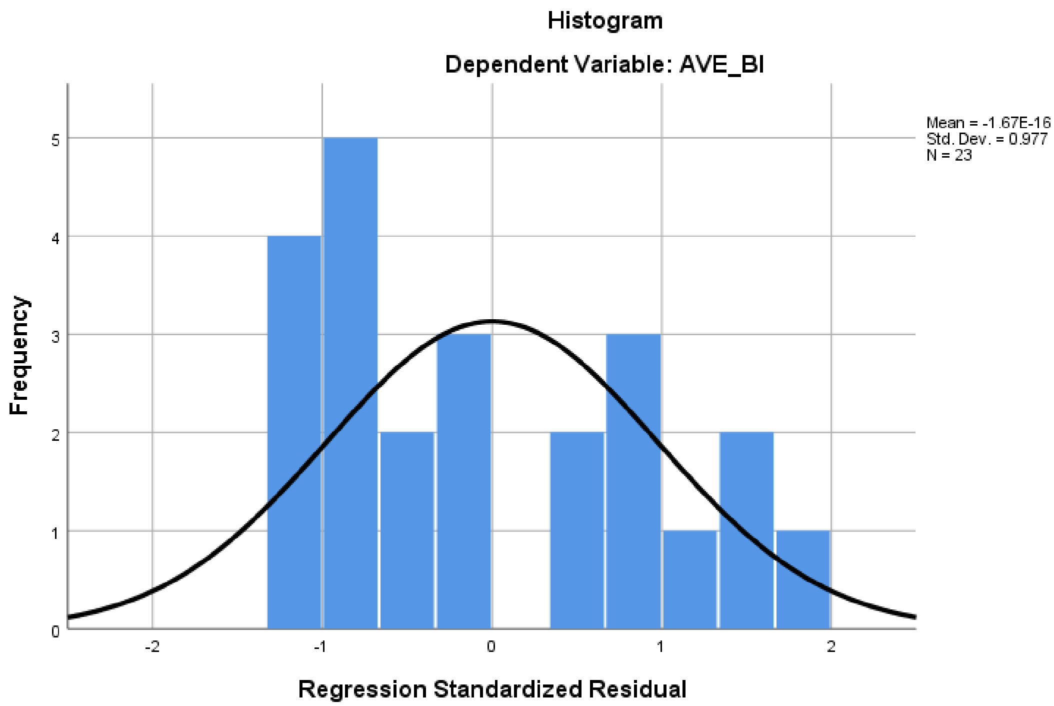


Figure 4-6 Linear Correlation Statistics between PEOU and BI – Histogram

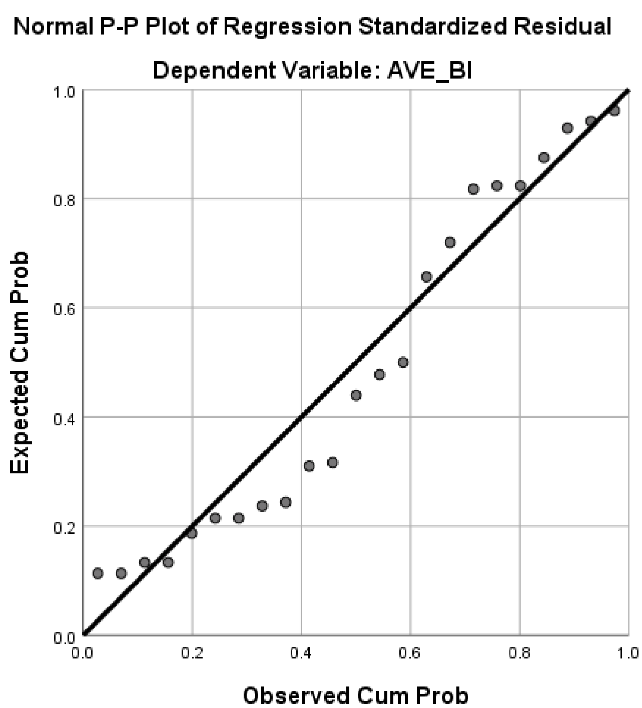


Figure 4-7 Normal P-P Plot of Regression Standardized Residual – PEOU and BI

The relationship between Perceived Usefulness (PU) and Behavioral Intent (BI) to adopt is significant with a *p* value of 0.001 (see Tables 4-19 and 4-20 and Figures 4-8 and 4-9). The model indicates that nearly 41% of the variance is explained by this model and the *F* statistic of 14.856 is greater than the critical value of the *F* statistic. The results of this analysis are directly relevant to Research Question 2 (RQ-2).

Table 4-19 Linear Correlation Statistics between PU and BI – Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.644[a]	.414	.386	1.43937

a. Predictors: (Constant), AVE_PU

b. Dependent Variable: AVE_BI

Table 4-20 Linear Correlation Statistics between PU and BI – ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	30.778	1	30.778	14.856	.001[b]
	Residual	43.507	21	2.072		
	Total	74.286	22			

a. Dependent Variable: AVE_BI

b. Predictors: (Constant), AVE_PU

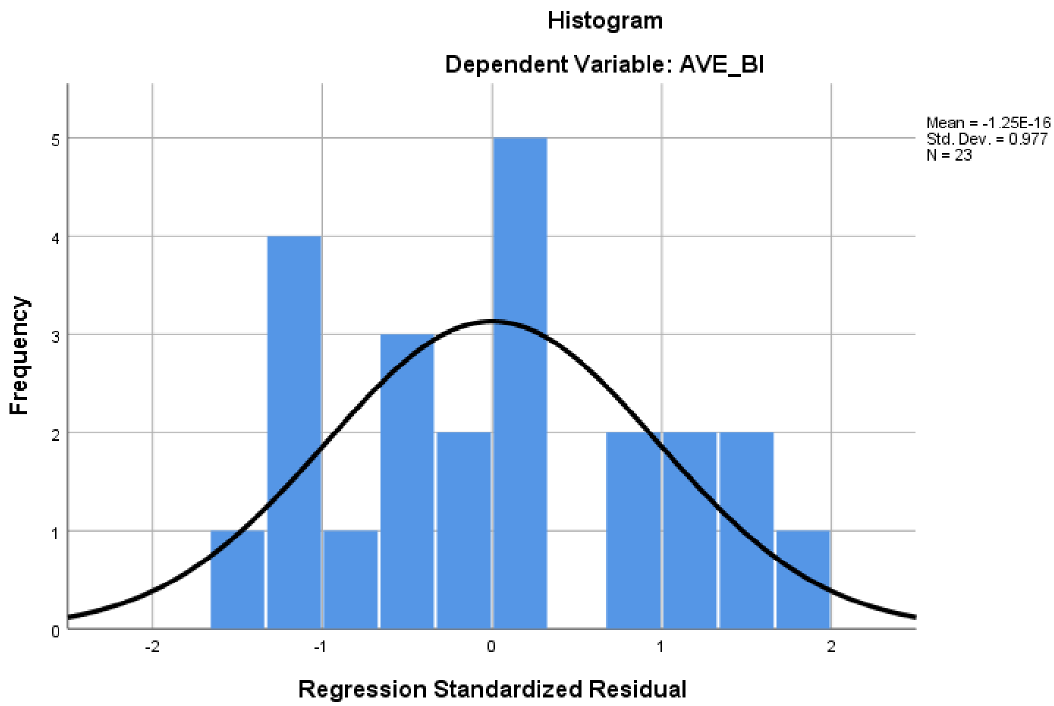


Figure 4-8 Linear Correlation Statistics between PU and BI – Histogram

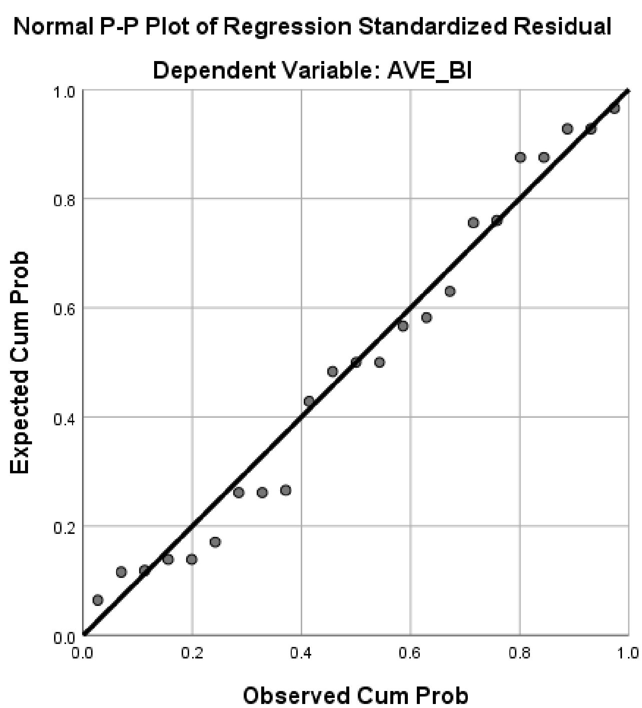


Figure 4-9 Normal P-P Plot of Regression Standardized Residual – PU and BI

The relationship between Relative Advantage (RA) and Behavioral Intent (BI) to adopt is significant with a *p* value of 0.000 (see Tables 4-21 and 4-22 and Figures 4-10 and 4-11). The model indicates that nearly 47% of the variance is explained by this model and the *F* statistic of 18.955 is greater than the critical value of the *F* statistic. The results of this analysis are directly relevant to Research Question 3 (RQ-3).

Table 4-21 Linear Correlation Statistics between RA and BI – Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.689[a]	.474	.449	1.36354

a. Predictors: (Constant), AVE_RA

b. Dependent Variable: AVE_BI

Table 4-22 Linear Correlation Statistics between RA and BI – ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	35.241	1	35.241	18.955	.000[b]
	Residual	39.044	21	1.859		
	Total	74.286	22			

a. Dependent Variable: AVE_BI

b. Predictors: (Constant), AVE_RA

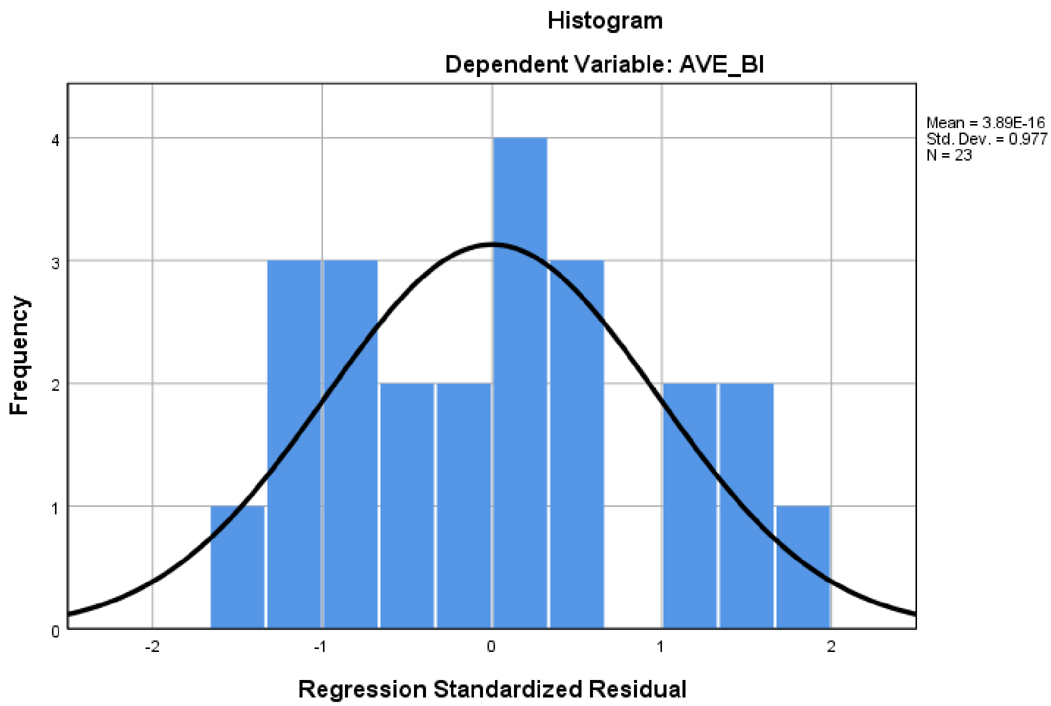


Figure 4-10 Linear Correlation Statistics between RA and BI – Histogram

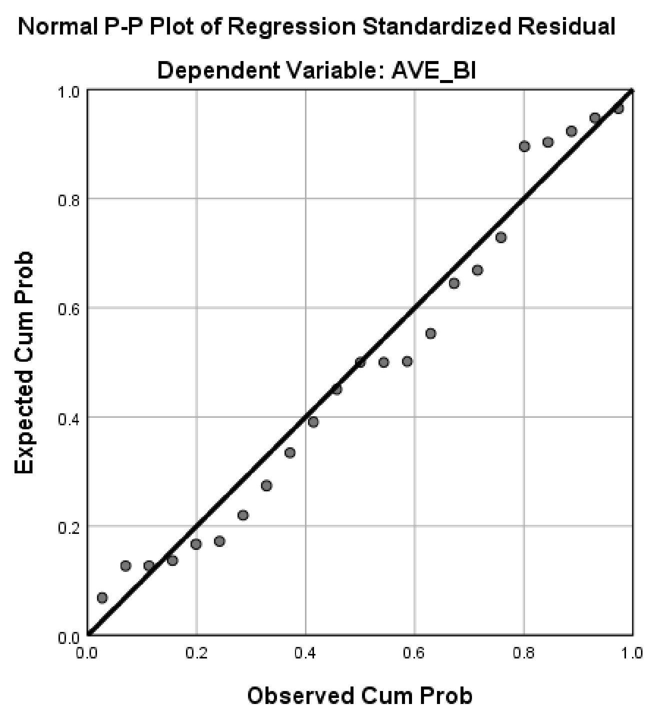


Figure 4-11 Normal P-P Plot of Regression Standardized Residual – RA and BI

The relationship between Compatibility (COMP) and Behavioral Intent (BI) to adopt is significant with a *p* value of 0.000 (see Tables 4-23 and 4-24 and Figures 4-12 and 4-13). The model indicates that nearly 49% of the variance is explained by this model and the *F* statistic of 20.02 is greater than the critical value of the *F* statistic. The results of this analysis are directly relevant to Research Question 4 (RQ-4).

Table 4-23 Linear Correlation Statistics between COMP and BI – Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.699[a]	.488	.464	1.34571

a. Predictors: (Constant), AVE_COMP

b. Dependent Variable: AVE_BI

Table 4-24 Linear Correlation Statistics between COMP and BI – ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	36.256	1	36.256	20.020	.000[b]
	Residual	38.030	21	1.811		
	Total	74.286	22			

a. Dependent Variable: AVE_BI

b. Predictors: (Constant), AVE_COMP

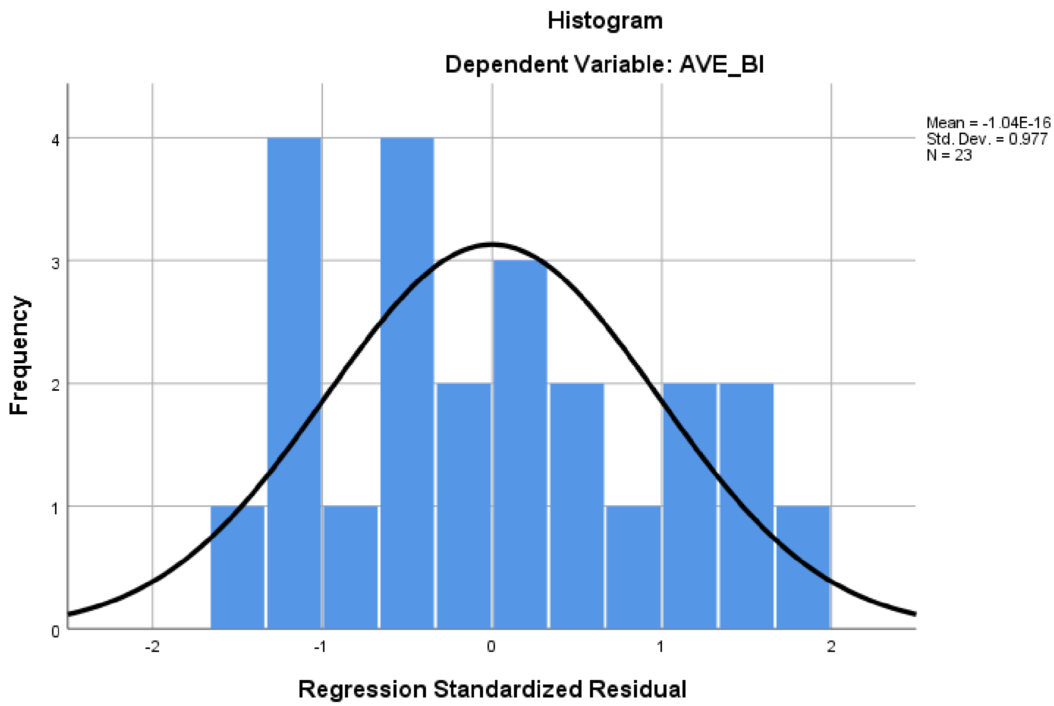


Figure 4-12 Linear Correlation Statistics between COMP and BI – Histogram

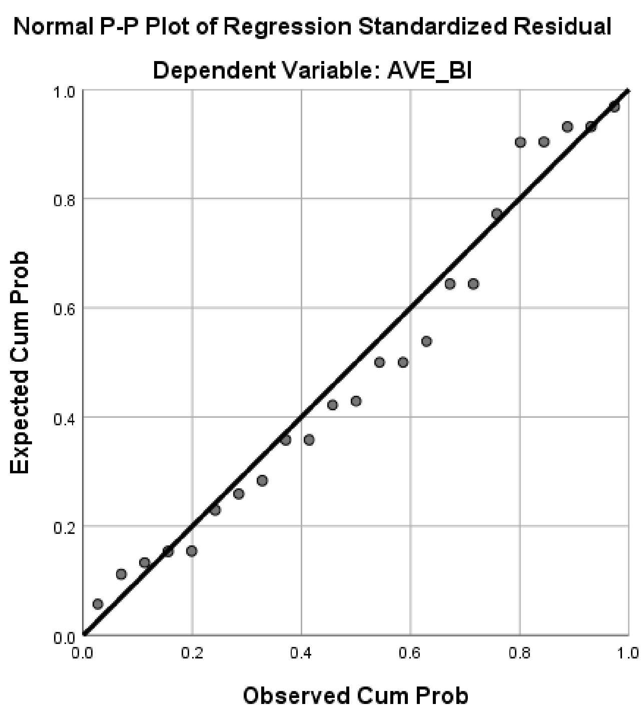


Figure 4-13 Normal P-P Plot of Regression Standardized Residual – COMP and BI

The following linear regression analysis was calculated between other variables for the purpose of observing the interactions for the entire model (see Table 4-25). These linear regressions are not germane directly to the four research questions, but may provide additional insights into of the over-all model. The ease and efficiency of utilizing SPSS® for calculations provides the ability to explore additional interactions among the various components. Below is a list of the additional tests between variables.

Table 4-25 Testing between Supplementary Variables

Independent	Dependent
PEOU	PU
PEOU	RA
PEOU	COMP
RA	PU
COMP	PU
RA	COMP

The relationship between Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) is significant with a *p* value of 0.000 (see Tables 4-26 and 4-27). The model indicates that nearly 64% of the variance is explained by this model and the *F* statistic of 37.779 is greater than the critical value of the *F* statistic.

Table 4-26 Linear Correlation Statistics between PEOU and PU – Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.802[a]	.643	.626	.75257

a. Predictors: (Constant), AVE_PEOU

b. Dependent Variable: AVE_PU

Table 4-27 Linear Correlation Statistics between PEOU and PU – ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	21.397	1	21.397	37.779	.000[b]
	Residual	11.893	21	.566		
	Total	33.290	22			

a. Dependent Variable: AVE_PU

b. Predictors: (Constant), AVE_PEOU

The relationship between Perceived Ease of Use (PEOU) and Relative Advantage (RA) to adopt is significant with a *p* value of 0.000 (see Tables 4-28 and 4-29). The model indicates that nearly 72% of the variance is explained by this model and the *F* statistic of 55.321 is greater than the critical value of the *F* statistic.

Table 4-28 Linear Correlation Statistics between PEOU and RA – Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.851[a]	.725	.712	.57791

a. Predictors: (Constant), AVE_PEOU

b. Dependent Variable: AVE_RA

Table 4-29 Linear Correlation Statistics between PEOU and RA – ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.476	1	18.476	55.321	.000[b]
	Residual	7.014	21	.334		
	Total	25.490	22			

a. Dependent Variable: AVE_RA

b. Predictors: (Constant), AVE_PEOU

The relationship between Perceived Ease of Use (PEOU) and Compatibility (COMP) to adopt is significant with a *p* value of 0.000 (see Tables 4-30 and 4-31). The model indicates that nearly 81% of the variance is explained by this model and the *F* statistic of 91.058 is greater than the critical value of the *F* statistic.

Table 4-30 Linear Correlation Statistics between PEOU and COMP – Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.901[a]	.813	.804	.64612

a. Predictors: (Constant), AVE_PEOU

b. Dependent Variable: AVE_COMP

Table 4-31 Linear Correlation Statistics between PEOU and COMP – ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	38.014	1	38.014	91.058	.000[b]
	Residual	8.767	21	.417		
	Total	46.781	22			

a. Dependent Variable: AVE_COMP

b. Predictors: (Constant), AVE_PEOU

The relationship between Relative Advantage (RA) and Perceived Usefulness (PU) is significant with a *p* value of 0.000 (see Tables 4-32 and 4-33). The model indicates that nearly 74% of the variance is explained by this model and the *F* statistic of 59.255 is greater than the critical value of the *F* statistic.

Table 4-32 Linear Correlation Statistics between RA and PU – Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.859[a]	.738	.726	.64405

a. Predictors: (Constant), AVE_RA
b. Dependent Variable: AVE_PU

Table 4-33 Linear Correlation Statistics between RA and PU – ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	24.579	1	24.579	59.255	.000[b]
	Residual	8.711	21	.415		
	Total	33.290	22			

a. Dependent Variable: AVE_PU
b. Predictors: (Constant), AVE_RA

The relationship between Compatibility (COMP) and Perceived Usefulness (PU) is significant with a *p* value of 0.000 (see Tables 4-34 and 4-35). The model indicates that nearly 56% of the variance is explained by this model and the *F* statistic of 26.603 is greater than the critical value of the *F* statistic.

Table 4-34 Linear Correlation Statistics between COMP and PU – Model Summary

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.748[a]	.559	.538	.83625

a. Predictors: (Constant), AVE_COMP
b. Dependent Variable: AVE_PU

Table 4-35 Linear Correlation Statistics between COMP and PU – ANOVA

ANOVA [a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.604	1	18.604	26.603	.000[b]
	Residual	14.686	21	.699		
	Total	33.290	22			

a. Dependent Variable: AVE_PU

b. Predictors: (Constant), AVE_COMP

The relationship between Relative Advantage (RA) and Compatibility (COMP) is significant with a *p* value of 0.000 (see Tables 4-36 and 4-37). The model indicates that nearly 76% of the variance is explained by this model and the *F* statistic of 68.228 is greater than the critical value of the *F* statistic.

Table 4-36 Linear Correlation Statistics between RA and COMP – Model Summary

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.874[a]	.765	.753	.72408

a. Predictors: (Constant), AVE_RA

b. Dependent Variable: AVE_COMP

Table 4-37 Linear Correlation Statistics between RA and COMP – ANOVA

ANOVA [a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	35.771	1	35.771	68.228	.000[b]
	Residual	11.010	21	.524		
	Total	46.781	22			

a. Dependent Variable: AVE_COMP

b. Predictors: (Constant), AVE_RA

Figure 4-14 puts these results into a graphical format for easier viewing.

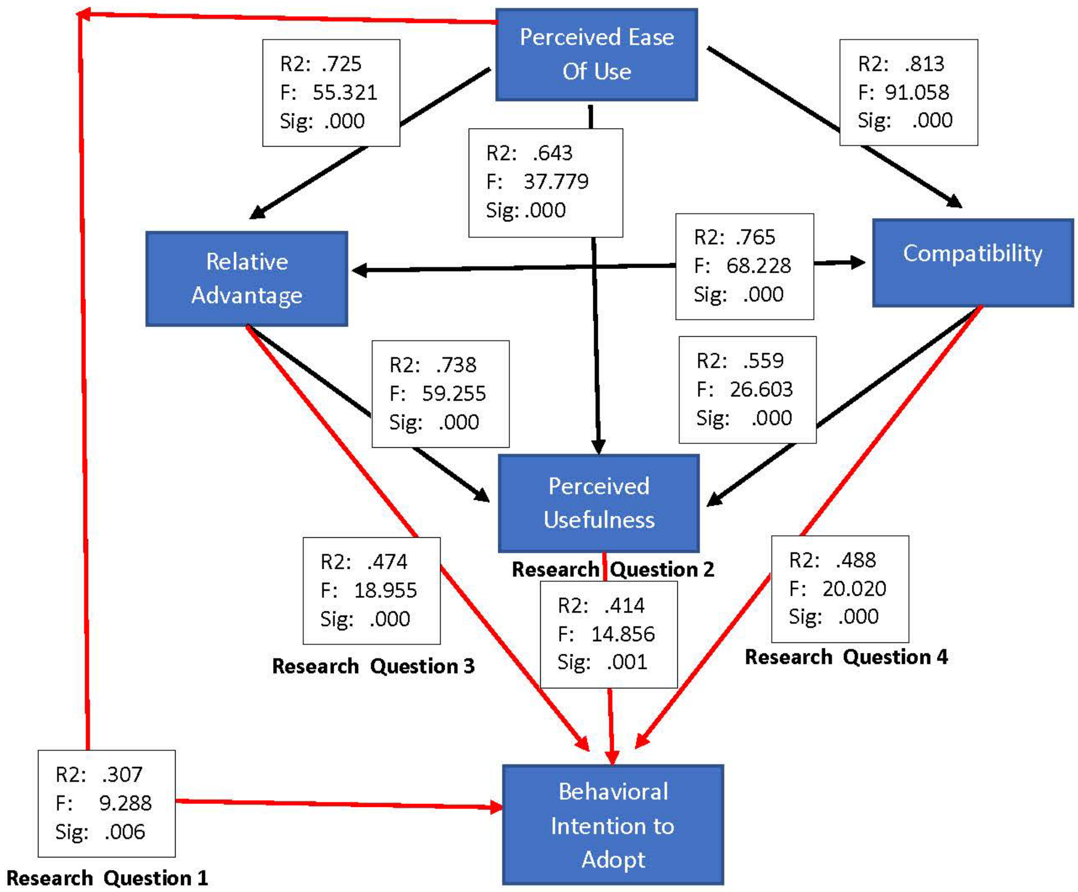


Figure 4-1 Linear Regression Results between Variables

Table 4-38 Summary Correlation Statistics

Correlations

		AVE_BI	AVE_PEOU	AVE_PU	AVE_RA	AVE_COMP
Pearson Correlation	AVE_BI	1.000	.554	.644	.689	.699
	AVE_PEOU	.554	1.000	.802	.851	.901
	AVE_PU	.644	.802	1.000	.859	.748
	AVE_RA	.689	.851	.859	1.000	.874
	AVE_COMP	.699	.901	.748	.874	1.000
Sig. (1-tailed)	AVE_BI	.	.003	.000	.000	.000
	AVE_PEOU	.003	.	.000	.000	.000
	AVE_PU	.000	.000	.	.000	.000
	AVE_RA	.000	.000	.000	.	.000
	AVE_COMP	.000	.000	.000	.000	.
N	AVE_BI	23	23	23	23	23
	AVE_PEOU	23	23	23	23	23
	AVE_PU	23	23	23	23	23
	AVE_RA	23	23	23	23	23
	AVE_COMP	23	23	23	23	23

Testing of Hypotheses

Table 4-39 shows the results in a hypothesis summary table. Based on the analysis of the data, each null hypothesis was rejected.

Table 4-39 Hypothesis Summary Table

Hypothesis	Evidence	Supported? (null rejected)
Ho1: β1=0. There is no linear correlation between the perceived ease-of-use (PEOU) and a technology leader's Behavioral Intention (BI) to adopt Bonded Cellular systems.	*R* square: .307 *F*: 9.288 Sig: .006	**Yes.** 30.7% of the variance is explained, the *F* statistic is greater than the critical value of the *F* statistic, and the results are significant (<0.05).
Ho2: β2=0. There is no linear correlation between the perceived usefulness (PU) and a technology leader's Behavioral Intention (BI) to adopt Bonded Cellular systems.	*R* square: .414 *F*: 14.856 Sig: .001	**Yes.** 41.4% of the variance is explained, the *F* statistic is greater than the critical value of the *F* statistic, and the results are significant (<0.05).
Ho3: β3=0. There is no linear correlation between the Relative Advantage (RA) and a technology leader's Behavioral Intention (BI) to adopt Bonded Cellular systems.	*R* square: .474 *F*: 18.955 Sig: .000	**Yes.** 47.4% of the variance is explained, the *F* statistic is greater than the critical value of the *F* statistic, and the results are significant (<0.05).
Ho4: β4=0. There is no linear correlation between Compatibility (COMP) and a technology leader's Behavioral Intention (BI) to adopt Bonded Cellular systems.	*R* square: .488 *F*: 20.020 Sig: .000	**Yes.** 48.8% of the variance is explained, the F statistic is greater than the critical value of the F statistic, and the results are significant (<0.05).

CHAPTER 5

SUMMARY AND CONCLUSIONS

This chapter presents conclusions and recommendations about the current study. The chapter includes a restatement of the project's purpose, discussions and conclusions, implications, and recommendations.

The purpose of this study was to investigate the determinants of Bonded Cellular TV technology adoption and use within US television broadcasting and video production organizations. This study applied two technology adoption theories: Technology Acceptance Model (Davis, 1986), and Diffusion of Innovation (Rogers, 1995).

Summary

The results of the current research led to the conclusion that a strong linear relationship exists between the four components being studied, Perceived Ease of Use (PEOU), Perceived Usefulness (PU), Relative Advantage (RA), Compatibility with existing work practices (COMP) and the behavioral intent (BI) to adopt Bonded Cellular technology (BC).

A comprehensive review of literature was conducted in order to provide historical perspective, highlight unifying themes, support theoretical fundamentals and provide a framework for the study's structure. A quantitative approach to this research allowed objectivity and the opportunity of being descriptive in nature.

The data was collected via a Qualtrics online survey instrument administered to a targeted sample population drawn from the U.S. television engineering and management industry. The target population consisted of decision makers with experience and knowledge of the TV broadcast industry as described in the demographics portion of the survey results. The survey was issued beginning in late November 2019 through early December 2019. A secure survey web link was distributed to 599 anonymous participants by Qualtrics email severer.

As presented in chapter 4, the data were inspected, screened, and scored. From a total of 24 responses, a range of 21 to 24 surveys were found to be useable for this study's data analysis depending upon the research question. The descriptive statistics summarized the sample characteristics and the variables were produced.

Participant Demographics

Industry Experience (Table 4-2) was heavily skewed toward the senior end of the Likert-Scale for years of experience of the job. Of the participants, 41.6% had 20 years or more of experience; 37.5% had between 10 and 20 years of experience; 20.8% had between 5 and 10 years of experience; and none of the respondents had less than 5 years of experience. Participants with more than 10 years of experience represented 79.1% of the total sample. This presents an interesting topic for future research, which may suggest that television broadcast engineering is a maturing career sector within an aging industry or that young engineers are not being presented with opportunities to pursue the field of broadcast engineering management, or perhaps because of lack of recruitment.

The positions held by the respondents demonstrated that 62.5% selected job descriptions within the categories of Executive, Director, Chief Engineer, Department Manager, or Operations (Table 4-1) signifying that the survey was able to reach a highly targeted and desirable audience for participation. Only 37.5% selected Other, as the job description.

KMO and Bartlett's Sampling Adequacy

The Kaiser-Meyer-Olkin (KMO) statistic is a measure of sampling adequacy. A KMO and Bartlett's Test of Sphericity was conducted (Table 4-6) and the results illustrated the KMO and Bartlett's test were suitable for factor analysis According to Gaskin, a KMO score greater than .7 is desirable. The survey results were higher at .725. A significance less than 0.5 is needed to consider the result significant (Gaskin, 2015). The survey results were significant at .000.

Communalities

All communalities were above the desired threshold of 0.3, as shown in Table 4-7. Additionally, many of the values are approaching 1.0, which is an indication that the extracted components represent the variables well.

Total Variances of Factors

Table 4-8 shows details about the total variance. Eigenvalues represent the explanation of the total variances of the factors. Generally, only eigenvalues greater than 1 should be considered factors. There are three factors with values greater than 1 and a fourth factor that was included because of an eigenvalue of 0.999 with a rounding threshold up to 1.0.

Pattern Matrix

For convergent validity, it is desirable to find results above 0.5, as shown in Table 4-9. The values should average above 0.72 (Gaskin, 2015). The results meet this criterion.

Factor (Component) Correlations

To avoid shared variance, there should be no factor correlations greater than 0.7 (Gaskin, 2015). The results in Table 4-10 show that the factor correlations are all significantly lower than 0.7, which indicated that the factors are distinct and uncorrelated and meet the requirements of discriminant validity.

Cronbach's Alpha Reliability Testing

Internal consistency reliability for each of the variables was assessed using Cronbach's alpha. All four variables returned an excellent reliability with all coefficients scoring above 0.8 as demonstrated in the Cronbach's alpha summary Table 4-16.

Discussion of Research Questions

1. Can a technology leader's behavioral intention (BI) to adopt BC tools be predicted by using an independent variable representing Perceived Ease-Of-Use (PEOU)?

The Linear Correlation statistics show that the relationship between Perceived Ease of Use (PEOU) and Behavioral Intent (BI) to adopt is significant with a *p* value of 0.006 (see Table 4-17). The model indicates that nearly 31% of the variance is explained by this model and the *F* statistic of 9.288 is greater than the critical value of the *F* statistic, of 2.96.

2. Can a technology leader's behavioral intention (BI) to adopt BC tools be predicted by using an independent variable representing Perceived Usefulness (PU)?

The Linear Correlation statistics show that the relationship between Perceived Usefulness (PU) and Behavioral Intent (BI) to adopt is significant with a *p* value of 0.001 (see Table 4-19). The model indicates that nearly 41% of the variance is explained by this model and the *F* statistic of 14.856 is greater than the critical value of the *F* statistic, of 2.96.

3. Can a technology leader's behavioral intention (BI) to adopt BC tools be predicted by using an independent variable representing the Relative Advantage (RA)?

The Linear Correlation statistics show that the relationship between Relative Advantage (RA) and Behavioral Intent (BI) to adopt is significant with a *p* value of 0.000 (see Table 4-21). The model indicates that nearly 47% of the variance is explained by this model and the *F* statistic of 18.955 is greater than the critical value of the *F* statistic, of 2.96.

4. Can a technology leader's behavioral intention (BI) to adopt BC tools be predicted by using an independent variable representing Compatibility with existing operations (COMP)?

The Linear Correlation statistics relationship between Compatibility (COMP) and Behavioral Intent (BI) to adopt is significant with a *p* value of 0.000 (see Table 4-23). The model indicates that nearly 49% of the variance is explained by this model and the *F* statistic of 20.02 is greater than the critical value of the *F* statistic, of 2.96.

Highest and Lowest Survey Standard Deviation Observations

The survey questions with the strongest agreement, or lowest standard deviation, were Q_10 and Q_19.

Question 10 is coded as a factor Perceived Ease of Use (PEOU) and asks whether "It would be easy for me to become skillful at using Bonded Cellular technology." 78% of responses are in the Agree or Strongly Agree categories.

Question 19 is coded as a factor for Relative Advantage (RA) and asks whether "Bonded Cellular technology will enable users to accomplish their job tasks quickly and effectively." 77% of responses in the Agree or Strongly Agree categories.

The survey questions with the weakest agreement, or highest standard deviation, was Q_30.

Question 30 was designated as a dependent variable (DV) and coded as the Behavioral Intent (BI) to adopt Bonded Cellular and asks whether "Our organization has prior experience with Bonded Cellular communications technology." The replies show that there is a strongly polarized range of responses with 54% Agree or Strongly Agree and 31% Disagreeing or Strongly Disagree. 13% were in the middle ground of staking a position. The polarity observed in the responses from Q_30 is also reflected in Q_1 of the demographics section, which asks, "Is your organization using any Bonded Cellular (BC) broadcasting technology today?" Responses were split with nearly bi-polar symmetrical answers of 54% Yes and 45% No (Table 4-3). This presents the most intriguing aspects of this survey for future study. Though the adoption of Bonded Cellular TV technology is a maturing and stable technology platform, these results may hint that there is still room for much more growth for even further adoption in the marketplace.

Rejection of the Null Hypothesis

The results and findings in the current study have indicated that PEOU, PU, RA and COMP all have a good linear relationship to the behavioral intent (BI) for the adoption of BC. The research questions were answered and all four null hypotheses were rejected (Table 4-39).

Implications

This study adds to what is known about technology adoption and acceptance in very specific ways. Although all four components show a statistically significant, linear relationship to the DV to adopt bonded cellular, the results indicated that the strongest factors that influence the behavioral intent (BI) to adopt Bonded Cellular are most closely shared between Compatibility with existing work practices (COMP) with an R-square value of 48.8% and Relative Advantage (RA) with an R-square value of 47.4%. Makers of these tools would benefit with the realization that technology leaders are unlikely to adopt such tools if they are not compatible with existing television standards and practices for workflow nor offering an advantage over existing live News gather practices, such as the use of dedicated ENG or SNG television remote trucks.

Recommendations for Future Research

The TAM and DOI was a good choice for this research study. However, there are opportunities to improve the model with future research specific to the acceptance of Bonded Cellular technology that explores additional TAM and DOI factors that were not addressed in this study. For example, other factors may include Complexity, Top Management Support, Organization Size, Experience, Perceived Barriers, Competitive Pressures, and Cost.

Rogers states, “When the price of a new product decreases so dramatically during its diffusion process, a rapid rate of adoption is encouraged (Rogers, 1995, p. 213). Specifically, the subject of a rapid decrease in cost of a technology, such as BC, especially in light of the high cost of legacy technologies for a fully equipped ENG remote truck or SNG truck for television production. There is nearly a 10 times cost difference between a Bonded-Cellular remote system in the price range of $10,000 to $15,000 dollars, compared to a basic remote ENG truck costing $100,000 to $200,000 dollars and up. This study did not consider the impact of cost as a dependent variable factor for adoption, for the reason that the difference is so inordinate, as to be a self-evident factor.

It is the goal of this research to provide a roadmap for future investigators to be able replicate this study with the step-by-step blueprint provided herein. I encourage scholars and researchers to implement the techniques imbued in this study and I offer the following suggestions for future study. Future researchers may want to limit the research questions to two (2) dependent variables or factors for the reason that it may encourage an increase in survey participation, resulting in additional survey data for those factors. Reducing the number of questions on the survey may encourage a higher response rate from participants. Future research may also be modified to broaden the target demographic to include, television operators, media students, producers and independent media producers to increase the sample size (n) of the survey. A larger sample size would yield additional data, while expanding the targeted participant demographic.

Possible Additional Research Questions for Future Studies

1. Does adoption of BC technology "fit" other models of Innovation Diffusion and Adoption and Technology Acceptance Models defined by Rogers, Davis or others?
2. How can "A Model of Stages in the Innovation-Decision Process" (Rogers, 1995) be applied to the adoption of BC?
3. Diffusion is the Process by Which (1) an Innovation (2) Is Communicated through certain Channels (3) Over Time (4) Among the Members of Social System (Rogers, 1995). How are these components relevant to the adoption of Bonded Cellular technology?
4. What technologies have made BC a capable technology positioned to possibly replace current transmission technologies?
5. What are the current and future pathways for innovation with the development of BC technologies?

6. What are the implications of future advances and innovations, such as 5G that may affect BC technologies?
7. How can technology managers further identify and leverage the benefits of Bonded Cellular systems?
8. What are the challenges and potential risks of utilizing Bonded Cellular systems?
9. What economic implications and business pressures does Bonded Cellular present to current ENG and SNG service providers' manufacturers?

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APPENDIX A: SURVEY QUESTIONNAIRE

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Demographic Questions

1. Is your organization using any **Bonded-Cellular** (BC) Technology today?
   - ☐ **Yes**
   - ☐ **No**

2. What is your company's primary communication industry sector(s)?
   - ☐ News Production
   - ☐ Sports Production
   - ☐ Event Video Production
   - ☐ IP Streaming Video
   - ☐ Remote Production Truck Provider
   - ☐ Other (please specify) ___________________

3. Please indicate the number of years of your industry experience.
   - ☐ Less than 5 Years
   - ☐ 5 – 10
   - ☐ 10 - 20
   - ☐ Over 20 Years

4. Please indicate what best describes your position within your organization.
   - ☐ Executive
   - ☐ Director
   - ☐ Chief Engineer/Technology Officer
   - ☐ Management
   - ☐ Non-Management (specify) ___________________
   - ☐ Supervisor
   - ☐ Other (specify) ___________________

5. To what extend does your organization value the use of remote video technology for producing live broadcasts or video streaming? Please indicate on the sliding scale (1-10) how much you agree or disagree with this statement. On the scale, 1 stands for Disagreement and 10 for Agreement.

Strongly Disagree **1**	Disagree **2**	Somewhat Disagree **3**	Neither **4**	Somewhat Agree **5**	Agree **6**	Strongly Agree **7**

Sections 2-6

For determinant factor Perceived Ease of Use, please indicate on a scale of 1-7 the extent to which you agree or disagree with the statements below. The scale ranges from 1 (Strongly Disagree) to 7 (Strongly Agree).							
Learning to operate BC technology would be easy.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
I would find it easy to get BC technology to do what I want it to do.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
My interaction with BC would be clear and understandable.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
I would find BC to be flexible to interact with.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
It would be easy for me to become skillful at using BC Technology.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
I would find BC technology easy to use.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
For determinant Perceived Usefulness, please indicate on a scale of 1-7 the extent to which you agree or disagree with the statements below. The scale ranges from 1 (Strongly Disagree) to 7 (Strongly Agree).							
Using BC technology would enable my organization to accomplish specific tasks more quickly.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Using BC technology would improve my job performance.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Using BC technology at work would increase my productivity.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Using BC technology would enhance my effectiveness on the job.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Using BC technology would make it easier to do my job.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
I would find BC technology useful in my job.	**1**	**2**	**3**	**4**	**5**	**6**	**7**

For the determinant factor, Relative Advantage please indicate on a scale of 1-7 the extent to which you agree or disagree with the statements below. The scale ranges from 1 (Strongly Disagree) to 7 (Strongly Agree).							
BC technology will improve our organization’s cost efficiency.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
BC will enable users to accomplish their job tasks quickly and effectively.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Using BC technology will improve the quality of our work.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Using BC will increase the organization’s productivity.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Using BC will improve our organizations operations.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
For the determinants Compatibility and Experience, please indicate on a scale of 1-7 the extent to which you agree or disagree with the statements below. The scale ranges from 1 (Strongly Disagree) to 7 (Strongly Agree).							
Using BC is compatible with our work style.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
BC technology is compatible with our organizations operations and work activities.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
BC technology use is compatible with existing distribution channels.	**1**	**2**	**3**	**4**	**5**	**6**	**7**

For the determinants Compatibility and Experience, please indicate on a scale of 1-7 the extent to which you agree or disagree with the statements below. The scale ranges from 1 (Strongly Disagree) to 7 (Strongly Agree).	**1**	**2**	**3**	**4**	**5**	**6**	**7**
My organization will use Bonded-Cellular technology for live video production.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Using Bonded-Cellular technology in performing my job responsibilities is something I would do.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
I would see my organization using Bonded-Cellular technology for the production of live video events.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Using BC is compatible with our organization's culture, values, and beliefs.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Our organization has prior experience with Bonded-Cellular communication technologies.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Our organization has some experience using Bonded-Cellular communication technologies.	**1**	**2**	**3**	**4**	**5**	**6**	**7**

6. If your company or organization is interested in BC technology, please indicate how soon they plan to adopt this technology.
   - ☐ In the next 6 months
   - ☐ Within 6 to 12 Months
   - ☐ Within 12 to 24 Months
   - ☐ More than 24 Months
   - ☐ No plans

Thank you for your participation.

APPENDIX B: ISU INSTITUTIONAL REVIEW BOARD LETTER

Indiana State University
More. From day one.

Institutional Review Board

Terre Haute, Indiana 47809
812-237-3088
Fax 812-237-3092

DATE:	September 2, 2019
TO:	Greg Phipps, MOAM
FROM:	Indiana State University Institutional Review Board
STUDY TITLE:	[1333291-3] Adoption of Bonded Cellular Video Transmission Technology: Employing Diffusion of Innovation and Technology Acceptance Models
SUBMISSION TYPE:	Revision
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	September 2, 2019
REVIEW CATEGORY:	Exemption category #2

Thank you for your submission of Revision materials for this research study. The Indiana State University Institutional Review Board has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations (45 CFR 46). You do not need to submit continuation requests or a completion report. Should you need to make modifications to your protocol or informed consent forms that do not fall within the exempt categories, you will have to reapply to the IRB for review of your modified study.

Internet Research: If you are using an internet platform to collect data on human subjects, although your study is exempt from IRB review, ISU has specific policies about internet research that you should follow to the best of your ability and capability. Please review Section L. on Internet Research in the IRB Policy Manual.

Informed Consent: All ISU faculty, staff, and students conducting human subjects research within the "exempt" category are still ethically bound to follow the basic ethical principles of the Belmont Report: 1) respect for persons; 2) beneficence; and 3) justice. These three principles are best reflected in the practice of obtaining informed consent.

If you have any questions, please contact Ryan Donlan within IRBNet by clicking on the study title on the "My Projects" screen and the "Send Project Mail" button on the left side of the "New Project Message" screen. I wish you well in completing your study.