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A DNA Framework to Predict the Role of Communication in System Reliability

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A DNA Framework to Predict the Role of Communication in System Reliability

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Dedication

To my inspirational Father, who motivated and encouraged me to pursue my Masters.

To my loving Mother, who has given everything to help me achieve my dreams.

To my beautiful Wife, for her constant support, and love through this journey.

To my caring Brothers, for always believing in me.

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Abstract

The global business environment involves an extreme level of risk and complexity which is an essential requirement for future growth. Each year, organizations around the world face astronomical project failure rates. A study revealed that on every $1 billion spent on the project, $135 million is at risk. From this $135 million more than half is on the risk due to poor communication. Most of the communication audit tools assessed in the literature, evaluate communication from the organization perspective and does not address how to evaluate communication between the departments and assess the reliability of communication. In this research, Clayton Homes was used as a case study to evaluate the communication between two departments. Sales/Engineering Department was considered as encoders and Production Department was considered as decoders. The attributes of communication were identified to develop the survey questions. One survey was developed for encoders and one for decoders. Analytical Hierarchical Process was used to find the weights of the attributes. T- test was used to compare the mean of two groups. Pearson Correlation was used to identify the correlation between the attributes. Probability Density Function was used to calculate the reliability of communication between two departments. This study will contribute to the current academic research by providing a method to analyze the reliability of communication between two departments.

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Chapter 1

Introduction

1.0.1 Human DNA

Deoxyribonucleic acid (DNA) is a hereditary molecule in human and almost all other organisms. It contains genetic instructions for the development and function of living things. It carries information that encodes genes responsible for giving different characteristics to an individual. These differences are key to techniques such as fingerprinting which helps to distinguish between different human beings. The DNA Structure is composed of a sugar molecule, phosphate molecule, and nitrogen bases. Together a base, sugar, and phosphate are called a nucleotide. There are four types of nitrogen bases: Adenine (A), Thymine (T), Guanine (G), and Cytosine (C) in DNA [35]. DNA Sequencing is the determination of physical order of the bases in a molecule of DNA [48]. The genetic code is composed of nucleotide triplets. Three letter code of nucleotides is called codon. This code is non-overlapping, i.e., the adjacent codon does not overlap. A non-overlapping code means that the same base is not used for two different codons. In simple words, no single base can take part in the formation of more than one codon.

1.1 Relating Human DNA to Organization

Basic characteristics, structure of human DNA, and system engineering approach were used to develop an organizational DNA method. Sequencing and non-overlapping characteristics

of human DNA were arrogated in organizational DNA. Strand formation of human DNA was used to represent organizational DNA Strand. System Engineering approach was used to develop the framework of an organization. System Engineering is a comprehensive, iterative and recursive problem solving process, applied sequentially top down by integrated teams. It emphasizes on how to design and manage complex systems over their life cycles. The International Council on System Engineering describes system engineering as "It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation [44]." This concept was used to determine the ability of the organization to address key projects and initiatives associated with organizational improvement. Each project requires a set of activities to be completed by various functions in the organization. The logic behind the organizational DNA is to understand external stakeholder requirements, translate internal stakeholder requirements into internal requirements and manage the project internally. The organizational DNA will include information starting from external stakeholder to internal stakeholders, and management components required to complete the project. All this information give unique identification details about the project. This information will be represented in the form of a strand. Functions involved in the organization and communication between them will be used to form an organizational DNA strand. These functions will be extracted from the framework of an organization. These functions will act as a phosphate molecule as indicated in Figure 1.1. Phosphate can be decomposed into phosphorous and oxygen. Similarly, functions can be classified into three categories: Translating External Stakeholder Requirements, Understanding the Impact on Internal Stakeholders, Management/Accountability. These categories can be further decomposed into eight subcategories. These subcategories are discussed in detail in Section 1.2.1. Sugar and nitrogen molecule will act as a communication link as indicated in Figure 1.1. Sugar can be decomposed into carbon, hydrogen, and oxygen. Similarly communication can be decomposed into three components such as encoding, medium, and decoding.

Encoding means that the message is converted into a language or a code that is easily understood by the receivers. The medium can be a means by which a message is conveyed. Decoding is the process that occurs at the reception level where instincts, figures, and symbols

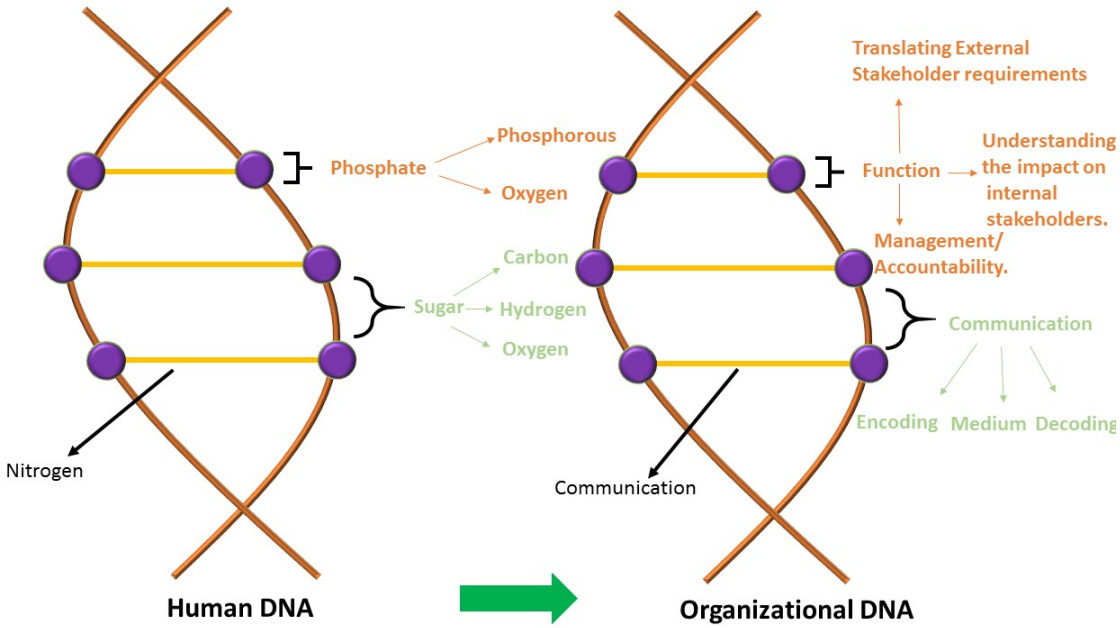


Figure 1.1: Human DNA Vs Organizational DNA

are interpreted and translated into meaningful information.Figure 1.1 is a transformation from human DNA to organizational DNA. These functions are represented in the form of nodes in the DNA Strand. The information in the DNA strand will be in a sequential manner. Sequencing of functions in the DNA strand will be done from three categories of a framework: Translating External Stakeholder Requirements, Understanding the Impact on Internal Stakeholders, Management/Accountability. This information on the DNA strand will start with the external stakeholders and will finish where the project will be completed. Every new project will have a different organizational DNA strand hence the information will be non-overlapping.

1.2 Technical Development

1.2.1 Framework of an Organization based on System Engineering

Systems Engineering theory was used as a foundation to develop the framework of an organization. "System engineering transform needs and requirements into a set of system

product and process description, generate information for decision makers and provide input for next level of development. This approach is applied sequentially, one level at a time, adding additional detail and definition with each level of development. System Engineering approach decomposes a function into the following categories: inputs, requirement analysis, functional analysis, design synthesis, verification, system analysis, and outputs [89]." Inputs consist primarily of customer needs and objectives. Requirement analysis translates customer requirements into a set of requirements that define what a system must do. The functional analysis identifies function internally in organization and decomposes higher level function to lower functions. Design synthesis includes the software and hardware requirements of a project or a system. Verification includes comparing the solution with the identified requirements. System analysis includes technical management activities to measure progress and evaluate solutions. Output includes the decision database. This approach provides an increasing level of comprehensive detail of projects or a system with each category. The framework proposed in this research for function decomposition can be classified into the following three categories such as:

a) Translating External Stakeholders Requirements

b) Understanding the Impact on Internal Stakeholders

c) Management/Accountability

1.2.2 Translating External Stakeholders Requirements

The purpose of this category is to include all the external stakeholders, necessary to operate an organization. This category has two subcategories which include stakeholders and life cycle impact. Stakeholders related to an organization can be identified from the components such as: Mission, Regulatory, and Contractual. Various stakeholders can be extracted from the mission component. Customers and suppliers are included in the mission component. For example, in an FMCG (Fast Moving Consumer Goods) organization, if the mission is to provide zero defect products to consumers, then customers become their important external stakeholders as shown in Figure 1.2. As their feedback in providing a quality product to an organization is essential. Different organizations need to comply with various regulations.

Figure 1.2: Framework of an Organization

In the regulatory component, all the government agencies are included. For example, if a manufacturing organization needs to comply with the safety laws of the country, then the government's safety department will become an external stakeholder of an organization. In a contractual component, all the contractors who do contract with an organization are included. These contractors are not directly related to the core operations of an organization. For example, a waste disposal contractor can be an external stakeholder in this component. So each of these components can be broken down into different functions depending upon the project. "X" represents any other function which will be impacted by the new project as shown in Figure 1.2.

Life Cycle impact includes the following functions: Architecture Requirements, Operations & Maintenance, Detail Design, Verification and Validation, and Integration and Testing. These components are the area of an organization which impacts the life cycle of a project. Architecture Requirements include projects associated with the plant layout and building structures. Operations & Maintenance includes projects associated with the general operations of an organization such as manufacturing, warehouse, logistics, and maintenance. Detail Design includes projects associated with the design of a new system or products. Verification and Validation include those projects which require validation of an existing system or a new product. Integration and Testing include projects associated with the testing of different types of equipment. "X" represents any other function which will impact the project depending upon the nature of an organization as shown in Figure 1.2. The external stakeholder category is highlighted with green in Figure 1.2.

1.2.3 Understanding the Impact on Internal Stakeholders

The internal stakeholders are involved in operating an organization or completing the new project. The purpose of this category is to identify the internal functions associated with the new project and understand the impact of external stakeholders on internal stakeholders. This category can be extended to subcategories such as: Functional Matrix, Sub-Functional Matrix, Operation Requirements, and Technical Requirements. The Functional Matrix includes the principal departments of an organization such as manufacturing, sales, finance, marketing, and engineering as shown in Figure 1.2. The Sub-Functional matrix includes

the extended departments of these functions. For example, engineering has a maintenance department, design department, and project engineering department. Finance has accounts and capital expenditure (CapEx) as their extended functions. Sales have e-commerce, retail store, as their extended functions. Manufacturing includes production, quality, and safety. HR includes public relations, training and employee relations as their extended functions. All these extended functions can be increased depending upon the nature of an organization. Operational Requirements are the contractors providing support to the operations of an organization such as hardware design, software design, configuration management, and logistics. Technical Requirements are the consultants providing technical support to an organization in the design of equipment, maintenance of equipment and improving the efficiency of an organization. All the four categories of an organization can be extended into more components depending upon the nature of an organization which is represented by "X" in Figure 1.2. This category is highlighted with red in Figure 1.2.

1.2.4 Management/Accountability

The purpose of this category is to define components associated with the internal management of projects. This category includes: Leading Indicators, Lagging Indicators, Control Plans, and Control Mechanism. "Leading indicators are activity or task-based metrics that are measured early and can be influenced to affect future outcomes" [66]. "Lagging indicators are the outcome measures that provide the basis for studying the deviations after the completion of activities" [56]. Leading and Lagging indicators can be derived from safety, quality, production, and reliability. For example in safety, the example of leading indicators could be hazard identification, and safety training and lagging indicators would be a number of injuries [79]. In quality, the example of lagging indicators could be customer complaints. The example of leading indicators in production would be overall equipment efficiency, raw material waste and packing material waste. The example of lagging indicators could be manpower availability and raw material availability. In addition to this, several more KPI can be added into the framework of an organization depending upon the nature of the project which is represented by "X" as shown in Figure 1.2. Control Plans and Mechanisms are the procedures developed to achieve the target set through leading and lagging indicators. For

example, a control plan could be to introduce the kanban system in a manufacturing plant to improve the OEE of a machine. Control mechanism could be an apparatus or machine installed to improve the operation of an organization. This category is highlighted with blue in Figure 1.2.

1.2.5 DNA Strand Formation

A new initiative or a project is mapped on this framework in the form of a strand. The strand will be created from where the project will impact the external stakeholders and will go through all the functions, indicators and control plans involved in this project. This DNA strand can cover all three categories or even one category depending upon the nature of the project or an initiative. For example, if the project involves external stakeholders, internal stakeholders, and management/accountability, DNA strand formation will be done across three categories, and if the project only belongs to internal stakeholders, and management/accountability, DNA strand formation will be done in two categories. Functions are represented by the nodes in the DNA strand. This DNA strand gives a unique structure to analyze the process, as it identifies all the stakeholders, functions and indicators involved in the new initiative or a project. DNA strand analysis also helps the organization to prioritize which function is critical in the overall project. Figure 1.3 is an example of strand formation using the information from the framework. This strand covers all three categories of the framework. In Figure 1.3 components are represented in the DNA strand. These components will be used to identify functions from the framework. This is a single strand; multiple strands can also be created depending upon the requirements of the project. The scope of this research would be only limited to a single strand.

1.2.6 Role of Communication in DNA Strand

Communication is a "basic function of all managers' jobs" because managers spend 80% of their daily duties communicating with others in order to drive the organization's success [2].

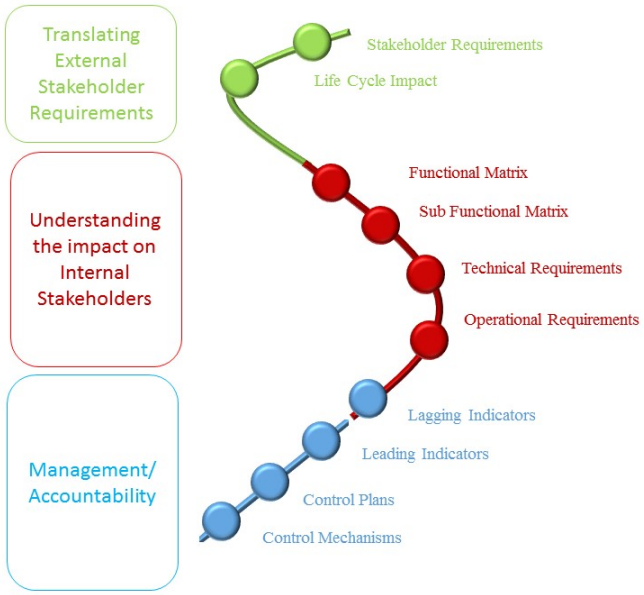


Figure 1.3: Single DNA Strand

A study "Pulse of the Profession In-Depth Report: The Essential Role of Communications" has discovered that highly effective communicators complete 80% of their original goals as compared to 52% of the minimally effective communicators. The delivery rate of completing the project of a highly effective communicator is 71% as compared to 37% of minimally effective communicators. "One out of five projects is unsuccessful due to ineffective communications [68]." The study revealed that on every US$1 billion spent on the project, US$135 million is at risk. From this US$135 million, more than half is at risk due to poor communication [68]. The most important element in any organizational communication is internal communication explicated by Bartlett and Ghoshal in a statement "Lifeblood of an organization" [11].

The DNA strand can have a considerable number of functions depending upon the nature of the project or a system. Therefore communication between these functions plays a pivotal role in the success of a project or a system. Research has shown that communication improves employee job performance [34]. An ineffective communication between two functions in the strand can hinder the success of a whole project. Hence communication is set as a linkage connecting these nodes in a DNA strand as described in Figure 1.4. These nodes as described earlier are the functions involved in the project.

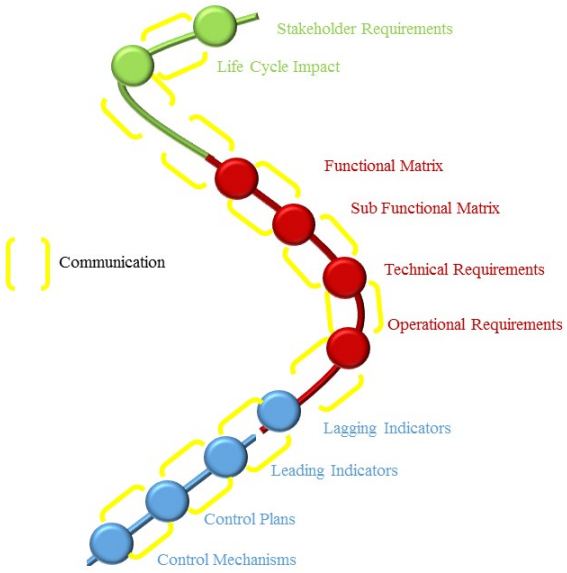


Figure 1.4: Communication Linkage between Nodes

1.2.7 Reliability of Strand

"The probability that an item will perform its intended function for a specified interval under stated conditions is regarded as reliability [71]." The reliability of the function in the strand can be calculated from the probability distribution data. This data includes the time between failure of these functions in the strand. The key distributions for reliability analysis are Exponential, Weibull, Normal and Lognormal. The reliability of the simple system can be calculated using three different structural relationships: Series, Parallel, K out of N. In this research, our focus would be on the series structure only as all the functions are in series in a single strand as described in Figure 1.5.

A series structure is defined as a system in which all the functions must be operating in a system to be successful. The reliability of the strand will give an estimation of risk. Reliability of the strand for Figure 1.5 is calculated by the following equation:

$$R_s = (\prod_{i=1}^{n} R_{Fi}) \tag{1.1}$$

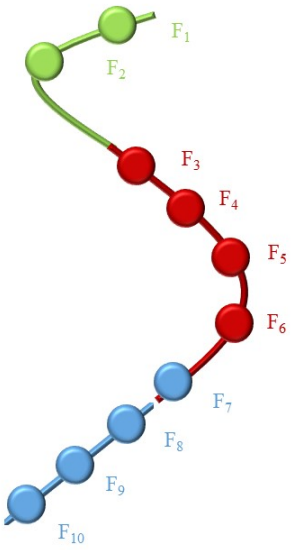


Figure 1.5: Single Strand with Functions

Where

R_s= Reliability of Strand

R_{Fi}= Reliability of function

1.2.8 Reliability of Strand with Communication

As communication between the function is in series as shown in Figure 1.6 and no project can operate without communication between the functions. Hence, the reliability of communication was incorporated into the reliability of a strand. The reliability of the communication is based on three components: Encoding, Medium, and Decoding. For example, function F_1 will act as an encoder, function F_2 will act as a decoder, and C_{12} is the communication between them as described in Figure 1.6. Hence the reliability of the strand is an amalgamation of system engineering theory and communication theory. This will generate information which will be key for decision makers to know the risk behind the implementation of project [1]. The final equation of the reliability of the strand is given below:

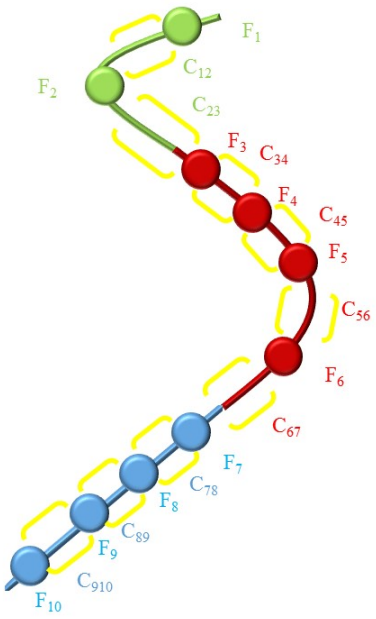


Figure 1.6: Single Strand with Functions and Communication

$$R_s = (\prod_{i=1}^{n} R_{F_i} R_{c_{i(i+1)}}) \qquad and \qquad R_{c_{n(n+1)}} = 1 \tag{1.2}$$

Where

i= Index of function

n= Total number of functions in the system

R_s= Reliability of Strand

R_F= Reliability of function

R_c= Reliability of communication

1.3 Evaluating Communication

Communication audits research mainly emphasizes employee communication satisfaction [25]. Researchers have revealed that effective and satisfactory communication contributes to organizational productivity and performance. Many researchers have provided empirical support for this claim [25], [40]. [54], [20], [67] .

Authors have developed different measurements such as Communication Satisfaction Survey [26], Organizational Communication Scale [73] , International Communication Association Audit [33], Organizational Communication Audit Questionnaire [96], to evaluate the organizational communication system. Communication Satisfaction Survey is the most widely used instrument for measuring organizational communication effectiveness. During the development stage of this survey, Down and Hazen were actually studying the relationship between job satisfaction and communication. The Communication Satisfaction Questionnaire comprehended eight dimensions, such as supervisory communication, subordinate communication, communication climate, personal feedback, organizational perspective, organizational integration, horizontal communication, and media quality. This communication audit tool has been used by many organizations to compare their communication effectiveness [38]. Not a vast structure of communication related dimensions were identified in this scale. International Communication Audit Questionnaire used a need-index approach making scoring more problematic, and the basic concept of need-index approach was questioned [38]. The Organizational Communication Audit Questionnaire lacks a comprehensive psychometric study assessing the reliability and validity of questions [38]. Less research has been conducted in the interdepartmental communication area [70]. So all of these communication evaluating methods did not assess interdepartmental communication or the reliability of communication between two departments or groups.

1.4 Problem Statement

Reliability of strand as described earlier in this research is the function of organization function and communication which is expressed below in the equation:

$$Reliability\ of\ Strand = f(Organization\ function, Communication) \tag{1.3}$$

Organization function will be extracted from the framework developed in this research. Communication is the linkage between these functions in an organization. The reliability of

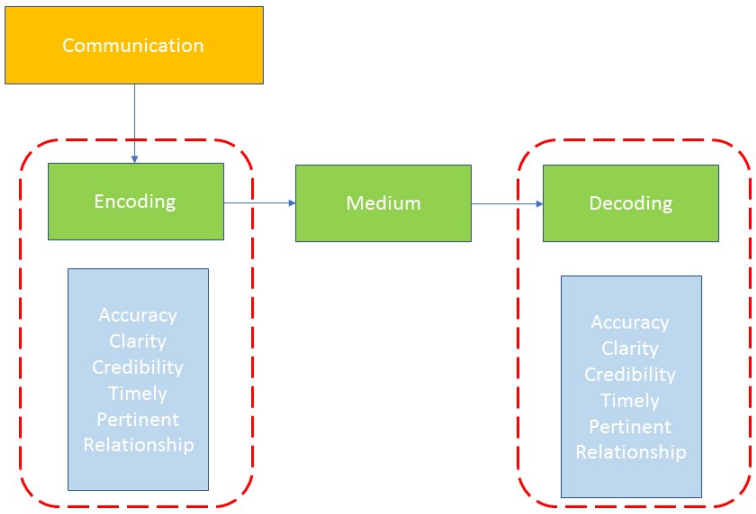


Figure 1.7: Communication Process

the strand can either be increased by increasing the reliability of function or by increasing the reliability of communication. As there is a lack of studies to assess communication between departments. Hence our problem in this research would be to identify the reliability of communication between two departments and develop a reliable communication matrix which could identify if the communication between two departments is reliable or unreliable. The process of encoding and decoding as described in Figure 1.7 can be assessed using communication attributes such as accuracy, clarity, timely, credibility, pertinent, and relationship. These attributes are explained in Chapter 2. Issues identified in these attributes, can help the organization understand which attribute impact the most on the reliability of communication. So by increasing the reliability of communication, the organization can increase the reliability of a strand or a system.

1.5 Anticipated Results

The results of this research will include the following:

- The weightage of the communication attributes to understand the importance of each attribute.

- The reliability of communication between two departments to analyze if the process of communication is effective.
- Attribute of communication with the highest impact on the reliability to identify an area of weakness.
- Correlation analysis to study the relation between the attributes.
- Reliability of a strand which includes reliability of function and communication. Reliability of function will be assumed in this research.

1.6 Approach

Phase 1:

An extensive literature review and interviews with the professionals in the industry were conducted to develop the framework of an organization and to find the attributes impacting the reliability of communication. The selection of the attributes is important as it gives the foundation on which the survey needs to be designed.

Phase 2:

A communication map was developed to identify the scope of the communication and employees involved in the communication. Then a survey was designed to understand the reliability of communication between two departments or groups. The survey asks respondents to indicate their perception about communication as encoder and decoders.

Phase 3:

A manufacturing site was selected as a case study. Clayton Homes was selected as a manufacturing site for the study. A paper-based survey was given to employees for responses. This paper-based survey was used because it was more friendly and easy to collect data and information.

Phase 4:

Several statistical tools were applied to the survey data to analyze the relationship between encoders and decoders. First, the raw data had to go through data screening to eliminate blank, missing, incomplete and unengaged responses. Cronbach's alpha was used to test the validity of the survey. AHP was used to identify the weight ages of these attributes. A T-Test was used to define a relationship between the encoders and decoders. Pearson Correlation was used to find the correlation between the attributes. Reliability of Communication Matrix was developed to define reliable and unreliable communication.

Phase 5:
Reliability of a strand was calculated by assuming the reliability of functions and using the reliability of communication calculated from the results. Furthermore, a sensitivity analysis was done to analyze the impact of communication on the overall strand by assuming different values of reliability.

1.7 Scope of the Study

The research methodology proposed in this study has the following scopes and limitations.

- This research would only be limited to a single strand analysis.
- This model is developed for organizational communication only.
- This model can be used to evaluate communication between two departments.
- This model was developed for manufacturing based organizations.
- The "language" attribute was not taken into consideration as most of the employees knew the English language, but it could be an important factor in evaluating communication.
- Informal communication, in any form (Oral and nonverbal), is not included in the scope of the study.

- Formal Communication, both horizontal and vertical, is the part of the process in the written form.
- Only project with series structure can be used with this methodology.

1.8 Impact of the Study

This study gives a method to analyze communication between two departments and calculate the reliability of communication. The results can help identify organizations whether or not the communication is reliable or unreliable between two departments or groups. This study helps us to find the reliability of new projects which are structured in the form of a series. These methods can help the organization identify where the communication is weak in their system. In this way, by rectifying communicational issues, organizations can increase the overall reliability of the system.

1.9 Organization of Thesis

This document is organized into five chapters. Following the introduction of this research, Chapter 2 provides a comprehensive overview of communication models developed over the years, audit tools for assessing the communication and the attributes affecting communication. Chapter 3 provides the methodology to assess the reliability of interdepartmental communication and the overall reliability of the strand. Chapter 4 discusses the case study and the results. Chapter 5 discusses the conclusion and future work.

Chapter 2

Literature Review

2.1 Introduction

This chapter summarizes the current literature on the communication models, methods for analyzing effective communication, attributes for effective communication, and techniques for analyzing the risk of implementing new projects in an organization. Relevant keywords as listed in Figure 2.1 were used to extract papers related to this study. Keywords such as communication, communication effectiveness, internal communication were used for analyzing communication models. Keywords such as organizational performance, worker performance, communication audits, communication surveys were used to understand the literature behind analyzing effective communication. Keywords such as factors affecting communication, internal communication and reliability of communication were used to extract information about attributes selection. Keywords such as risk analysis, project risk analysis, organizational DNA, change management were used to find literature about analyzing the risk of implementing new projects in an organization. The following sources were used for the literature research:

- Journal papers downloaded using google scholar.
- E-books downloaded using the University of Tennessee Library.
- Reports generated by audit firms.

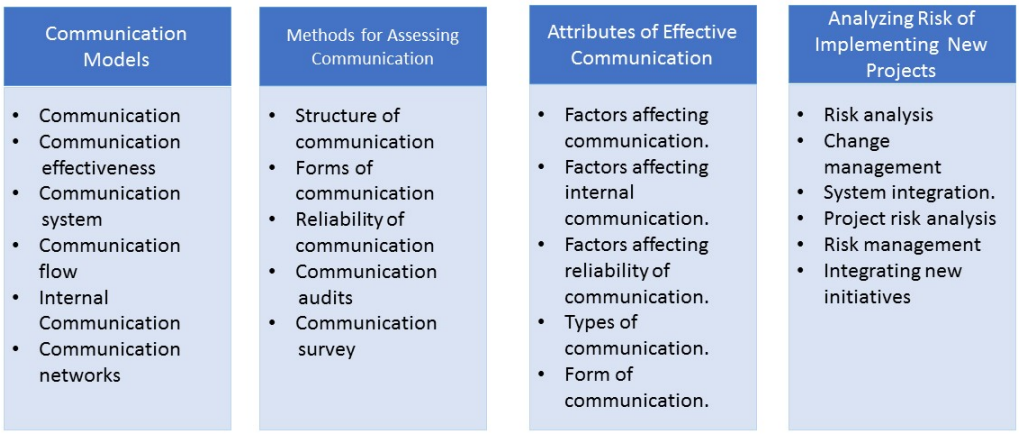


Figure 2.1: Keywords for Literature Research

2.2 Criteria for Literature Review

Several criteria were designed to evaluate articles for this research. These criteria included various questions which are listed below. Over 100 articles were reviewed to understand the current literature behind these questions. Only relevant papers were included in the summary of criteria as described in Table 2.1. Letter "a" in Table 2.1 represents the question a, similarly b,c,d,e,f represents the respective questions.

a) Does an article present a method to analyze the risk of implementing new projects?

b) Does an article present organizational DNA?

c) Does an article present models for effective communication?

d) Does an article present technique to analyze effective communication?

e) Does an article present attributes for effective communication?

f) Does an article present reliability of communication?

This research concluded that over the years a lot of studies had developed models for effective communication, but there is a lack of studies which have defined a model for

Table 2.1: Summary for Criteria Evaluation (Yes=Y)

Publication	a	b	c	d	e	f
Aryal, A. (2013)			Y			
Argyle, M. (1972).			Y			
Baker, K. A. (2002).			Y			
Banihashemi, S. (2011)			Y			
Barrett, D. J. (2006).			Y			
Shannon, C. E., Wyner, A. D., & Sloane, N. J. (1993)			Y			
Goldhaber, G. M., & Krivonos, P. D. (1977)				Y		
Thomas, G. F., Zolin, R., & Hartman, J. L. (2009).			Y	Y		
Wiio, O. A., Goldhaber, G. M., & Yates, M. P. (1980).			Y	Y		
Kraut, R. E., Fish, R. S., Root, R. W., & Chalfonte, B. L. (1990)			Y	Y		
Douglas, C., Martin, J. S., & Krapels,R. H. (2006).			Y	Y		
Bennett, J. C., & Olney, R. J. (1986).			Y	Y	Y	
Kramer, M. W., & Hess, J. A. (2002).				Y		
Ertürk, A. (2008).			Y	Y		
Marques, J. F. (2010).			Y	Y	Y	
Chapman, C. (1997).	Y					
Raftery, J. (2003)	Y					
Simister, S. J. (1994).	Y					
Shen, L. Y. (1997).	Y					
Todnem By, R. (2005)	Y					
Carnall, C. (2018)	Y					
Femi, A. F. (2014).				Y		
Ngozi, N. P., & Ifeoma, O. R. (2015).			Y	Y		
Moorman, C., Deshpande, R., & Zaltman, G. (1993).					Y	
Raina, R. (2010).				Y	Y	
Roberts, K. H., & O'reilly, C. A. (1974).			Y	Y		
Ruck, K., & Welch, M. (2012).			Y	Y	Y	
Watson, T. (2010). 2009/2010				Y		
White, C., Vanc, A., & Stafford, G. (2010)			Y	Y		
Quinn, D., & Hargie, O. (2004).				Y		
Al-Ghamdi, S. M., Roy, M. H., & Ahmed, Z. U. (2007).				Y		
Fischer, P. E., & Stocken, P. C. (2001)			Y		Y	
Downs, C. W., & Adrian, A. D. (2012).			Y	Y		
McKay, K., Kuntz, J. R., & Näswall, K. (2013).	Y		Y	Y		
Greenbaum, H. H., Clampitt, P., & Willihnganz, S. (1988).			Y	Y		
Hall, S. (2001).			Y			
Husain, Z. (2013)	Y		Y			
This Study	Y	Y	Y	Y	Y	Y

assessing reliable communication. Furthermore, the author has analyzed communication from the organization perspective and not between two groups or two departments. Reliability of the communication is defined in context to telecommunication systems and not specifically to the communication between employees in the organization. Researches have been conducted with respect to analyzing new risk and initiatives, but organizational DNA strand methodology has not been introduced so far.

2.3 Overview

In order to substantiate the past literature with the methodology proposed in Section three of the thesis, this literature review is divided into four subsections which are listed below:

- Communication Models
- Methods for Assessing Communication
- Attributes of Effective Communication
- Analyzing Risk of Implementing New Projects

2.4 Communication Models

Communication (from Latin "communis", meaning to share) is the activity of conveying information through the exchange of thoughts, messages, or information as by speech, visuals, signals, writing or behavior (Bateson:1955). Many authors have defined communication in different ways. Definitions of communication are defined in Table 2.2.

There are various models with the explanation of communication between different groups which includes sender or source, receiver, feedback, channel, message, noise, encoding, decoding, and context. All the models have a unique connection as well as a nature to come from somewhere [4].

Claude Shannon developed the first model of communication in 1940s as shown in Figure 2.2 [78]. Shannon has described communication as a linear and one-way process. The process

Table 2.2: Definitions of Communication

Author	Year	Definition
Bateson	1955	"Communication (from latin "communis", meaning to share) is the activity of conveying information through the exchange of thoughts, messages, or information as by speech, visuals, signals, writing or behavior."
Schramn	1965	"Communication is from a Latin word-communis, which means common or shared understanding.Communication, therefore, is a purposeful effect to establish commonness between a source and receiver."
Obilade	1989	"A process that involves the transmission of message from a sender to the receiver"
Soola	2000	"'Communication is the process by which any person or a group shares and impacts information with/to another person (or group) so that both people (or groups) clearly understood one another."
Folarin	2003	"Any means by which a thought is transferred from one person to another."
Baran	2004	"In its simplest form, however, communication is the transmission of a message from a source to a receiver... or the process of creating shared meaning." (Baran, 2004:4).
Obamiro	2008	"Communication refers to the exchange of information between a sender (source) and a receiver(destination) so that it is received, understood and leads to action."

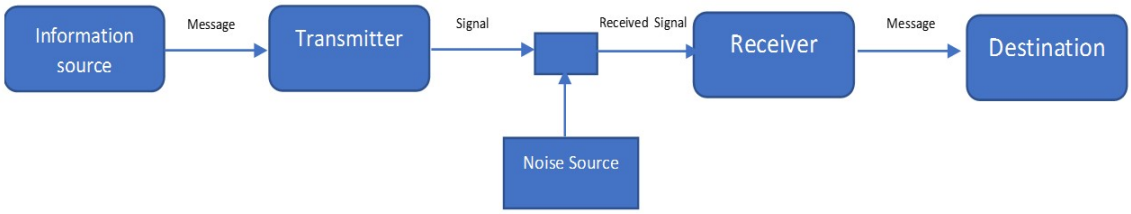


Figure 2.2: Shannon and Weaver Model of Communication [78]

starts with the information source creating a message or bundle of messages which needs to be sent. In the following step, the message is created into signals by a transmitter. A channel is used to send the signal to the receiver. The receiver recreates the message from the signal. The received message then reaches the destination. The signal can be disrupted by a various number of elements such as noise and interference. Interference occurs when there are many signals on the same channel at the same time. This means that sometimes sent and received messages are not identical. Johnson and Klare in their review of communication models said [47]

"Of all single contributions to the widespread interest in the models today, Shannon's is the most important. For the technical side of communication research, Shannon's mathematical were the stimulations to much of the later effort in this area".

DeFluer remodified the Shannon and Weaver Model [6]. In order to eradicate the linearity of the model, DeFluer added another set of components to indicate how the source get its feedback. The feedback gives source the possibility of adopting more effectively with the destination. In this way, the continuity of the process was established. This is explained in Figure 2.3.

Harold D. Lasswell, the American political scientist in 1948, came up with the single phrase to describe the process of communication [49]. This model is described in Figure 2.4. "Who" is described as someone who is communicating or sending, "Says what" is the message, "in which channel" is the medium, "To whom" is the receiver which is receiving the message and "with what effect" is the effect analysis. This formula was used by various academicians in several ways. It was frequently used to give structure to the discussions such as politics and speeches in different organizations. It was widely used in politics, but it was further criticized for not including the feedback element in it [50].

Osgood and Schramm developed a communication model which could be termed as a circular model as described in Figure 2.5 [15]. Shannon and Weaver discussed in the previous model, made a clear distinction between source and transmitter and between the receiver and destination. Two functions are fulfilled at the transmitting end and two at the receiving end. In this model, Osgood and Schramm did not add transmitter and receivers.

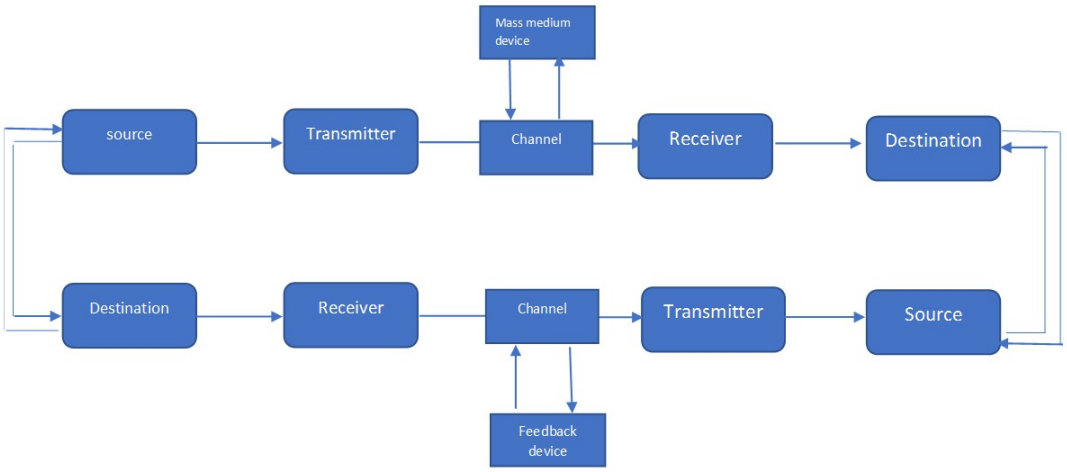


Figure 2.3: DeFluer Model of Communication [49]

Figure 2.4: Laswell Model of Communication [49]

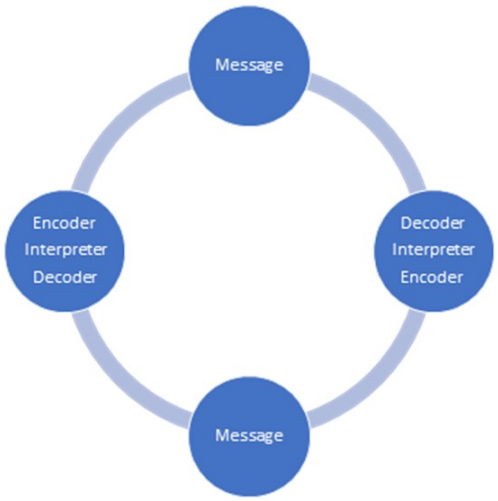


Figure 2.5: Osgood and Schramm Model of Communication [15]

They defined the two parties as equals, performing similar functions as equals, performing identical functions namely encoding, decoding and interpreting. The encoding function was similar to the transmitting, and the decoding function was similar to receiving.

2.5 Assessing Communication Effectiveness

2.5.1 Communication Audits

After an extensive eight year of study, Gerald Goldhaber developed an "ICA Audit" or the Communication Audit Survey. The survey consists of 122 questions categorized into eight major sections. The five questions used a scaling format with 1 (very little) to 5 (very great) scale. Employees were asked to indicate the amount of information; they receive now versus the amount of information, they need to receive [33]. In this way, there were able to analyze the communication gap between management and employees. Robert and O'Reilly (1973) developed a communication organization scale to compare communication practices across organizations [85]. The organization communication scale had 35 questions that can be disintegrated into 16 dimensions. Thirteen were related to communication.

Table 2.3: Comparison Between Four Audit Surveys

	CSQ	ICA	OCD2	OCS
Developer	Down & Hazen	Goldhaber & Krivonos	Wiio	Roberts & O' Rielly (
Number of Items	46	122	76	35
Dimension	10	8	12	16
Scaling Device	Satisfaction Level	Likert Scale	Satisfaction	Likert-Type
Open ended questions	Yes	Yes	Yes	Yes
Data Bank available	Yes	Yes	No	No
Average Completion time (minutes)	10-15	45-60	30-40	5-10
Year	1977	1977	1975	1973

The 7-point Likert scale was used in this study for the participants to respond. Below are some of the dimensions. Osmo Wiio, in 1975, developed an Organizational Communication Audit questionnaire to determine how well the communication system helps the organization convert its goal into desired results. This survey is a modified version of an earlier developed survey (LTT) developed by Wiio in 1972 [95]. This version has 76 items that are grouped into 12 categories. Table 2.3 illustrates a comparison between the four audit surveys. These four communication audits are widely used in assessing communication in the organization.

2.6 Communication Surveys

Hussain (2013) identified the role played by communication during a change in the business organization as essential for successful change management [45]. Kibe (2014) evaluated the impact of communication on the performance of organization. It was concluded that for any organization to be successful, an open communication environment must be created, where all the members of the organization can give feedback, ideas, and criticism. Neves and Eisenberger revealed that effective communication in the organization improves performance because it gives the impression that the organization cares about the contribution of employees. Elving shows the impact of communication in resistance to change [29]. He created a framework in which there were six propositions which had an impact on the

resistance to change. Clark (1992) propounded that communication is an essential factor for achieving high perceived service quality. Strong communication skills are required to make sure the client understands the investments done. Clients form a perception of quality based on nature, frequency, and effectiveness of communication.

2.6.1 Communication Structure

In a manufacturing organization, communication can be done in various hierarchical levels such as management, staff, and union. In order to assess communication, the structure of the communication needs to be understood. Figure 2.6 gives an overview about communication structure. The communication can have different patterns such as formal and informal.

2.6.2 Formal Communication

The formal communication is the official paths that are followed by the organization. They followed a developed procedure and line of authority [53].

Internal Communication

Internal communication occurs within the organization. It is done through various departments and employees in the organization. The communication is done through various methods such as emails, memos, letters and circulars [90]. It is divided into three categories such as:

a) Horizontal Communication

This communication is done along with a similar level or laterally in the organization. It is also called lateral communication. This communication is done between the employees who belong to the same hierarchy level. This communication has increased in the past few years due to the advent of email, and messages through various applications. This has enabled employees, based on different locations in the same organization, to communicate more effectively [81].

b) Vertical Communication

This communication involves two directions, such as "up to down" and from "down to up." Upward communication is done from the lower level staff to top management. This communication is mostly in the form of feedback or grievances on certain issues in the organization. Downward communication is done from top management to lower level staff. This communication is mostly through policies that are communicated by the senior officials in the organization to the employees or the procedures which need to be implemented [10].

External Communication

External communication is done with external stakeholders such as customers, suppliers, regulatory bodies and contractual organizations. This communication is mostly done through formal means and with defined procedures [87].

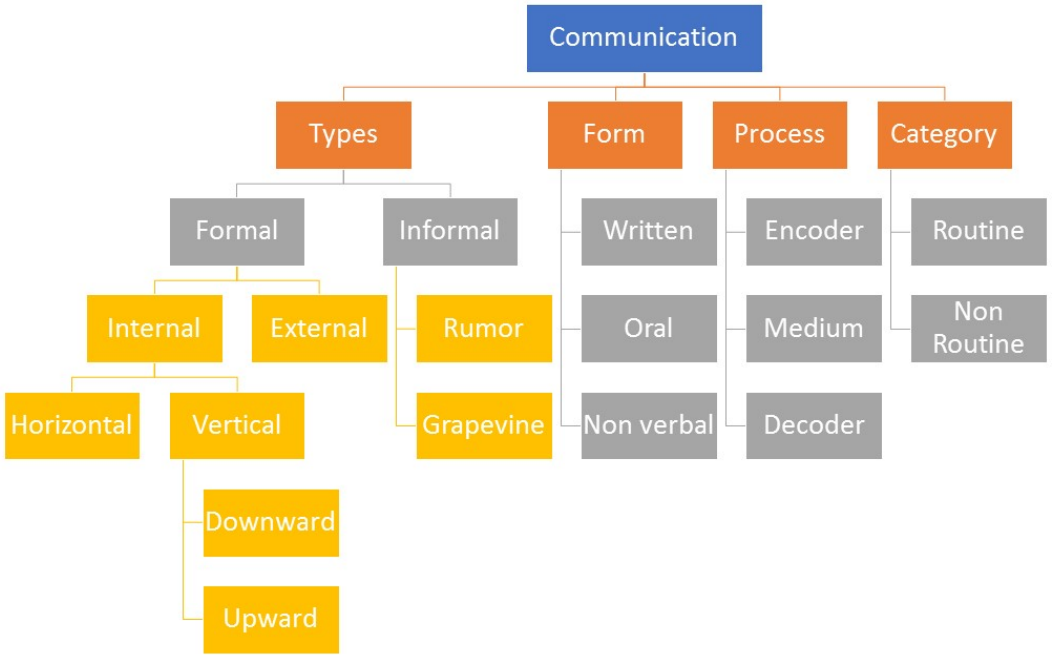


Figure 2.6: Overview of Communication Structure

2.6.3 Informal Communication

In a manufacturing organization, informal communication is done in all directions. This communication is done through various means. The most common way is spreading the rumors in the organization. This information is mostly unreliable. The other way of doing informal communication is called grapevine [93].

2.6.4 Forms of Communication

The major forms of communication used in the organization are as follow: [5]

- Written Communication
- Oral Communication
- Nonverbal Communication

a) Written Communication

This communication is done in a written form and can be part of a record. It can be done through various means such as letters, procedures, policies, manuals, books and numerous more [65].

b) Oral Communication

This communication is mostly done face-face. It is also considered the most effective form of communication. It is easier to get feedback in this communication. This communication is done through seminars, meetings, interviews, and many other ways [86].

c) Non-verbal Communication

This includes any other form besides written and oral communication. It includes gestures, facial expressions, body movements, and personal appearance to transmit information. There are several other ways that can be used for communicating the message such as behavior, physical distance, and tone of voice [3].

2.6.5 Communication Networks

The communication network is the pattern through which communication is circulated in the organization among the employees [80]. There are different ways in which communication flows through such as:

Chain Network

In the chain network, the information flows up and down in the organization hierarchy. As information has to pass different hierarchical levels, so it slows down the communication.

Circle Network

The circle network is a loop which allows the information to flow in a circular pattern. All the members can communicate with one another on either side. This is a very effective way of communicating as it can provide you with a greater opportunity for feedback.

Completed Connected network

This network allows all the employees to communicate with each other directly.

2.7 Attributes of Effective Communication

2.7.1 Responsibility

The attribute responsibility could be divided into two categories, such as content and context. Responsibility can be interpreted in various ways [84]. The responsible communication from the sender's perspective can be defined as carefully written in a way that it is not hurtful to either party. It is presented in a way to reduce the chances of misinterpretation. In order to be responsible, the receiver needs to protect confidential information. He needs to do a proper interpretation of a message with no unnecessary offense or confusion. With respect to the context of the communication, the delivery of the message is very important. Different messages required different formats, not every message needs to be sent from email or not every message needs a face-face discussion. Douglas further underscored the

importance of style and form in communicating the message [24]. Norton quoted "Style gives communication both form and function, with people gaining a sense of how literally or non-literally a message should be taken [64]." Wheatly, defined responsibility in communication with respect to context and content "Communicating commitment means being in the right place, at the right time, with the right message, for the right people, using the right words and actions, through the right processes using the right communication technology [91]." Wheatley also reiterated the responsibility of managing organizational communication "To say this never-ending challenge doesn't require ongoing management of people, process and technology is to totally misunderstand the task."

2.7.2 Conciseness

The communicating message should not be verbose; it should be communicated directly and expeditiously. The message should be delivered in a way that it is not digressing from the topic because this will affect the accuracy, understandability, and importance of the message [13]. Silverman (1981 p. 36) highlights the importance of conciseness " Only the succinct will survive. The Optimum Legibility Formula can reduce a written message to its basic elements such as recommendation, acknowledgment, request or authorization."

2.7.3 Professionalism

Poorly written messages could harm the writer's reputation. Even though you follow all the other major attributes such as timely, clarity, accuracy, pertinent, and credibility, it can still highlight an impression of mediocrity about the sender. For example, if a supervisor sends a badly spelled message, it could harm the reputation of the supervisor [82]. Kramer, emphasizes that professionalism is of particular importance in emotionally laden situations and further elaborate "Although there were many nuances to what professionalism entailed, its most essential elements were having control over one's emotion displays and maintaining a business like atmosphere [52]."

2.7.4 Sincerity

Employees with lower educational levels also have emotional intelligence and can judge whether the communication is real or not. Lack of sincerity in communication will decrease the trust and respect of receivers. Inman highlights the importance of sincerity in organizational communication by exclaiming "You must be honest and sincere with the employees. They must trust you before they can believe you [46]. Honest and open communication probably works best with superiors." Erturk conducted a study with 878 employees from public organizations in Turkey and found that "Increased participative management and managerial communication practices will lead to increased trust, and in turn, openness to change [30]."

William and Geller said that emphatic communicators "foster an improved sense of appreciation and respect, which in turn leads to increased levels of interpersonal trust, respect, honesty, and openness. The end result is enhanced organizational communication, high moral and better performance [97]."

2.7.5 Accuracy

Accuracy in communication is one of the most important communication skills. It encompasses how well a communicator creates verbal and nonverbal messages that are understood by others [62]. "Accuracy refers to an objectively quantifiable metrics by which the communication that is sent or received can be compared with some objective standard [72]." If your message is accurately delivered and received, the possibility of misunderstandings, misinterpretations and even poor decisions is radically reduced. There are several factors which could affect the accuracy of communication such as perception, assumption, cultural barriers, environmental factors, and stress [59]. On July 23, 1983, an Air Canada Flight famously ran out of fuel halfway through its Montreal to Edmonton Flight. At that time, Canada was converting to the metric system, and the resulting confusion with units caused the ground crew to use a conversion factor they mistakenly believed to be in kilograms when it was actually in pounds. So the crew member assumed that fuel was being filled in kilograms, but actually, it was not. Accuracy and clarity, are closely linked,

but there is a difference. Assume that you receive a clearly written communication about an upcoming assembly. The message had the following information. You are invited to attend a competition at 6:15 am. The competition is to be held in University of Tennessee Thompson-Boling Arena. The competition will have five judges. The session will be completed at 8 am. The written message could not have been more clear. Assume; however, the information is inaccurate, and the meeting is supposed to occur at 5:15 am. So people will arrive late and will miss the function [99].

2.7.6 Timely

Receivers must send the message on time when the information is meaningful. Moorman, state that timely communication fosters trust by assisting in resolving disputes and aligning perceptions and expectations [60]. By contacting stakeholders at regular intervals and providing them timely information, one can solve problems and develop trust [61]. Relevant, timely and reliable information always results in greater trust. The message is meaningless if it arrives too late for the receiver to act upon it. If you receive a message about a report on Thursday which is due on Wednesday, this will reduce the uncertainty but will not allow the task to be completed fully. Therefore, one must choose a way that will allow the message to be sent [94]. Timely communication is of utmost importance in the health care industry. Effective and timely communication between patients, physicians, nurses, pharmacists, and other health care professionals is vital to good health care. If a patient does not fully communicate the information about his medical situation on time, then the doctor won't be able to give his correct diagnosis. Communicating the message in a timely manner can be divided into three periods which are given below:

a) Before: What advance notice or message you can send to employees, so they are well acquainted with the upcoming demands and challenges?

b) During: What is occurring that may prompt employee question or requires further clarification?

c) After: What milestone have recently been accomplished that can be celebrated, learned from or built on for further success?

2.7.7 Clarity

A well known philosopher, Rene Descartes described clarity as, "Clear means evident and distinct from other things." This definition was further modified by logician C.S Pierce, when he proposed a formula called C-L-E-A-R. The rationale behind this formula can be summarized as

"C: Conciseness is crucial for clarity as too much information cannot be transferred in one knowledge. L: A logical structure is needed to have scaffold with which to build new knowledge. E: Explicit context is imperative in order to be able to re-contextualize and consequently reapply knowledge as one has to understand the context of insight or practices. R: Resonance is important as knowledge can be incorporated and finally applied most easily when one can relate new insights to already existing ones and when there is emotional connotation to them [36]."

2.7.8 Pertinent

The receiver of the message should view the message as relevant to him or her. Otherwise, messages that are irrelevant may begin to taint the values of those that are relevant. The message should not be time-consuming to read; it should be concise and to the point. It should avoid using excessive and needless words. The content of the message should be non-repetitive in nature. Sometimes managers communicate many messages for the reason of saving time. However, if all the messages are broadcast to all the receivers, eventually the value of one these messages will be reduced. It has been argued that receivers in the organization have the responsibility of reading all the messages, but most receivers only read messages which have some priority or are urgent to them [57].

2.7.9 Credibility

The credibility of the message is mostly dependent on the source as opposed to the method used for dissemination. Messages received must be believed, or they will be disregarded [69]. There are three elements of credibility: Competence, Trust, and Goodwill. "Competency is the set of behaviors or patterns that the incumbent needs to bring to a position in order

to perform its tasks and functions with competence [31]." Competence can be defined as the person sending and receiving the message has appropriate education, skills, training, values, experiences and so forth. Trust can also be defined in terms of "confidence" "assured reliance" and "assured anticipation". Expectation and predictability are the most common elements to many usages of trust [31]. Goodwill is the intent of a friendly behavior and sincere attitude towards others. It is about developing positive relations with your colleagues and genuinely caring about them. If the subordinates believe that their superior believes in evaluating them fairly, they will be productive to the organization.

2.7.10 Relationship

Human beings are naturally social creatures; they crave friendships and positive interactions just as they do food and water. So the better the relationship between people, the more productive the organization is going to be. The relationship in any organization can be based on the following features [36].

- Trust: This is the foundation of any relationship when you trust your colleagues and your superiors you form a bond which helps you to work and communicate more effectively. If you trust people with whom you are working, you can be open and honest in your thought and actions [63].

- Mutual Respect: If you will respect your colleagues, subordinates, and superiors and value their inputs, they will be more productive for an organization.

- Mindfulness: Mindfulness means taking responsibility for your words and actions. Standing behind your subordinates in times of difficulties and helping them to achieve their goals and target. Those employees who are mindful don't let their negativity impact the emotions of the people around them.

2.8 Analyzing Risk of Implementing New Projects

2.8.1 Risk Perspective

The literature behind project risk management has been developed for years now, but the common definition of risk is still debated by the community. Hilson 2002(a) has identified two ways to define risk. "The risk with a positive result is known as opportunity and risk with negative effects is known as threat [42]." Risk can also be described as uncertainty. "Uncertainty is defined as the unknown probability of occurrence that is derived from external factors, change of business, and ill-defined methods for project implementation [51]."

2.8.2 Risk Management

The foundations of risk management can be traced down to 1940 in the insurance industry of USA. "Chapman (1997) has defined risk management to facilitate better business and project results, providing insight, knowledge, and superior decision making capability [17]." "Green (2001) delineates risk management as a process of adopting opportunity management with a risk efficiency perspective and a defined goal of full amalgamation of opportunity management and risk management [37]."

2.8.3 Risk Management Framework

There are several standards which are developed over the years for risk management. The Australian and New Zealand standard were developed in 1995 and revised in 1999 and 2004. This standard is directly related to project risk management. The standard illustrates a general methodology to risk management which can be applied to all the areas. This framework is a five-step process. In the first step, the organization needs to identify the objectives and the stakeholders associated with the project. In the second step, the organization needs to identify the risk associated with the project. In the following steps, the organization needs to analyze, evaluate and treat the risk as illustrated in Figure 2.7 [22]. The MOR (Management of Risk) is a risk management guideline mainly for organizations

in public sectors. This methodology consists of the risk management process, management structure, roles, and responsibilities and checklists to support different phases of the project. The MOR guideline also takes into consideration other factors such as culture. Figure 2.8 presents the risk management process of MOR guideline.This standard is quite similar to AS/NZS standard; the only difference is that this standard also includes the option of ensuring the effectiveness of responses.

In addition to this, there are several, risk management guidelines such as IEC 6218 (2001), Project Risk Management guidelines, Office of Government Commerce (OGC), UK (2002) and Treasury Board of Canada (2001), Integrated Risk Management Framework. The different frameworks of risk management guidance do not differ so much from one another [22].

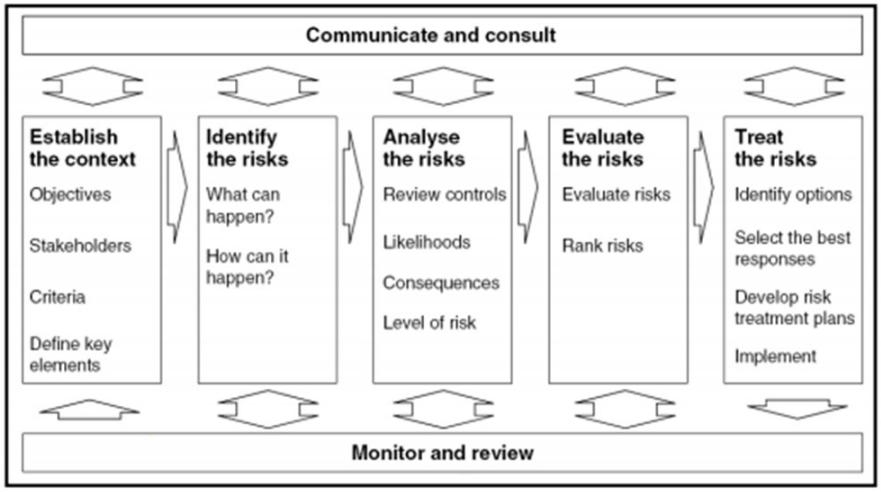


Figure 2.7: The AS/NZS Risk Management Process [22]

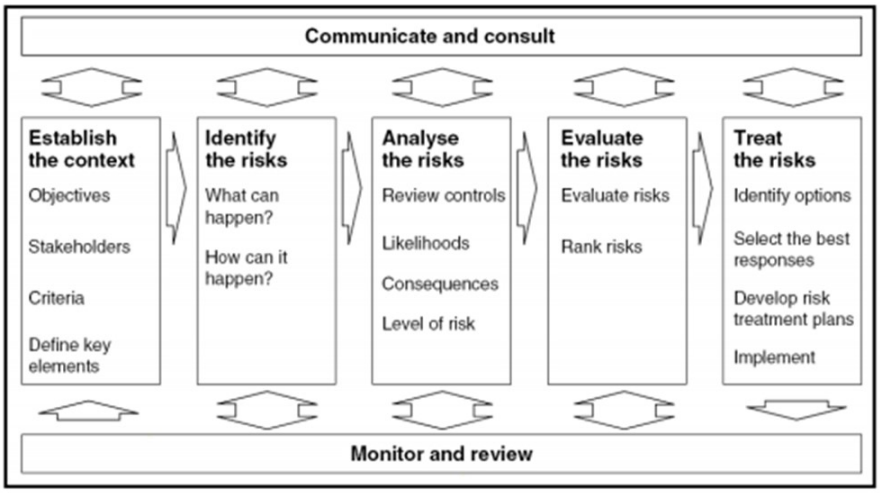


Figure 2.8: MOR Guideline [22]

Chapter 3

Methodology

3.1 Introduction

The methodology adopted in this chapter is illustrated in Figure 3.1. DNA strand has two main components; Function and Communication. In order to find the reliability of the DNA strand, the reliability of the function and communication needs to be calculated. This research was designed to calculate the reliability of communication between the two departments in the manufacturing organization. The process of communication is discussed in Section 3.2 which reveal details as to how communication is done between two groups. Then in the next step, a survey was designed by assigning one group as encoders and the other as decoders. Then a communication model was developed for assessing reliable communication. Analytical Hierarchical Process was used to prioritize communication attributes. Statistical Analysis such as T-test and Pearson Correlation were to identify the communication gaps from the survey. A matrix was developed for assessing reliable communication, and probability density function was used to identify the reliability of communication.

3.2 Communication Process

The basic communication between any two departments, any two organizations or any two people consist of the following three components (Deborah J, 2006):

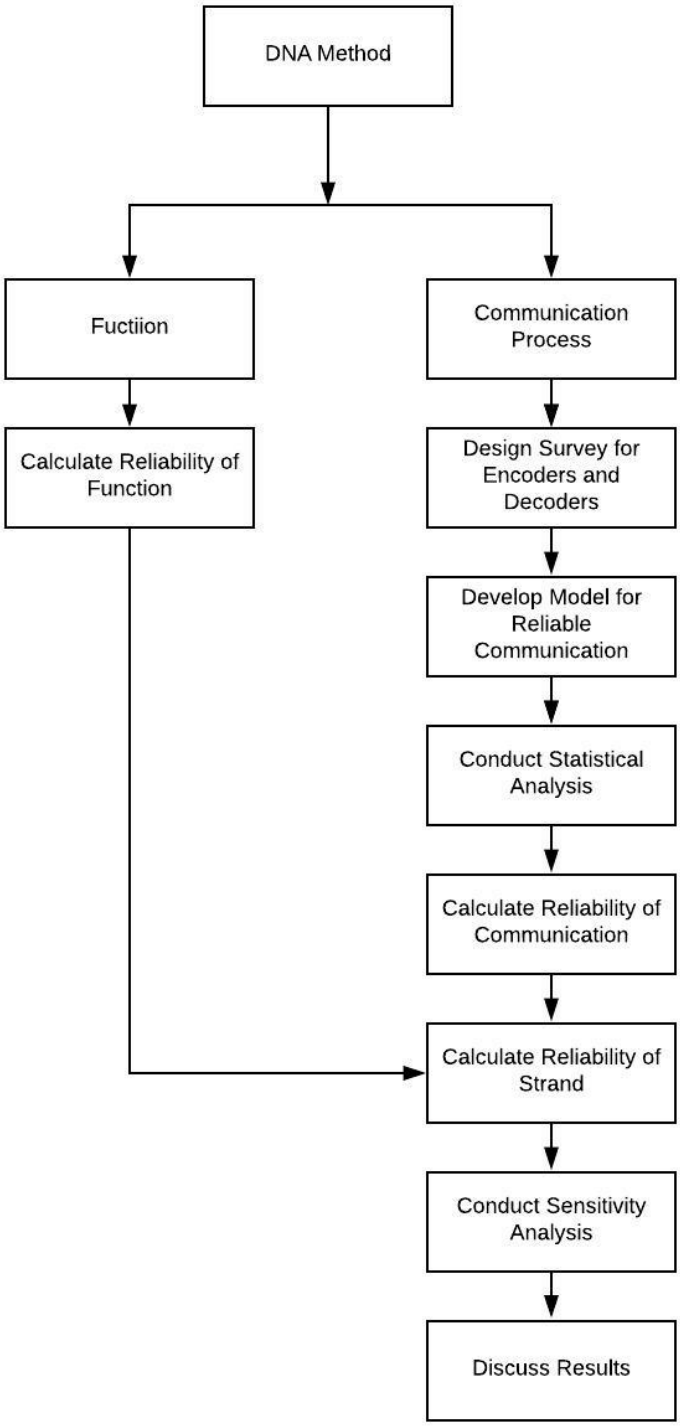


Figure 3.1: Methodology Steps

(a) Encoding

(b) Medium

(c) Decoding

3.2.1 Encoding

The process of communication begins with the source known as an encoder. The person sending the message is called an encoder. Encoding means that the message is converted into a language or a code that is easily understood by the receivers. Encoding encompasses the activities within a person that are involved in transforming inner thoughts, ideas, feelings and information into a message [9]. For effective coding, the sender needs to understand the audience and the background of the message. Encoding is a type of active sending of a message and technically refers to the process of constructing stimuli that may represent meaning [41]. The signal or message may not be transmitted. There are at least four factors which can increase the fidelity of encodings, such as communication skills, attitude, knowledge level, and socio-cultural system [98]. Encoding could be done through various means, such as verbal (words, signs, images, and video), nonverbal (body language, hand gestures, face expressions and written) [7]. For example, during an organizational meeting, you may hear another person comment and then decide to respond with a different opinion. In this situation, you would like to think about what you will say and then encode your message.

3.2.2 Medium

The medium can be means by which a message is conveyed [8]. The medium has the utmost importance during the communication process because it identifies the speed of communication. Different types of the medium can be used for communicating the message, such as oral communication (radio, television, phone, in person) or written communication (letters, emails, text messages and social media). Different scenarios require a different medium to be used for effective communication. For example, sometimes a verbal

communication is far more effective than written communication and then sometimes when you have to record the message, written communication is effective as compared to oral communication [55].

3.2.3 Decoding

The person who receives the message from the encoder is called the decoder. "Decoding is a process that occurs at the reception level where instincts, figures, and symbols are interpreted and translated into meaningful information[74]." Effective communication can only occur when the message is received and understood in an intended way. There is always a possibility that a decoder understands or interprets the message in a completely different way from what the encoder was trying to communicate. This is when "distortions" or "misunderstandings" arise from "lack of equivalence" between the two sides in a communicative exchange [9]. For example, when you are watching someone who makes a face, you decode that facial expression so that it has some meaning for you. When you read the sentence, you decode it so that it is comprehensible to you. In nearly all communicative interactions and particularly in the group and dyadic context, you take on the role of both encoder and decoder throughout the interaction.

3.3 Survey Design for Encoders and Decoders

This survey was designed for assessing communication between two departments. One department was considered as encoders and the other as decoders. It was based on interviews and a literature review. Several attributes were considered before finalizing the survey, only attributes which were pertinent to written communication and formal communication were considered. The final survey had a total of 42 questions. The questions fell into six categories: Accuracy, Clarity, Credibility, Timely, Pertinent and Relationship. The questions in the survey were intended to probe respondents perception on the procedural communication. The five-point Likert scale was used to measure the observation of the employees ranging from 1=rarely, 2=Little, 3=Sometimes, 4=Often, and 5= Always. The distribution of survey questions is listed in Table 3.1.

Table 3.1: Distribution of Survey Questions

Sections	No. of questions
Accuracy	**10**
Clarity	**7**
Timely	**5**
Credibility	**9**
Pertinent	**5**
Relationship	**5**

3.3.1 Interview

Closed, Fixed-ended interview method was used in this research as the target audience belonged to the manufacturing industry. This method enables the respondents to choose the answer from the same set of alternatives [19]. All of the interviewees were at the same level of understanding, so it was decided to use a closed, fixed-ended interview approach. The same set of questions were developed and asked from different employees in different departments. A Face-Face interview was conducted among employees in different departments. The open ended questions that were asked between the employees are listed below. The interview questions asked for developing survey are listed in Table 3.2.

3.3.2 Attributes Impacting Reliable Communication

While addressing communication in organizational settings, there are a number of specific criteria that have been listed as the driver for success. The following are five foundational criteria for effective communication; Accuracy, Timely, Clarity, Pertinent and Credibility [57], [99],[75]. Based on the interviews conducted from the professionals, the relationship was included as the sixth criteria. These criteria were taken into consideration for assessing how reliable the communication is between the two departments. The subfactors of these attributes, as described in Figure 3.2, were identified from the literature review.

Table 3.2: Interview Questions for Developing Survey

Question
Q-1) Is Reliability of communication an important subject to study?
Q-2) What do you understand by the reliability of communication?
Q-3) On what factors does the reliability of communication depends?
Q-4) Do we need to take account the whole communication in the organization or between departments?
Q-5) Is communication between the departments an issue in your organization?
Q-6) What are the issues you faced as an organization due to communication errors?
Q-7) How do you assess the communication between departments?
Q-8) Does communication play a key role in your organization results?
Q-9) Should we take into account the informal communication?
Q-10) Does relationship between the employees affect the communication between the department?
Q-11) Does the medium of communication important?
Q-12) Is credibility important while receiving information?
Q-13) How do you define credibility?
Q-14) Is training important for the employees to communicate?
Q-15) What role communication has in change management?
Q-16) Should we should structure questions or unstructured questions in the survey?
Q-17) Which kind of rating scale should be used?

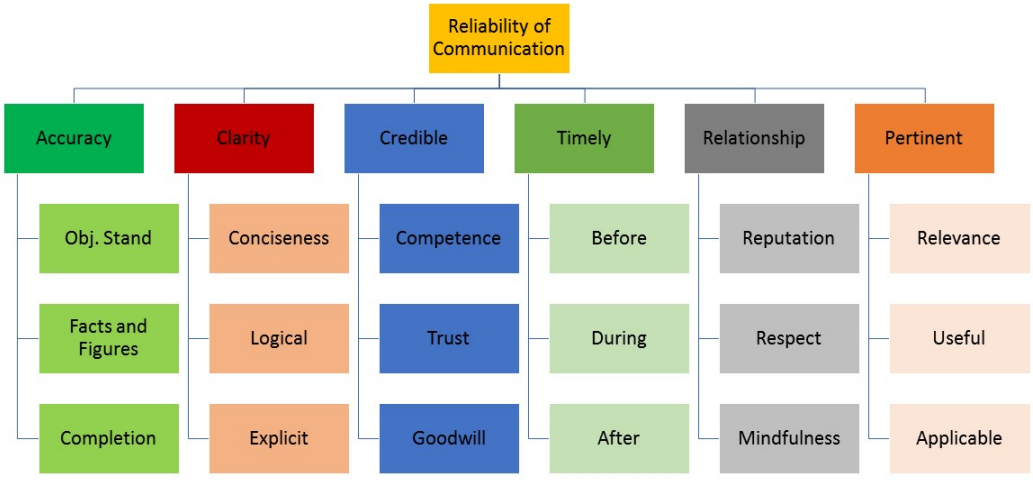


Figure 3.2: Subfactors of Attributes

a) Accuracy

"Accuracy refers to objectively quantifiable metrics by which the communication is sent and received. It can also be compared against some objective standard or what is often regarded to as ground truth [92]." Below are the following steps required for assessing the accuracy of communication:

Define objective standard

While assessing the accuracy of communication, first we need to define what is an objective standard. For example, when there is communication between the production and sales department about the production units, the objective standard is the specifications and the quantity details of the production units.

Identify facts and figures

Identify what facts and figures are in the communication between the sender and the receiver. For example, when there is a communication between the production and engineering departments regarding the production details, the figures of following items must be checked in a typical production order for assessing the accuracy of communication.

i) Production Unit Type ii) Production Unit Serial Number iii) Production Unit Quantity

b) Timely

The timely attribute can be assessed by identifying all the factors related to time which could hinder the effectiveness of communication. In any organization where communication takes place, information can be sent in the following three periods [94]:

Before actual communication

During an organizational meeting, there could be some information which needs to be sent earlier for any effective communication. For example, if there is a monthly factory operations meeting, previous meeting minutes must be sent on time in order to make the meeting effective.

During communication

During communication, all those things must be taken into consideration which could impede effective communication. For example, the meeting must start or end at the scheduled times.

After communication

After communication, there are certain items which need to be sent on time. For example, sending the meeting of minutes of the current meeting.

c) Clarity

The questions developed for the clarity attribute were based on three factors such as Clear, Logical, and Explicit as discussed in literature review [14]. For example, when there is communication between the Production and Sales Departments regarding the production details, sender and receiver must clearly understand the communication. This communication may include details such as product types are easily understood, the production order is readable, the format in which the production detail is sent is logical, and it is so methodologically explained that the receiver understands the emotional connotation as well.

d) Credibility

Credibility in any communication is based on three factors such as competence, trust, and goodwill. In order to assess whether the communication is credible, several factors associated with the sender and receiver must be considered [69]. For example, when there is communication between certain group members. The competence of sender or receiver is defined on education, training, experience, workload, and health of workers. So one must know how many years of experience is required to do the work, what is the health criterion and what trainings are required to do the particular job. Trust can be developed when two people work together, or you trust another person due to his previous background. Goodwill can be assessed in a manner in which the person is communicating the message.

e) Pertinent

The pertinency in the study was based on factors such as relevance, usefulness and applicability [27]. For example, if there is communication between the Production and Sales Departments regarding the production details, the Sales Department is only interested in receiving number of units produced on daily basis. Any information other than that such as the line losses will be considered as irrelevant.

f) Relationship

The impression behind developing questions for the relationship attribute was to address the concern of personal liking and disliking during communication. The relationship is based on trust, mutual respect, and mindfulness. There are several instances in the organizations where you don't respect or trust your subordinates due to several reasons. The reasons could be several such as personal liking or disliking, bad performance, work stress, and numerous others. This affects your relationship with the person and therefore impacts the efficacy of communication [63].

3.3.3 Communication Map

Communication map is the stepping stone for creating an efficient survey for assessing the reliable communication between encoder and decoder. Communication map helps to define the boundaries of communication between two groups or two departments. It actually defines a standard against which the communication between the two groups is assessed [28]. Communication map helps us to answer the following questions:

a) Which type of communication is being studied such as formal or informal?

b) Which form of communication such as written, oral and nonverbal?

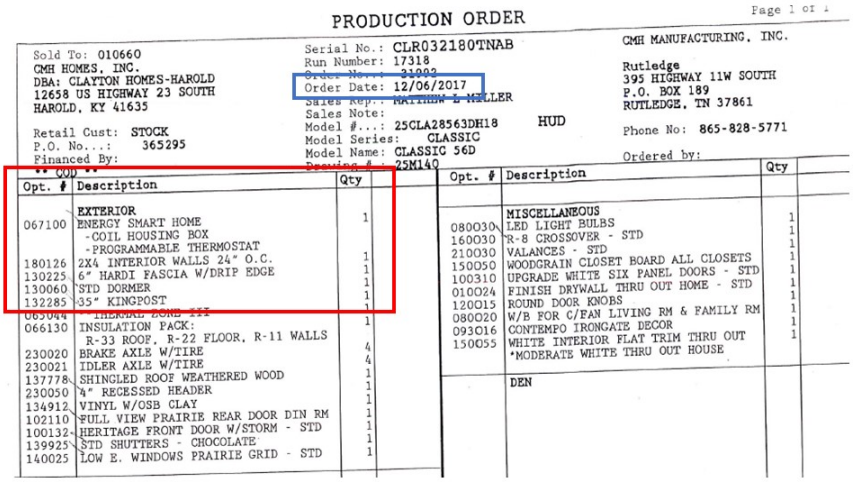
c) What are the categories such as routine and non-routine?

d) How many employees are in both groups?

e) Is it a procedural communication?

f) On what aspects, facts and figures are gauged?

g) What is the information required on time?



PRODUCTION ORDER

Page 1 of 1

Sold To: 010660
CMH HOMES, INC.
DBA: CLAYTON HOMES-HAROLD
12658 US HIGHWAY 23 SOUTH
HAROLD, KY 41635

Retail Cust: STOCK
P.O. No...: 365295
Financed By:
** COD **

Serial No.: CLR032180TNAB
Run Number: 17318
Order No...: 21092
Order Date: 12/06/2017
Sales Rep.: MATTHEW L MILLER
Sales Note:
Model #...: 25CLA28563DH18 HUD
Model Series: CLASSIC
Model Name: CLASSIC 56D
Drawing #.: 25M140

CMH MANUFACTURING, INC.
Rutledge
395 HIGHWAY 11W SOUTH
P.O. BOX 189
RUTLEDGE, TN 37861
Phone No: 865-828-5771
Ordered by:

Opt. #	Description	Qty
	EXTERIOR	
067100	ENERGY SMART HOME	1
	-COIL HOUSING BOX	
	-PROGRAMMABLE THERMOSTAT	
180126	2X4 INTERIOR WALLS 24" O.C.	1
130225	6" HARDI FASCIA W/DRIP EDGE	1
130060	STD DORMER	1
132285	35" KINGPOST	1
063044	[illegible]	1
066130	INSULATION PACK:	1
	R-33 ROOF, R-22 FLOOR, R-11 WALLS	
230020	BRAKE AXLE W/TIRE	4
230021	IDLER AXLE W/TIRE	4
137778	SHINGLED ROOF WEATHERED WOOD	1
230050	4" RECESSED HEADER	1
134912	VINYL W/OSB CLAY	1
102110	FULL VIEW PRAIRIE REAR DOOR DIN RM	1
100132	HERITAGE FRONT DOOR W/STORM - STD	1
139925	STD SHUTTERS - CHOCOLATE	1
140025	LOW E. WINDOWS PRAIRIE GRID - STD	1

Opt. #	Description	Qty
	MISCELLANEOUS	
080030	LED LIGHT BULBS	1
160030	R-8 CROSSOVER - STD	1
210030	VALANCES - STD	1
150050	WOODGRAIN CLOSET BOARD ALL CLOSETS	1
100310	UPGRADE WHITE SIX PANEL DOORS - STD	1
010024	FINISH DRYWALL THRU OUT HOME - STD	1
120015	ROUND DOOR KNOBS	1
080020	W/B FOR C/FAN LIVING RM & FAMILY RM	1
093016	CONTEMPO IRONGATE DECOR	1
150055	WHITE INTERIOR FLAT TRIM THRU OUT	1
	*MODERATE WHITE THRU OUT HOUSE	
	DEN	

Figure 3.3: Example for Developing Standard

h) What is the information which both sender and receiver need to understand clearly?

i) What is competency criteria such as years of experience for assessing the credibility?

j) What is exact information required by the receiver to check the pertinence?

Figure 3.3 is an example of a production order used in the manufacturing industry and how this information can be used to assess the attributes of reliable communication. The details are listed below.

Accuracy: As highlighted in red, description, qty, opt. can be used for checking accuracy.

Timely: As highlighted in blue, order date can be used for checking timeliness.

Clarity: The production order is in authorized format and easily readable. Employees can be interviewed about how clearly they understand the production order.

Pertinence: Employees can be interviewed if there is any irrelevant information in production order.

Credibility: Sales representative competency can be checked for credibility.

3.3.4 Survey Questions

There are different types of questions that can be used to collect information. The first is called the structured or fixed question and the second is called the non-structured question. Structured questions are a closed set of questions that offer respondents with definite choices. These questions make data collection and analysis much simpler, and it takes less time to answer. Structured questions are best applied when you have a thorough understanding of the subject and when you are not trying to capture new ideas and initiatives. Non-structured questions are the open-ended questions. These are the questions where respondents do not have any fixed answer to choose. They are simply asked to write their response to the question. Structure question technique was used to develop the question for the survey [21].

3.3.5 Rating Scale

A rating scale is designed to elaborate information about a quantitative or a qualitative attribute. There are different types of rating scales, such as the numeric rating scale, graphic rating scale, and descriptive graphic rating scale [16]. In this research, we have used the numeric rating scale known as the Likert Scale. Likert Scale ranges from a group of categories:

a) Least to Most

b) Agree or disagree

c) Approve or disapprove

d) True or False

The questions designed in this research are based on the frequency of occurrence. So the rating scale adapted for this research was least to most. The rating scale was designed on five points such as rarely, little, sometimes, often and always. The description of the rating is given below:

Rarely: Means that the occurrence of event happens on a yearly basis.

Little: Means that the occurrence of event happens on a bi-annual basis.

Sometimes: Means that the occurrence of an event happens on a weekly basis.

Often: Means that the occurrence of the event happens on a daily basis.

Always: Means that the occurrence of the event happens every time.

3.4 Model for Assessing Reliable Communication

Based on the interviews and the literature research, below (Figure 3.4) is the model for assessing the reliability of communication. A1 (Accuracy), A2 (Clarity), A3 (Credibility), A4 (Timely), A5 (Pertinent), A6 (Relationship) are the attributes which will be used to identify if the communication is reliable between the two groups. The subfactors of these attributes are explained in Section 3.3.2.

3.5 Prioritizing Communication attributes

3.5.1 AHP

Analytical Hierarchical Process (AHP) will be used to prioritize the communication attributes. AHP is multi-criteria decision making technique that allows people to make decisions by organizing the judgments in a hierarchical structure [77]. AHP uses a survey based approach to reach a goal by assigning an alternative through the comparison of criteria affecting the decision. AHP is conducted using the following approach [88]:

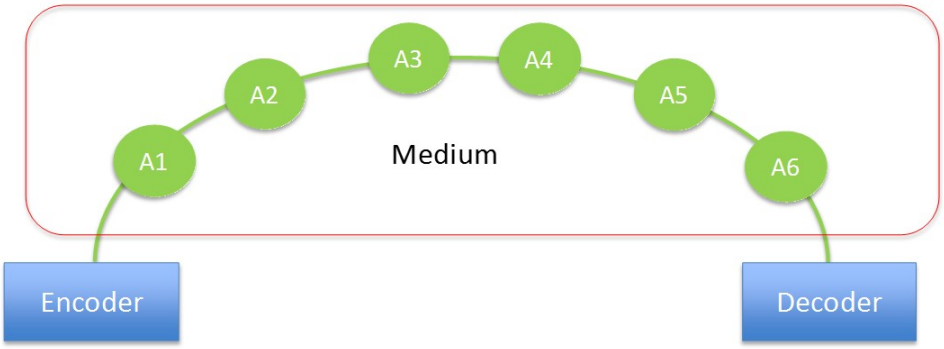


Figure 3.4: Model for assessing Reliable Communication

- Determine the goal of the problem.
- Determine the criteria impacting the goal of problem.
- Determine the available alternatives to reach the goal.
- Conduct a pairwise comparison between criteria-criteria and, alternatives-alternatives for every criterion.
- Weight the priorities obtained using the pairwise comparison matrices.
- Rank the alternatives to satisfy the goal.

Saaty's scale of relative importance was used to conduct the pairwise comparison as shown in Figure 3.5. This scale allows the respondent to rank the relative importance between 1 to 9. The pairwise comparison matrix is represented as

$$A_{n*n} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix}$$

where a_{ij}, $(\forall i, j \in n)$ represent the degree of importance of i^{th} element in comparison with j^{th} element. The value of n is dependent upon the type of the matrix being constructed.

3.5.2 Consistency

The numeric values of AHP are obtained from the subjective judgment of respondents. Hence, inconsistencies are bound to occur. For this reason, AHP calculates a consistency ratio (CR), comparing the consistency index (CI) of the matrix used for research versus the consistency index of a random like matrix (RI). (RI) is selected as random index value. [76]. Below is the equation of consistency index:

Importance Intensity	Definition
1	Equal importance
3	Moderate importance of one over another
5	Strong importance of one over another
7	Very strong importance of one over another
9	Extreme importance of one over another
2,4,6,8	Intermediate values
Reciprocals	Reciprocals for inverse comparison

Figure 3.5: Saaty Scale for Pairwise Comparison

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

where λ is the maximum eigenvalue of the pairwise comparison matrix, and n is the number of alternatives considered. The Consistency Ratio is defined as:

$$CR = \frac{CI}{RI}$$

3.5.3 Aggregation of Group Responses

The geometric mean method was used to aggregate the group responses. "The geometric average of two numbers is the middle term in a geometric progression of three terms including the two given numbers [32]." The geometric mean is also defined as the nth root of the product of n numbers, i.e., for a set of numbers x_1, x_2,...x_n, the geometric mean is defined as:

$$(\prod_{i=1}^{n}(\sqrt[n]{x_i})) = (\sqrt[n]{x_1 * x_2 * x_3 ... x_n}) \tag{3.1}$$

3.6 Reliability of Data

Cronbach's alpha was used to assess the consistency of the data. The higher the value of Cronbach's alpha, the more reliable the data would be. The value of 0.7 is an acceptable reliability coefficient. However sometimes smaller values are also acceptable [23].

3.7 Statistical Significance

An adequate number of respondents is required to validate your research. A sufficient number of a sample size in any group is needed to have confidence that the survey is an actual representation of the population. While calculating the sample size, one needs to take into account the values of confidence level and confidence interval. The confidence interval is the margin of error and confidence level tells how certain is the result. Krejice and Morgan formula was used to calculate the sample size. The formula to calculate the sample size is given below.

$$Sample\ Size = \frac{x^2 N p(1-p)}{e^2(N-1) + x^2 p(1-p)} \tag{3.2}$$

Where N=Population size.

n= sample size (decimal).

e= acceptable sampling error.

x^2= chi-square for confidence interval 95

p= proportion of population.

3.8 T-test

There are different kinds of t-test, a one sample location test, and a two sample location test. One sample location test is whether the mean of the sample has a specific value in the null hypothesis. A two sample location t-test is used to check whether the means of two population are equal or not. Assuming that the variance of the two means is equal. Then these type of tests are called Student t-test. If the variation of two samples is not equal, then the t-test is called Welch t-test [39].

3.8.1 Independent T-test

The independent sample t-test evaluates the difference of mean between the two unrelated groups. It identifies whether the mean of one group is different from the mean of the other group. Two variables must be used in independent sample T-test: Grouping variable and test variable. The grouping variable splits group into two different categories such as male and female while the test variable delineates each group on quantitative dimension.

3.8.2 Hypothesis for Independent Sample T-test

Null Hypothesis

$$H_o = \mu_1 = \mu_2$$

$$\mu_1 = Mean\ of\ the\ first\ group$$

$$\mu_2 = Mean\ of\ the\ second\ group$$

Alternative (Nondirectional) Hypothesis

$$H_a = \mu_1 \neq \mu_2$$

$$\mu_1 = Mean\ of\ the\ first\ group$$

$$\mu_2 = Mean\ of\ the\ second\ group$$

Alternative (Directional) Hypothesis

$$H_a = \mu_1 < \mu_2$$

$$H_a = \mu_1 > \mu_2$$

$$\mu_1 = \textit{Mean of the first group}$$

$$\mu_2 = \textit{Mean of the second group}$$

3.8.3 Assumptions for Independent Sample T-test

- The data of the groups is independent of each other (Scores of one group are different from the scores of another group). This is known as the assumption of independence [43].
- The variable of the t-test is normally distributed within each of the groups . This is commonly known as the assumption of normality [43].
- The variances of the test (dependent) variable in two groups are equal. This is called as the assumption of homogeneity of variance [43].

3.9 Pearson Correlation

Pearson Correlation coefficient is the measure of the linear correlation between two variables."Pearson Correlation coefficient is a measure of the strength of association between the two variables. It has the value between +1 and -1, where 1 is the total positive linear correlation, 0 is the no linear correlation and -1 is a total negative linear correlation [12]." In this research, the correlation between different attributes such as Accuracy, Clarity, Credibility, Timely and Relationship was identified.

3.10 Reliability of Communication

Reliability of Communication is defined as the probability that encoding and decoding event occur effectively. Both encoding and decoding event are independent events and are in the

series structure. The survey of encoder and decoder were designed in a way that medium was included in it. Hence reliability of communication is

$$R_c = P(E) * P(D) \tag{3.3}$$

The probability of encoding event and the decoding event occurring effectively is calculated by probability density function. The probability density function is a function, whose value at any given sample in the sample space can be interpreted as providing a relative likelihood that the value of the random variable would equal that sample. The Equation for calculating the PDF is

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} exp(\frac{-(x-\mu)^2}{2\sigma^2}), \sigma > 0 \tag{3.4}$$

Where

μ= mean of the sample

σ= Standard Deviation x

3.11 Matrix for Reliable Communication

If both the encoder and decoders are on the same level of perception that the communication between them is effective, then the communication is reliable, or if both the decoder and encoder are on the different level of perception or of the view that the communication is not effective, then the communication is unreliable. The threshold value in this research is defined as 3.5. Figure 3.6 explains the different scenarios on which the communication would be reliable and unreliable. Figure 3.7 summarizes the purpose of using different statistical techniques in this research.

Encoder	Decoder	Reliability of Communication
$1 \leq$ Mean ≤ 3.5	$1 \leq$ Mean ≤ 3.5	Unreliable
$1 \leq$ Mean ≤ 3.5	$3.5 \leq$ Mean ≤ 5	Unreliable
$3.5 <$ Mean ≤ 5	$3.5 <$ Mean ≤ 5	Reliable
$3.5 <$ Mean ≤ 5	$1 \leq$ Mean ≤ 3.5	Unreliable

Figure 3.6: Reliable Communication Matrix

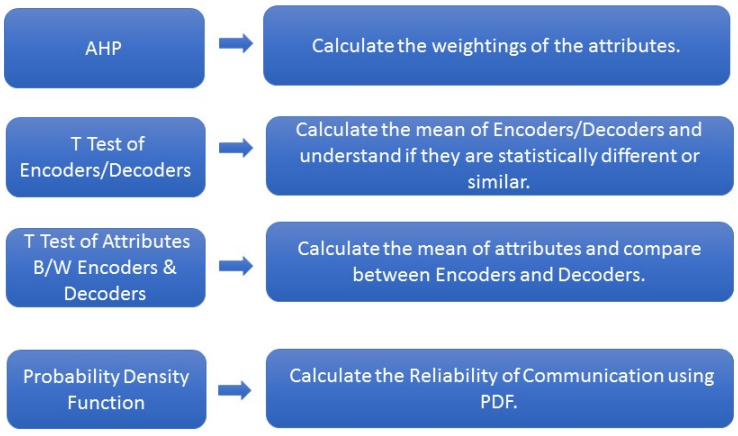


Figure 3.7: Description of Statistical Analysis

Chapter 4

Case Study and Results

4.1 Introduction

This chapter discusses the case study and results of the research. Clayton Homes, Rutledge was used as a case study to assess the reliability of communication between the departments. Employees in different organizations were asked to fill the AHP survey for prioritizing the attributes of communication. Clayton Homes is the largest builder of manufactured housing and modular homes in the United States. Clayton Homes Rutledge has the following departments: HR, Production, Engineering, Purchase and Quality. The maximum number of employees are recruited in the Production Department. Clayton Homes manufactures different types of houses. The Sales Department with the help of Purchase and Engineering Department is responsible for making production orders and ensuring that correct material and drawings are available for the Production Department. The Production Department is responsible for manufacturing the houses in liaison with the quality department. To study the communication between the departments was a challenge. As a lot of communication happens every day between all the departments, it was decided to analyze one procedural communication. Sales and Engineering Departments were considered as one group sending the information, and the Production Department was considered as one group receiving the information. Figure 4.1 illustrates the topics which were the focus of this Chapter.

Figure 4.1: Main Topics of this Chapter

The reliability of communication was calculated between the Sales/Engineering Department and Production Department of Clayton Homes. Section 4.2 explains the communication map on which this research was done. Following results were reported in this chapter:

- AHP Pairwise Comparison Matrix
- Data Reliability of Attributes
- Data Reliability of Survey
- Independent t-test of the Encoders and Decoders.
- Independent t-test of Attributes between Encoders and Decoders.
- Correlation between Attributes
- Sensitivity Analysis
- Reliability of a Strand

4.2 Communication Map

An extensive study was done to develop a communication map between the encoders and decoders. Figure 4.2 displays the identification of encoders and decoders. Figure 4.3 displays the communication done between the encoders and decoders. The questions identified in Section 3.10 are answered in the Table 4.1.

4.3 Data Collection

Reliability of Communication Survey was given to Clayton Homes employees, and AHP Survey was given to employees from different organizations. They were given two weeks to complete the survey. The survey was given in the paper form and was collected manually from the employees. A total of 36 responses were collected from the Clayton Homes and 10 responses for AHP.

4.4 Data Coding

Reliability of Communication Survey was conducted using printed data collection templates. The survey responses were manually entered into an MS-Excel Workbook. Column A2-A41 had the categories defined such as encoders and decoders. Column B2-B41 had the respondents identification. Column M1-S1 had the responses of Accuracy. Columns T1-AB1 has the responses of Clarity. Column AC1-AG1 has the responses of Timely. Columns AH1-AK1 has the responses of Credibility. Column AM1-AQ1 has the responses of Pertinent. Row AM1-AQ1 has the responses of Relationship. The excel sheet was downloaded in the SPSS for statistical analysis. The AHP survey was also conducted using printed data collection templates. The pairwise comparison matrix after aggregating the responses was developed in the MS-excel Workbook from C3-C8 to H3-H8. Column P3-P8 had the priority vector.

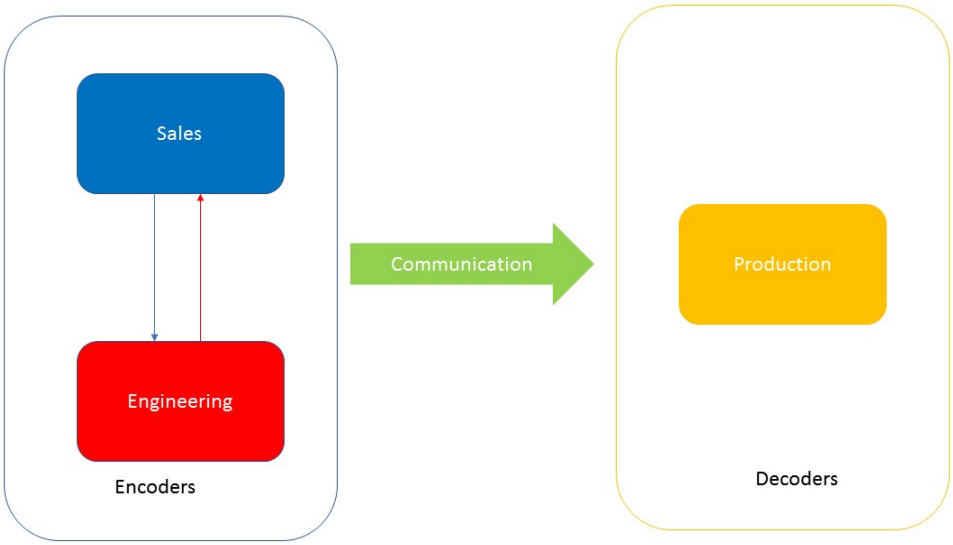


Figure 4.2: Identifying Encoders/Decoders

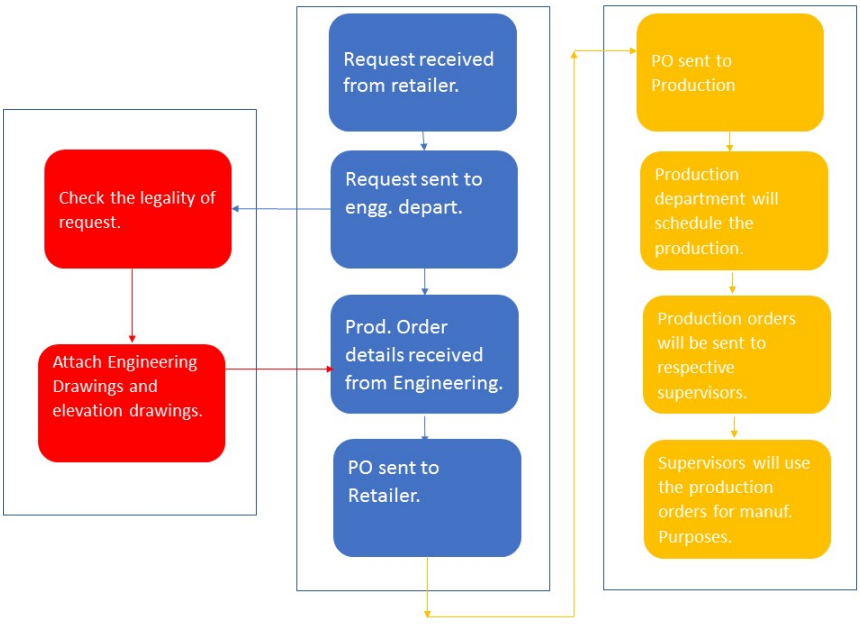


Figure 4.3: Communication between Encoders and Decoders

Table 4.1: Understanding Communication between Encoders and Decoders

Question	Answers
a)Which type of Communication is being studied such as formal or informal?	Formal
b) Which form of Communication such as written, oral and nonverbal?	Written
c) What are the categories such as routine and non-routine	Routine
d) How many employees are in both the groups?	30
e) Is it a procedural communication?	Procedural Communication
f) On what aspects, facts and figures accuracy is gauge?	Production Units, Type, Description and Order#
g) What is the information which is required on time?	Initiation Date Order No. Offline Date
h) What is the information which both sender and receiver needs to clearly understand	Production Order
i) What is the competency criteria such as years of experience for sender and receiver?	1 Year
j) What is the exact information required by the receiver to check the pertinence?	Production Order, Engineering Drawings and Details.

4.4.1 Blank Responses

Responses having more than 10% of the missing values were considered as blank responses. Excel command was used to calculate the missing value of each person. The following steps were executed to remove the blank dataset.

- Entering all the data in the excel sheet.
- Counting all the missing data.
- Deleting the respondent with more than 10% of the missing value.

4.4.2 UnEngaged Responses

It is necessary to remove the engaged responses from the study as it alters the results. The responses were collected manually. Encoders were given 16 survey templates and decoders were given 20 survey templates respectively. There was no engaged response found in the survey. AHP Survey was given to ten respondents and similarly no engaged response was found.

4.4.3 Calculating Sample Size

Krejice and Morgan formula was used to calculate the sample size of Encoders and Decoders. The margin of error is assumed as 3%, proportion of population is assumed as 0.5 and Chi-square for confidence interval of 95% is 3.841. The sample size for Encoders was 15.7 and for Decoders was 19.8. A criteria was developed to select the respondents of AHP. Ten respondents were selected to complete the AHP Survey. Small sample size is accepted in AHP [83] [18].

4.5 AHP

AHP was used to prioritize communication attributes. Ten survey responses were collected from different organizations. Figure 4.4 displays the hierarchal structure for prioritizing communication attributes. To extract the relative importance of alternatives, the following steps were performed:

Step 1: Geometric mean was used to aggregate different responses received from the survey. For example, while assessing the importance between accuracy and clarity, all the responses such as (7,7,5,5,5,7,7,7,5) were multiplied and the 10th root was taken as there were 10 respondents. In this way, a pairwise comparison matrix was formed as shown in Table 4.2. Table 4.3 will be used to evaluate consistency.

Step 2: The next step is normalizing the matrix, this is done by totaling the numbers in each column and then dividing each entry in the column by the column sum. Table 4.4 displays the matrix with the sum of the columns.

Step 3: In this step, the average of each row is taken to formulate the priority vector as shown in Table 4.5. As there is only one criterion, hence this priority vector will be considered as the weights of attributes.

Step 4: To evaluate the consistency of the pairwise comparison matrix, the following steps were taken:

- Multiply each column of the pairwise comparison matrix by the corresponding weight.
- Divide the sum of the row entries by the corresponding weight and compute the average.

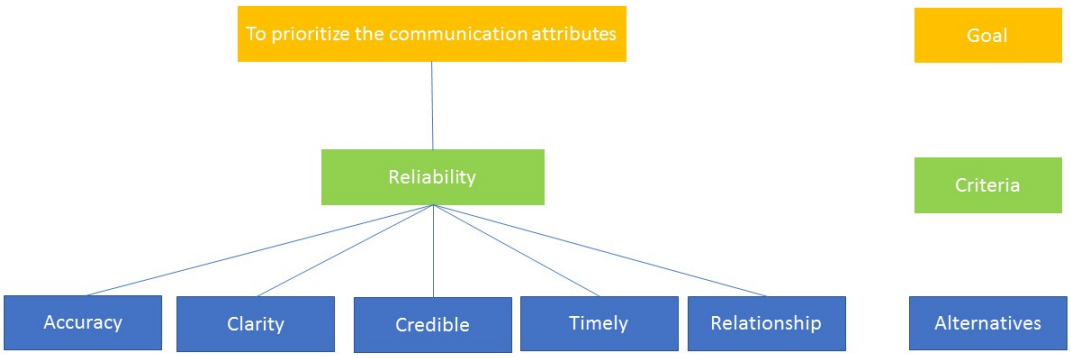


Figure 4.4: Hierarchal Structure

Table 4.2: Pairwise Comparison Matrix

Alternative	Accuracy	Clarity	Credibility	Timely	Relationship
Accuracy	1	5.036594904	3.523856829	3.61650178	4.075965548
Clarity	0.198546839	1	0.356244667	0.455655378	2.828746335
Credibility	0.283779974	2.807059567	1	3.133024234	2.285454742
Timely	0.276510302	2.194641057	0.319180423	1	3.441816804
Relationship	0.245340641	0.333333333	0.437549684	0.290544226	1

Table 4.3: Random Index Table

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 4.4: Pairwise comparison matrix with the sum of columns

Alternative	Accuracy	Clarity	Credibility	Timely	Relationship
Accuracy	1	5.036594904	3.523856829	3.61650178	4.075965548
Clarity	0.198546839	1	0.356244667	0.455655378	2.828746335
Credibility	0.283779974	2.807059567	1	3.133024234	2.285454742
Timely	0.276510302	2.194641057	0.319180423	1	3.441816804
Relationship	0.245340641	0.333333333	0.437549684	0.290544226	1
Sum	2.004177757	11.37162886	5.636831603	8.495725617	13.63198343

Table 4.5: Pairwise Comparison Matrix with Priority Vector

Alternative	Accuracy	Clarity	Credibility	Timely	Relationship	Priority Vector
Accuracy	0.498957738	0.442908836	0.625148501	0.425684861	0.299000184	0.458340024
Clarity	0.099066482	0.08793815	0.063199452	0.053633486	0.207508053	0.102269124
Credibility	0.141594214	0.246847624	0.177404626	0.368776532	0.167653867	0.220455373
Timely	0.137966955	0.192992674	0.056624083	0.11770625	0.252481	0.151554192
Relationship	0.122414611	0.029312717	0.077623338	0.034198871	0.073356897	0.067381287

- This average is considered to be λ_{max}.

$$CI = \frac{\lambda_{max} - n}{n - 1}$$
$$CI = \frac{5.43 - 5}{5 - 1}$$
$$CI = 0.106$$

where RI=1.12 was selected from random index Table 4.3. The consistency ratio

$$CR = \frac{CI}{RI}$$
$$CR = \frac{0.106}{1.12}$$
$$CR = 0.094$$

The same method as described above was applied to find the weighting of factors affecting respective attributes. Figure 4.5 is the hierarchical structure of the credibility attribute. Table 4.6 is the pairwise comparison matrix with the priority vector for the credibility attribute. Figure 4.6 is a tree diagram which displays the weighted average of all the attributes and their factors. These weights can be used by an organization to assess the importance of these attributes with respect to each other.

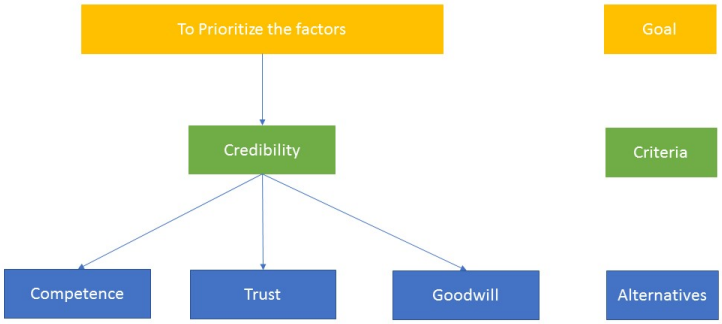


Figure 4.5: Hierarchal Structure of Attribute Credibility

Table 4.6: Pairwise Comparison Matrix for Credibility Attribute

Credibility	Competence	Trust	Goodwill	Priority Vector
Competence	0.737704918	0.818181818	0.642857143	0.732914626
Trust	0.098360656	0.109090909	0.214285714	0.140579093
Goodwill	0.163934426	0.072727273	0.142857143	0.126506281

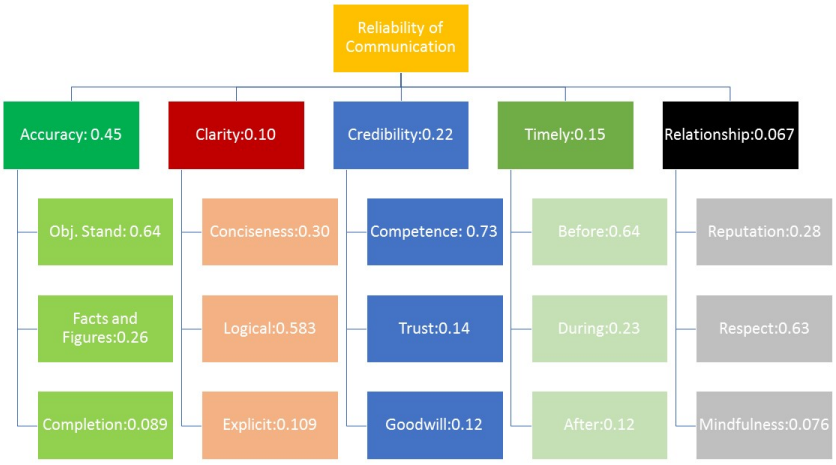


Figure 4.6: Tree Diagram of Attributes and Factors

4.6 Data Reliability of Attributes

The participants in the Reliability of Communication Survey were the employees of Clayton Homes who belonged to the production, sales and engineering department. Blank and unengaged responses were deleted from the data. The data was also treated for the missing value. The final data consisted of 16 responses from the encoder and 20 responses from the decoder. As the Sales and Engineering Department have a smaller number of employees, hence this organization was not able to arrange 20 employees for encoding survey. Most people who reported for the encoding survey were from management. The decoding survey was filled by the production employees which included management, supervisors, and workers. The Cronbach's alpha was used to analyze the validity of data. The Cronbach's alpha was calculated to know the relevance of the questions used in the survey. Mostly all the attributes were within the acceptable ranges except the pertinent attribute. As shown in the Table 4.7, the Cronbach's alpha value of accuracy was **0.871**, **0.879** for clarity, **0.825** for credibility, **0.791** for timely, **0.520** for pertinency and **0.939** for relationship.

4.6.1 Why Omitting an Attribute?

The acceptable value of Cronbach's alpha is above 0.7 as discussed in Section 3. The Cronbach's alpha of pertinency was 0.520 which is considered unacceptable as shown in Figure 4.7. SPSS software was used to analyze the validity of data which showed questions used in the survey were not consistent. The questions were also checked separately to find out if we could delete any questions or will that make the Cronbach's alpha value increase? No significant difference was identified after analyzing all the questions. The details

Table 4.7: Data Reliability of Attributes

Attributes	Cronbach Alpha
Accuracy	0.871
Clarity	0.879
Credibility	0.825
Timely	0.791
Pertinency	0.520
Relationship	0.939

are given in the Figure 4.8. Hence, it was decided not to use the attribute "pertinency" for future research analysis, such as correlation analysis, as it's Cronbach alpha value was less than 0.7.

4.7 Data Reliability of Survey

Data reliability of the overall surveys were analyzed using all the attributes. All 41 questions were used for analyzing the consistency of the survey. Both the surveys were used simultaneously in calculating the validity of the data. The Cronbach Alpha value of the overall survey was 0.919, which showed excellent consistency and design of the questions. Even though the value of the pertinency was 0.52, the overall value of Cronbach's alpha was very high. Hence, it was decided to report the value of Cronbach's alpha containing all the attributes. The resulting output from the SPSS is given in Figure 4.9.

Case Processing Summary

		N	%
Cases	Valid	36	90.0
	Excluded[a]	4	10.0
	Total	40	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.520	5

Figure 4.7: SPSS Output for Pertinency

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
P1	14.97	2.771	.326	.441
P2	15.08	3.107	.116	.576
P3	15.03	2.656	.421	.383
P4	14.81	2.790	.349	.429
P5	14.78	2.806	.268	.478

Figure 4.8: Data Reliability of Pertinency Questions

Case Processing Summary

		N	%
Cases	Valid	36	90.0
	Excluded[a]	4	10.0
	Total	40	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.919	41

Figure 4.9: Data Reliability of Encoding and Decoding Survey

4.8 Independent T-test for Encoders/Decoders

The independent t-test was conducted between the group of encoders and decoders. The purpose of conducting an independent t-test was to identify the difference in the perception of communication between the two groups and how much they vary. This was done by comparing the mean values of the two groups.

4.8.1 Group Statistic Result

The overall mean value of the encoders was 4.0087, and the overall mean value of decoders were 4.0111 as shown in Figure 4.10. The standard deviation of the encoders were 0.30911, and the standard deviation of the decoders were 0.41909. The standard error mean for the encoders is 0.7728 and the standard error mean for the decoders is 0.0937. The results are illustrated in Figure 4.10.

4.8.2 Assumption of Independence

The two groups were completely independent as one was assigned the responsibility of encoders, and the others were assigned the responsibility of decoders.

4.8.3 Assumption of Equal Variances

The Levene's test for the equality of variances was conducted, and significance value was 0.135, which was higher than 0.05, which means the two variances were equal.

4.8.4 Assumption of Normality

The Shapiro Wilk test was conducted to test the normality of the data. The significance value of the encoder's survey was 0.088, and the decoder's survey was 0.3598 which were greater than 0.05. Hence the normality condition was validated.

4.8.5 Independent T-test Result without Weights

The t statistic value is -0.19 and the degree of freedom is 34. The significance value was 0.985 which is greater than 0.05. The value of alpha is 0.05. Alpha refers to significance level, the probability of making a type 1 error. Hence, there is no significant difference between the mean of two groups. The mean difference between the two groups is -0.00243. The Confidence interval between the two groups is Lower bound: -0.25775 and Upper bound: 0.25289 as shown in Figure 4.10.

4.8.6 Independent T-Test Result with Weights

The t statistic value is -0.22 and the degree of freedom is 34 as shown in Figure 4.11. The significance value was 0.105 which is greater than 0.05. Hence there is no significant difference between the mean of two groups. The mean difference between the two groups is -0.028. The Confidence interval between the two groups is Lower bound: -0.2897 and Upper bound: 0.2331. The mean value of encoder group is 3.887, and the mean value of decoder group is 3.9154 as shown in Figure 4.11.

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
Overall_mean_woP	E	16	4.0087	.30911	.07728
	D	20	4.0111	.41909	.09371

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Overall_mean_woP	Equal variances assumed	2.342	.135	-.019	34	.985	-.00243	.12563	-.25775	.25289
	Equal variances not assumed			-.020	33.818	.984	-.00243	.12146	-.24932	.24446

Figure 4.10: Mean Value Comparison of Encoders and Decoders without Weights

T-Test

Group Statistics

	V1	N	Mean	Std. Deviation	Std. Error Mean
Weighted Mean	E	16	3.887111111	.3034908333	.0758727083
	D	20	3.915410317	.4364840867	.0976008089

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Weighted Mean	Equal variances assumed	2.747	.107	-.220	34	.827	-.028299206	.1286425763	-.289732376	.2331339629
	Equal variances not assumed			-.229	33.436	.820	-.028299206	.1236227559	-.279687097	.2230886842

Figure 4.11: Mean Value Comparison of Encoders and Decoders with Weights

4.9 Independent T Test Comparison for Attributes

4.9.1 Accuracy

The T-test was conducted between the attributes of the encoders and decoders. The mean of accuracy for the encoders was 4.0125, and the mean value for decoders was 4.0050 as shown in Figure 4.12. The significance value of accuracy was 0.961 as shown in Figure 4.13, which is greater than 0.05. Hence, the two means were not statistically different.

4.9.2 Clarity

The mean of clarity for the encoders was 4.0625 and for the decoders was 4.1357 as shown in Figure 4.12. The significance value of clarity was 0.676 as shown in Figure 4.13, which is greater than 0.05. Hence, the two means are not statistically different.

4.9.3 Credibility

The mean value of credibility for the encoder is 3.778 and for the decoder is 3.922 as shown in Figure 4.12. The significance value of credibility was 0.397 as shown in Figure 4.13, which is greater than 0.05. Hence the two means are not statistically different.

4.9.4 Timely

The mean value of the attribute timely for the encoder was 3.812, and the mean value of decoder was 3.9500 as shown in Figure 4.12. The significance value of timely was 0.400 as shown in Figure 4.13, which is greater than 0.05. Hence the two means are not statistically different.

4.9.5 Relationship

The mean value of the relationship for the encoder was 4.5375, and the mean value of the decoder was 4.0700 as shown in Figure 4.12.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
A_mean	Equal variances assumed	1.939	.173	.050	34	.961	.00750	.15096	-.29928	.31428
	Equal variances not assumed			.052	33.586	.959	.00750	.14536	-.28803	.30303
CL_mean	Equal variances assumed	1.923	.175	-.421	34	.676	-.07321	.17372	-.42625	.27982
	Equal variances not assumed			-.434	33.961	.667	-.07321	.16866	-.41599	.26956
CR_mean	Equal variances assumed	.055	.816	-.858	34	.397	-.14444	.16840	-.48667	.19778
	Equal variances not assumed			-.850	31.028	.402	-.14444	.16995	-.49105	.20216
T_mean	Equal variances assumed	1.954	.171	-.852	34	.400	-.13750	.16134	-.46539	.19039
	Equal variances not assumed			-.879	33.909	.385	-.13750	.15635	-.45528	.18028
R_mean	Equal variances assumed	.069	.795	2.172	34	.037	.46750	.21523	.03011	.90489
	Equal variances not assumed			2.275	32.777	.030	.46750	.20545	.04940	.88560

Figure 4.13: Identifying if the attributes are statistically different

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
A_mean	E	16	4.0125	.36125	.09031
	D	20	4.0050	.50936	.11390
CL_mean	E	16	4.0625	.43945	.10986
	D	20	4.1357	.57232	.12797
CR_mean	E	16	3.7778	.52431	.13108
	D	20	3.9222	.48379	.10818
T_mean	E	16	3.8125	.40311	.10078
	D	20	3.9500	.53459	.11954
R_mean	E	16	4.5375	.48287	.12072
	D	20	4.0700	.74346	.16624

Figure 4.12: Mean Value Comparison of Attributes

The significance value of the relationship is 0.037 as shown in Figure 4.13, which is the less than 0.05. Hence the two means are statistically different.

4.10 Correlations

The null hypothesis for this research was that all the attributes are positively correlated. If the accuracy of the communication increases, all the other attributes such as credibility, clarity, timely and relationship, will increase. Pearson Correlation was used to analyze the correlation between these attributes. The Pearson Correlation coefficient of the accuracy with clarity was 0.704, with credibility was 0.585, with timely was 0.642 and with the relationship was -0.002. The Pearson Correlation coefficient of the clarity with accuracy was 0.704, with credibility was 0.679, with timeliness was 0.644 and with the relationship was -0.012. The Pearson Correlation coefficient of the credibility with accuracy was 0.585, with clarity was 0.679, with timeliness 0.679, with relationship -0.068. The Pearson Correlation coefficient of timely with accuracy was 0.642, with clarity was 0.644, with credibility was 0.679 and with timely was 0.134. The Pearson Correlation coefficient of relationship with accuracy was-0.002, with clarity, was -0.012, with credibility, was -0.068, with timely, was

0.134. As shown in Figure 4.14 all the attributes were positively correlated except the relationship attribute.

4.11 Reliability of Communication

$$R_c = P(E) * P(D)$$

Before calculating the probability of encoding, we first need to find the right fit of distribution for the data. Hence the Shapiro-Wilk test was considered, and the p-value was 0.0664 which is greater than 0.05. Hence the data was considered to be normal. The following code was used in R Studio to calculate the probability of encoding event. The value for reliable communication is derived from the Likert Scale. The rating of effective communication is 4 on a daily basis. So in this research, the value of reliable communication was set more than 3.5. Hence the value of q=3.5.

$P(E)$= 1-pnorm(q=3.5, mean = 3.887, sd=0.293,)

$P(E)$= 0.906712

Correlations

		A_mean	CL_mean	CR_mean	T_mean	R_mean
A_mean	Pearson Correlation	1	.704**	.585**	.642**	-.002
	Sig. (2-tailed)		.000	.000	.000	.990
	N	36	36	36	36	36
CL_mean	Pearson Correlation	.704**	1	.679**	.644**	-.012
	Sig. (2-tailed)	.000		.000	.000	.944
	N	36	36	36	36	36
CR_mean	Pearson Correlation	.585**	.679**	1	.679**	-.068
	Sig. (2-tailed)	.000	.000		.000	.694
	N	36	36	36	36	36
T_mean	Pearson Correlation	.642**	.644**	.679**	1	.134
	Sig. (2-tailed)	.000	.000	.000		.438
	N	36	36	36	36	36
R_mean	Pearson Correlation	-.002	-.012	-.068	.134	1
	Sig. (2-tailed)	.990	.944	.694	.438	
	N	36	36	36	36	36

Figure 4.14: Correlations Between Attributes

Similarly, for the decoding event, the Shapiro-Wilk test was conducted. The p-value was 0.5326, which is greater than 0.05; hence the data was considered to be normal. The following code was used to calculate the probability of the decoding event.

$P(D)$= 1-pnorm(q=3.5, mean = 3.915, sd=0.4254,)

$P(D)$= 0.8353568

R_c= $P(E) * P(D)$

R_c=$0.9067 * 0.8353$

R_c=0.747

4.12 Reliability of Strand

In this strand, there are two nodes as shown in Figure 4.15. The reliability of the Sales/Engineering function is assumed as 0.8, and the reliability of the production function is assumed as 0.7. The reliability of the communication as calculated in this research is 0.747.

R_s= $Rf_1 * R_c * Rf_2$

R_s= $0.8 * 0.747 * 0.7$

R_s= 0.41

4.13 Sensitivity Analysis

Sensitivity analysis is the study of how the uncertainty in the output of the system can be apportioned to different sources of uncertainty in its input. In this research, two types of sensitivity analysis were conducted.

- Reducing the probability of Encoding and Decoding.
- Strand Analysis covering all three categories

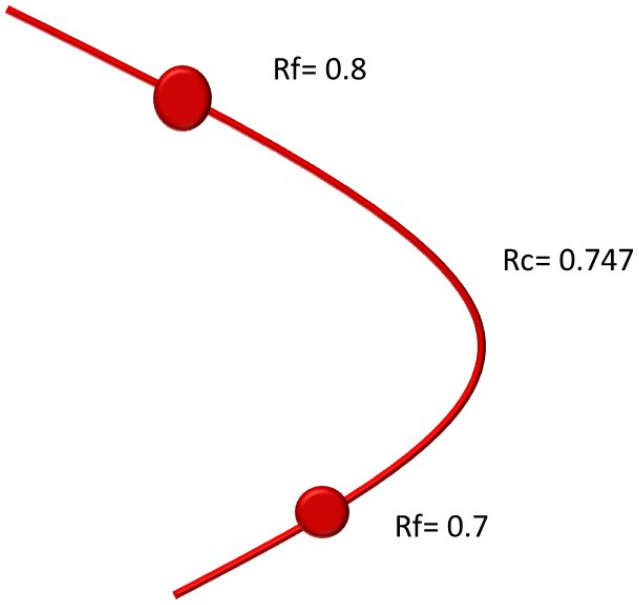


Figure 4.15: Single Strand Analysis

4.14 Reducing the Probability of Encoders and Decoders

New data sets were prepared to reduce the reliability of communication. In the first analysis encoder responses were reduced to 20%, 10%, and 5% to see the impact on the overall reliability of the strand. By reducing 20% value of encoder responses, there was a drastic decrease in the reliability of the strand as compare to 10% and 5% reduction. The results are shown in Table 4.8. Figure 4.16 exhibits that as the reliability of communication decreases the reliability of strand also decreases. In the second analysis decoder's response were reduced to 20%, 10% and 5% as shown in Table 4.9. It was identified that reliability of the strand was almost similar when there was 5% reduction in decoder response and the encoder response separately. Figure 4.17 displays the comparison between the reliability of the communication and the reliability of the strand.

Table 4.8: Reduction in Encoder Responses

Reduction in encoder responses	P(E)	Reduction in decoder response	P(D)	Rc	Rs
20%	0.04	0%	0.835	0.0334	0.018704
10%	0.496	0%	0.835	0.41416	0.2319296
5%	0.754	0%	0.835	0.62959	0.3525704

Table 4.9: Reduction in Decoder Responses

Reduction in encoder responses	P(E)	Reduction in decoder response	P(D)	Rc	Rs
0%	0.906	20%	0.111	0.100566	0.05631696
0%	0.906	10%	0.52	0.47112	0.2638272
0%	0.906	5%	0.6982	0.6325692	0.354238752

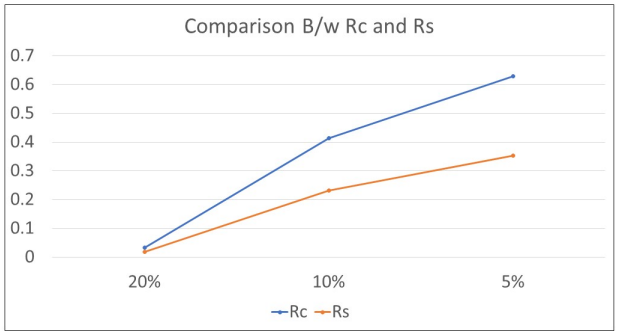


Figure 4.16: Comparison Between Rc and Rs (Reduction in Encoder Responses)

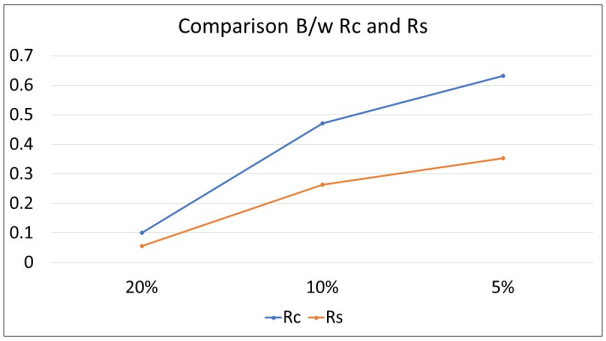


Figure 4.17: Comparison Between Rc and Rs (Reduction in Decoder Responses)

4.15 Strand Analysis Covering all three Categories

In this analysis, all three categories were considered. Two types of analysis were done as shown in Figure 4.18. In the first analysis the reliability of communication was assumed to be low, and in the second analysis, the reliability of the communication values was considered to be high. The reliability of functions were assumed in both the analysis. The reliability of the strand with lower communication reliability was 0.032 and reliability of the strand with higher communication reliability was 0.173. This shows that even with the increased reliability of communication, the reliability of the all overall strand was increased by 440 %.

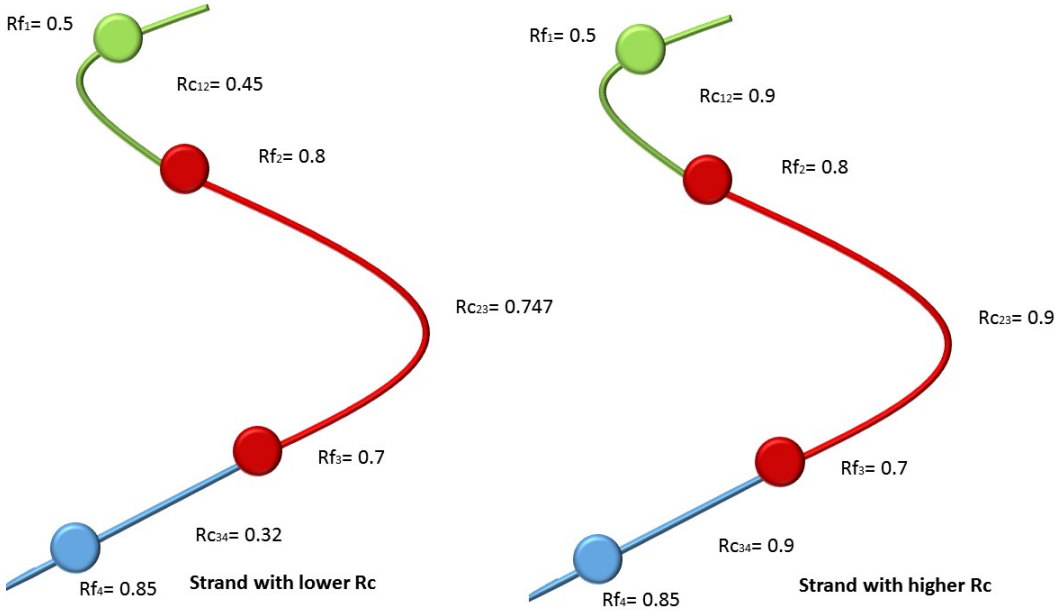


Figure 4.18: Strand Analysis Covering all Three Categories

Chapter 5

Discussion and Future Work

5.1 Conclusion

This research provides a completely new method to predict the role of communication in system reliability. Two new approaches were introduced in this research.

- DNA method
- Reliability of Communication

DNA method provides a framework to map the new initiatives or projects in the form of a strand. If there are several new initiatives then multiple DNA strands can be formed. Multiple DNA Strand is discussed in Section 5.1.1. This strand can be used to do the various analysis. In this research reliability analysis of the strand was done to identify the risk. If the reliability of the strand was lower than the risk of implementing a new project was higher and if the reliability of the strand is higher than the risk of implementing a new project was lower.

A new method was introduced in this research to calculate the reliability of the communication. Five attributes of communication such as accuracy, clarity, timely, credibility and relationship were considered to find the reliability of communication. AHP was used to identify the weights of these attributes. The weight of accuracy was 0.45, Clarity was 0.102, Credibility was 0.22, Timely was 0.15 and Relationship was 0.067. T-test was used to identify the mean of Encoders and Decoders. The mean of Encoder was

3.887 and Decoder was 3.91. The significance value was 0.827 which is greater than 0.05, hence statistically there was no difference between the groups. The communication between the two groups was considered to be reliable as identified from the reliable communication matrix. The probability density function was used to calculate the probability of encoding and decoding event. The reliability of communication was 0.747 in this research.

5.1.1 Multiple DNA Strands

Every project can be represented by multiple DNA strands in the real world. Each project can have several functions which impact the project and so multiple strands can be created as a result. Multiple DNA strand analysis can help the organization to understand the impact of interconnections on the overall project. As discussed earlier, strand formation is done from the framework of an organization. If we consider an operational excellence project as an example and the goal of the project is to install a new packing machine. Table 5.1 is an example of identifying functions from the framework. In this table, all the functions are identified which impact the installation of the machine. In the first category, the project impact customers and operations/maintenance. In the second category, it impacts three functions such as finance, engineering, and manufacturing of the functional matrix. In the sub-functional-matrix, it impacts CapEx controller, design and production. In operation requirements, it impacts logistics, and in technical requirements, it impacts maintenance consultant. In the third category, on time installation is identified as the lagging indicator and OEE is identified as a leading indicator. Plan A is included as a control plan as it gives detail instruction about the installation of a machine. There is no control mechanism identified in this example. This table will help us to develop multiple strands. Figure 5.1 is the formation of multiple strands of this example. As it is evident from the figure that there are various functions which communicate with each other in the multiple strands. So the probability that they can communicate effectively is a key constraint. The shared node on Figure is a key focus of analysis on multiple DNA Strands as it is most vulnerable to the faults, which results in system failure. The impact this node creates on the overall reliability of a system can help an organization to improve its processes.

Table 5.1: Identifying Functions from the Framework

Translating External Stakeholder Requirements	Stakeholders	Customer		
	Life Cycle Impact	Operations & Maintenance		
Understanding the Impact onInternal Stakeholders	Funtional Matrix	Finance	Engineering	Manufacturing
	Sub Functional Matrix	CAPEX Controller	Design	Production
	Operation Requirement		Logistics	
	Technical Requirement		Maint. Constultants	
Management/Accountability	Lagging Indicator		OEE	
	Leading Indicator		On time Installation	
	Control Plan		Plan A	
	Control Mechanism		-	

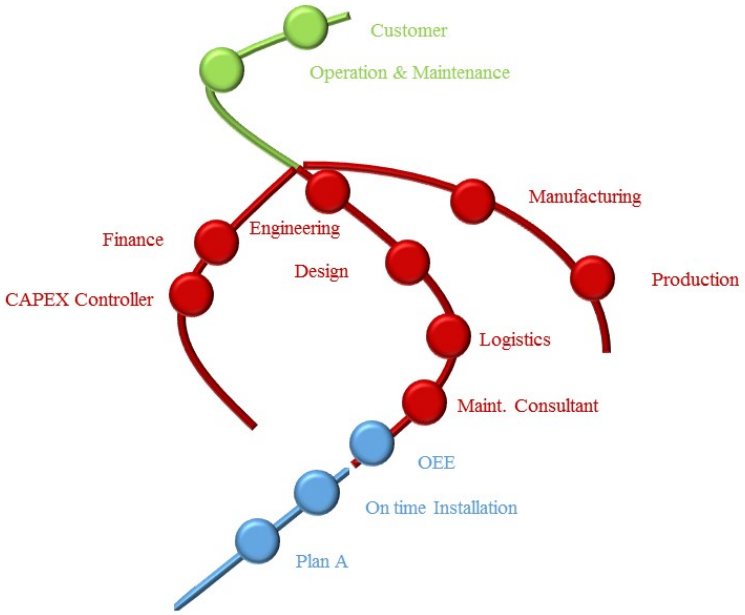


Figure 5.1: Multiple Strands

5.2 Limitations

This research provides a valuable contribution to the literature with the risk of implementing new initiatives. However, it is important to be aware of the limitation associated with this research which are given below:

- Only Series structure was considered in analyzing the reliability of the strand. There could be instances where the parallel structure or n out k structure can be used.
- This research does not provide a methodology to work on complex structures such as multiple strands.
- This research can only be applied to a specific communication between two department or two groups.

5.3 Future Work

This research can be extended to the following areas:

- Developing a method to analyze multiple strands together. In a scenario where different initiatives are implemented together, analyzing multiple strands together could give a key insight into implementing those initiatives.
- Developing a method to analyze the importance of shared nodes in the multiple strand analysis. These nodes are the functions that are involved in more the one initiatives and must have higher importance.
- This research does not provide a reliability matrix for the strand analysis. This matrix could provide a benchmark to identify on what reliability values it is safe to implement a new initiative.
- There are several ways defined in literature to calculate reliability. A specific method can be developed to identify factors on which the reliability of the function depends.

- The attributes and method identified in this research can also be used to indicate the effectiveness of Objectives and Key Results as identified in the book "Measure What Matters".

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Appendices

Reliability Communication Survey

(Encoding)

April 2018

Dear participant,

Please be assured that your responses will be kept completely confidential. There will be no attempt to identify any individual person from the answers to the survey. Your participation is voluntary, and you may withdraw at any time and can decline to answer any survey items. Thank you in advance for your participation. Your help is greatly appreciated and critical to this research.

Instructions:

- All survey questions use the following response scale:
  1. Rarely 2. Little 3. Sometimes 4. Often 5. Always
- Please fill in each item with a circle of the number.
- Choose one number per question.

1. Accurate	**Rarely**	**Little**	**Sometimes**	**Often**	**Always**
Product identification details such as (Serial#, Order No. , Model#, Run#, Drawing#) are written correctly.	1	2	3	4	5
The description details of the product are written correctly.	1	2	3	4	5
Quantity of parts in the description are written correctly.	1	2	3	4	5
Engineering Drawing (Hard Card) of the products are correct.	1	2	3	4	5
The part locations identified in the drawing are correct.	1	2	3	4	5
The dimension of the figure are correct.	1	2	3	4	5
Elevation drawings are correct.	1	2	3	4	5
Medium (Paper or Electronic) used for the transfer is Correct.	1	2	3	4	5
Engineering Drawing is related to the product being manufactured.	1	2	3	4	5
Product Change order notification is done.	1	2	3	4	5
Changes identified in the Product change order are correct.	1	2	3	4	5

2. Clarity					
The product description details are clearly understood by the sender.	1	2	3	4	5
The Elevation drawings are clearly understood by the sender.	1	2	3	4	5
The Engineering drawings are clearly understood by the sender.	1	2	3	4	5
The production order is readable.	1	2	3	4	5
Message is sent in authorized format.	1	2	3	4	5
It is clear where to send the message.	1	2	3	4	5
It is clear who will send the message.	1	2	3	4	5
Is sender notified of any changes made by receiver.	1	2	3	4	5

3. Credible					
The message you send is substantiated by the Credible data. (E.g Order is only given after PO is approved)	1	2	3	4	5
There are changes in the product design after the Order has been sent.	1	2	3	4	5
All required approvals are taken for the Product Change order.	1	2	3	4	5
All required legal approvals are taken for the product.	1	2	3	4	5
Education of the sender while communicating is Considered.	1	2	3	4	5
On the job training of the sender while communicating is considered.	1	2	3	4	5
Experience of the sender while communicating is considered.	1	2	3	4	5
Work load of the sender while communicating is considered.	1	2	3	4	5
Health of the sender while communicating is considered.	1	2	3	4	5

4. Timely					
The Production order is sent on time.	1	2	3	4	5
Does the message get delayed because of the medium. (Paper, Electronic)	1	2	3	4	5
Product change management done on time.	1	2	3	4	5
Are the legal approvals for the product manufacturing are taken on time.	1	2	3	4	5
The Production Order and drawings are easily accessible.	1	2	3	4	5

5. Pertinent					
More product description is required.	1	2	3	4	5
The production order has irrelevant information.	1	2	3	4	5
The production order is time cosuming to read.	1	2	3	4	5
More details on Engineering drawing are required.	1	2	3	4	5
The Engineering drawing has irrelevant information.	1	2	3	4	5
The Engineering drawing is time consuming to read.	1	2	3	4	5

6. Relationship					
The message you sent is without any hidden motives.	1	2	3	4	5
The message you sent is without any personal rivalvry or conflicts.	1	2	3	4	5
The message you sent is without the influence of your manager.	1	2	3	4	5
The message you sent is without the influence of Personal performance.	1	2	3	4	5
The message you sent is without any favoritism.	1	2	3	4	5

Reliability Communication Survey

(Decoding)

April 2018

Dear participant,

Please be assured that your responses will be kept completely confidential. There will be no attempt to identify any individual person from the answers to the survey. Your participation is voluntary, and you may withdraw at any time and can decline to answer any survey items. Thank you in advance for your participation. Your help is greatly appreciated and critical to this research.

Instructions:

- All survey questions use the following response scale:
  1. Rarely 2. Little 3. Sometimes 4. Often 5. Always
- Please fill in each item with a circle of the number.
- Choose one number per question.

1. Accurate	**Rarely**	**Little**	**Sometimes**	**Often**	**Always**
Product identification details such as (Serial#, Order No. , Model#, Run#, Drawing#) are written correctly.	1	2	3	4	5
The description details of the product are written correctly.	1	2	3	4	5
Quantity of parts in the description are written correctly.	1	2	3	4	5
Engineering Drawing (Hard Card) of the products are correct.	1	2	3	4	5
The part locations identified in the drawing are correct.	1	2	3	4	5
The dimension of the figure are correct.	1	2	3	4	5
Elevation drawings are correct.	1	2	3	4	5
Medium (Paper or Electronic) used for the transfer is Correct.	1	2	3	4	5
Engineering Drawing is related to the product being manufactured.	1	2	3	4	5
Product Change order notification is done.	1	2	3	4	5
Changes identified in the Product change order are correct.	1	2	3	4	5

2. Clarity					
The product description details are clearly understood by the receiver.	1	2	3	4	5
The Elevation drawings are clearly understood by the receiver.	1	2	3	4	5
The Engineering drawings are clearly understood by the receiver.	1	2	3	4	5
The production order is readable.	1	2	3	4	5
Message is sent in authorized format.	1	2	3	4	5
It is clear where the message will be received.	1	2	3	4	5
It is clear who will receive the message.	1	2	3	4	5
Is sender notified of any changes made by receiver.	1	2	3	4	5

3. Credible					
The message you recieve is substantiated by the Credible data. (E.g Order is only given after PO is approved)	1	2	3	4	5
There are changes in the product design after the Order has been received.	1	2	3	4	5
All required approvals are taken for the Product Change order.	1	2	3	4	5
All required legal approvals are taken for the product.	1	2	3	4	5
Education of the receiver while communicating is Considered.	1	2	3	4	5
On the job training of the receiver while communicating is considered.	1	2	3	4	5
Experience of the receiver while communicating is considered.	1	2	3	4	5
Work load of the receiver while communicating is considered.	1	2	3	4	5
Health of the receiver while communicating is considered.	1	2	3	4	5

4. Timely					
The Production order is sent on time.	1	2	3	4	5
Does the message get delayed because of the medium. (Paper, Electronic)	1	2	3	4	5
Product change management done on time.	1	2	3	4	5
Are the legal approvals for the product manufacturing are taken on time.	1	2	3	4	5
The Production Order and drawings are easily accessible.	1	2	3	4	5

5. Pertinent					
More product description is required.	1	2	3	4	5
The production order has irrelevant information.	1	2	3	4	5
The production order is time cosuming to read.	1	2	3	4	5
More details on Engineering drawing are required.	1	2	3	4	5
The Engineering drawing has irrelevant information.	1	2	3	4	5
The Engineering drawing is time consuming to read.	1	2	3	4	5

6. Relationship					
The message you receive is without any hidden motives.	1	2	3	4	5
The message you receive is without any personal rivalvry or conflicts.	1	2	3	4	5
The message you receive is without the influence of your manager.	1	2	3	4	5
The message you receive is without the influence of Personal performance.	1	2	3	4	5
The message you receive is without any favoritism.	1	2	3	4	5

Vita

Muhammad Arsalan Tariq was born in Karachi, Pakistan, on October 12, 1988. He is the son of Muhammad Tariq Khan and Yasmin Tariq. He has two younger brothers: Muhammad Hassan Tariq and Noman Tariq. He is married to Mahrukh Siddiqui. He graduated from NED University Karachi in 2011 as a Mechanical Engineer. After that he worked for five years in manufacturing industry in different organizations such as Unilever, Reckitt Bencksier and Coca Cola. In Aug 2016, he joined University of Tennessee to complete his Masters in Industrial and Systems Engineering Department. He graduated with a Masters of Science degree in Industrial and Systems Engineering in May 2019.