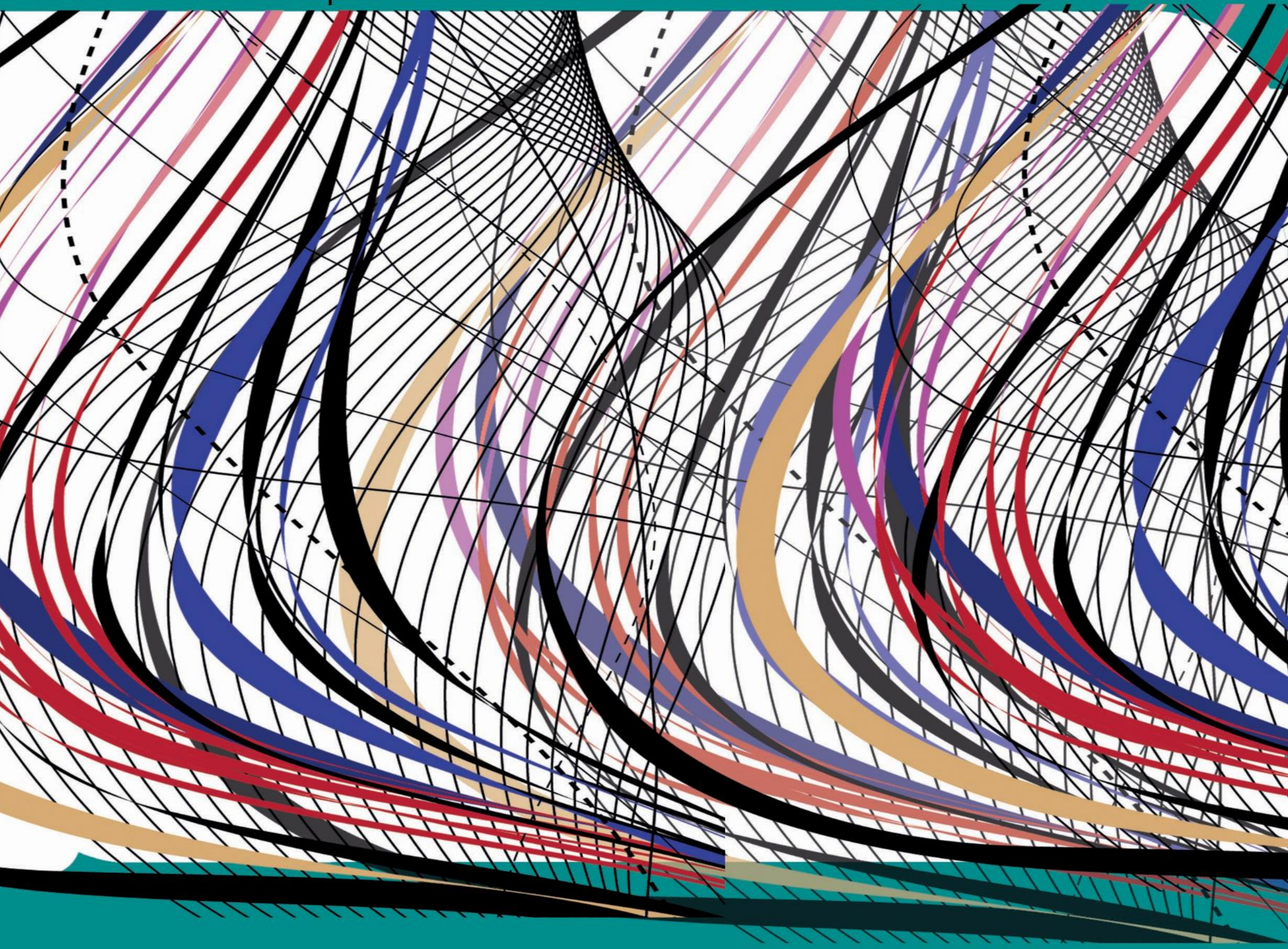
ISSN: 2454-1311

International Journal of Advanced Engineering, Management and Science

Journal CrossRef DOI: 10.22161/ijaems

(IJAEMS)

An Open Access Peer-Reviewed International Journal



Vol-9, Issue- 11 | Nov 2023

Issue DOI: 10.22161/ijaems.911

INFOGAIN PUBLICATION

https://www.ijaems.com/ | ijaems.editor@gmail.com

International Journal of Advanced Engineering, Management and Science

(ISSN: 2454-1311)

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Vol-9, Issue-11

November, 2023

Publisher

Infogain Publication

Email: ijaems.editor@gmail.com ; editor@ijaems.com

Web: www.ijaems.com

Editorial Board/ Reviewer Board

Vol-9, Issue-11, November, 2023

(10.22161/ijaems.911)

International Journal of Advanced Engineering, Management and Science (IJAEMS)
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ISSN: 2454-1311 | Vol-9, Issue-11; Nov, 2023
Journal Home Page: https://ijaems.com/
DOI: https://dx.doi.org/10.22161/ijaems.911.1

Using Knowledge Management to Enhance Organizational Performance and Effectiveness

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Received: 15 Sep 2023; Received in revised form: 25 Oct 2023; Accepted: 04 Nov 2023; Available online: 11 Nov 2023

***Abstract*— *Beyond just system deployment efficiency and labor competency, a number of crucial aspects affect an organization's effectiveness. While the effectiveness of these factors is important, they are not the only factors that matter. The performance as a whole is greatly influenced by a number of other important factors. Recent observations have revealed a consistent upward trend in the metrics related to organizational performance, highlighting the importance of different elements cooperating. Therefore, the main goal of this research project is to carry out a thorough analysis into the complex and dynamic relationship between knowledge management inside an organization and its overall performance. The goal of this study is to delve deeply into the underlying mechanisms and examine how knowledge management techniques directly affect and contribute to an organization's overall performance. The approach used in this study is survey-based, providing for a detailed understanding of the respondents' viewpoints on a variety of topics, including knowledge dissemination, knowledge responsiveness, and organizational skills. By using this technique, the researchers were able to quantitatively and qualitatively evaluate the participants' points of view and acquire important insights into the intricate relationships that exist between knowledge management techniques and an organization's overall success. The survey's findings showed a strong positive relationship between increased organizational performance and effective knowledge management. This beneficial effect was apparent across a number of variables, illuminating the critical roles that organizational capacities, responsiveness to knowledge, and knowledge distribution play in boosting overall efficiency and production within the company. The results do, however, highlight the significance of developing a solid strategy or methodology that guarantees the successful deployment and seamless integration of knowledge management methods inside the business. Recognizing that a complete strategy involving careful planning, strategic alignment, proper resource allocation, and ongoing evaluation is required for the effective transformation of knowledge management within the organizational structure is crucial. Organizations can better harness their intellectual assets and maximize their total performance by concentrating on the implementation of a well-structured strategy, which will support sustained growth and competitive advantage in the dynamic business environment.*

***Keywords*— Knowledge Management, Organizational Performance, Transformation.**

I. INTRODUCTION

The importance of knowledge management in facilitating organizational functions has grown significantly in the modern business landscape, which is defined by fierce competition and a dynamic marketplace. The importance of knowledge management in the current context cannot be understated; according to Asongu and Simplice (2017), it plays a crucial role in helping firms to grow and prosper in both internal and external market situations. The scope for assessing the efficiency of knowledge management is complex and multifaceted, spanning a range of elements and situations. The cornerstones of knowledge management are inextricably tied to an organization's performance. After careful examination, it has become clear that knowledge management is a systematic process that involves the generation, sharing, and use of information within the context of an organization's operations (Pauleen, David, & Gary, 2016). Knowledge management is frequently used to refer to a thorough and multidisciplinary approach that aims to effectively match corporate goals with the best use of the knowledge resources at hand. This strategy places a strong emphasis on the necessity of successfully utilizing knowledge to guide strategic decision-making and improve organizational performance.

As identified by Lavia, Oro, Martin, and Hieb in 2014, a trio of crucial steps form the basis of knowledge management. These phases, which cover a variety of actions directly related to knowledge management initiatives, include the pre-process phase, the active phase during the knowledge management process, and the succeeding phase post-implementation. These phases all work together to help firms comprehend knowledge management holistically and put it into reality. As a crucial instrument for improving operational efficiency inside business networks, knowledge management strategies are used. Additionally, these tactics are crucial in helping firms use the strength of knowledge management to their advantage as they navigate the difficult terrain of a fiercely competitive market environment (Asongu & Simplice, 2017). Organizations can streamline their operations, improve decision-making skills, and ultimately strengthen their competitive advantage in the ever-changing business environment by utilizing knowledge management's capabilities.

The primary goal is to examine & analyze the real effects of knowledge management on the general effectiveness of companies. This investigation's focus is on understanding the procedural complexities of knowledge management, the mechanisms of knowledge acquisition (Kwon, Ohbyung, Namyeon, and Bongsik, 2014), the dynamics of knowledge dissemination (Pauleen, David, and Gary, 2016), the responsiveness to knowledge in organizational settings (Lavia, Oro, Martin, and Hieb, 2014), and the assessment of organizational capability. These essential elements work together to help us understand the complex connections between the many aspects of knowledge management and their effects on organizational performance (Arnold, Markus, and Martin, 2015). This study intends to shed light on the diverse nature of knowledge management and its crucial role in molding and boosting organizational efficiency and success through a thorough examination of these components.

The main objective of this study project is to discover and clarify the wide range of advantages connected to the application of knowledge management within organizational structures. The main goal is to comprehend the amount to which these advantages can be utilized, which would result in a notable improvement in performance and general productivity at work. This study explores the complex dynamics of how the application of knowledge management strategies might favorably affect a number of organizational functioning factors, ultimately resulting in a richer and more productive workplace. This research aims to provide a comprehensive understanding of the transformative role that effective knowledge management can play in fostering organizational success and productivity by carefully examining the visible benefits and their potential impact.

Problem Statement

In the emergence of globalization and advancements of technologies, role of knowledge management is incredibly inevitable. Knowledge management deals with the efficient utilization and management of resources and information. It is considered that significance of knowledge management deployment is organization carries immense importance. In Pakistani organizations and businesses, knowledge management is still not being implemented to its full potential. Furthermore, there is still debate on the relationship between knowledge management and the overall effectiveness and trustworthiness of these companies. This study's main objective is to carefully examine and scrutinize how knowledge management affects organizational performance, with a focus on determining how much it helps those businesses grow and prosper. This study intends to shed light on the complex relationship between the adoption of efficient knowledge management techniques and the subsequent improvement of an organization's performance, growth trajectory, and financial viability by examining these crucial factors.

Research Questions

RQ-1: How knowledge management and acquisition does impacts on organization's performance?

RQ-2: What is the role of knowledge dissemination and increase responsiveness to knowledge on the organization's performance?

RQ-3: What are major benefits of deploying knowledge management on the organizational performance and how the advantages can be improved?

Research Objectives

- Examine and investigate the influence of KM & acquisition on organization's performance.
- Identify and examine the role of knowledge dissemination and increase responsiveness to knowledge on the organization's performance,
- Investigate the impact of organization's capabilities and learning orientations on the organization performance in terms of profitability and growth.

Gaps in the Existing Research

The research has determined particular major gaps that are inextricably linked to the influence of knowledge management on organizational performance after a thorough analysis and evaluation of the relevant literature. These gaps draw attention to crucial areas where knowledge management's existing understanding and application may fall short in satisfying the all-encompassing needs of enhancing organizational performance. This study attempts to identify these gaps and offer insightful information that can help open the door for a more thorough and successful integration of knowledge management strategies within the organizational structure, ultimately leading to increased success and performance.

The finding shows that organizations prioritize performance, but their inadequate grasp of information systems or knowledge management is a substantial barrier. As a result, many organizations find it difficult to identify and assess the precise information systems that would improve their performance and increase operational efficiency.

The act of making decisions is frequently acknowledged as a difficult undertaking, and it has been noted that when this process is not carried out well, there is a significant risk of failing to achieve important goals. Within the parameters of this study, attention will be paid to assessing and figuring out ways to improve the decision-making process along with other important factors.

Research Significance

In order to effectively analyze the genuine impact of organizational performance in the market, this research looks into the vital relevance of understanding the fundamental principles of knowledge management. Within the contemporary business environment, the field of knowledge management is broad and complex. Its main objective is to facilitate procedures for the production, transfer, and effective management of pertinent knowledge and information inside an organization. By providing management teams with the resources they need to not only complete their jobs but also strengthen their competitive advantage in the market, this strategic approach to knowledge management serves as a priceless asset that helps them meet and even exceed the changing expectations of consumers.

II. LITERATURE REVIEW

Knowledge Management

The generation, use, and efficient processing of information within any organization worldwide are all components of an effective knowledge management process. This multidisciplinary method known as the holistic approach aims to maximize the goals of a company by making the most use of knowledge. Additionally, this aspect of knowledge management plays a key role in ensuring that the appropriate people have easy access to essential knowledge, facilitating informed decision-making and promoting an organizational culture of continual learning. Organizations are empowered by the adoption of such a management system to not only gain information but also to successfully retrieve and use it in real-world situations. By facilitating coordination and utilizing the organizational knowledge base, knowledge management is used to give the company a competitive edge in the market. Furthermore, the integration of knowledge management is closely related to an organization's strategic and tactical needs, highlighting the requirement to continuously expand the organizational knowledge base and strengthening the ability to address complex problems and do so in an effective and efficient way (Malhotra & Segars, 2001).

Fig.1: Knowledge Management Cycle

The use of knowledge management within businesses, according to Gibbert and Leibold (2002), centers around the systematic administration of corporate knowledge, assuring its acquisition, retention, organization, application, sharing, and timely renewal. This comprehensive strategy acknowledges the tacit and explicit knowledge's dual nature and makes use of it to improve workforce productivity and foster corporate value. This management method is praised for its proactive approach to utilizing organizational resources, enabling beneficial enhancements intended to secure and utilize knowledge resources to meet the changing needs of the business. Additionally, by enabling organizational learning from prior mistakes, this dynamic process fosters continued success and progress. The management framework works to secure a competitive advantage for the firm by strategically utilizing these resources, encouraging ongoing development and the cultivation of the necessary skills and competencies, and methodically getting rid of out-of-date knowledge. Internally, this management structure strengthens the organization's ability for innovation by encouraging a positive atmosphere that supports a culture of constant improvement and adaptation (Bhatt, 2001).

Fig.2: Knowledge Management Strategies

(Source: https://www.slideteam.net/6-types-of-knowledge-management-strategies.html#images-1)

Knowledge Acquisition

In order for knowledge-based systems to operate properly, many ontologies and rules must normally be established during the knowledge collecting process. In this essential acquisition phase, which acts as the first step in building an expert system, specialists in the given topic are methodically sought, interrogated, and their knowledge is properly recorded. This complete technique lays the framework for the creation of a successful knowledge-based system by extracting important knowledge about objects, rules, and frame-based ontologies. This acquired knowledge is used by numerous organizations around the world as the foundation for the creation of strong external knowledge repositories, facilitating the development of priceless external knowledge sources that can be used for improved operational efficiency and strategic decision-making (Fu, Sun, & Ghauri, 2018). Additionally, these outside knowledge sources play a crucial part in fostering a thorough awareness of the complex business environment by providing a holistic view of the interconnected value chain. Moreover, there are different sources including customers, suppliers, partners, and others.

Knowledge about the customer: This is the type of knowledge that enable for the customers to get awareness about better customers to gain understanding and motivating them by fulfilling needs, purchasing, and expecting the activities.

Knowledge for customers: This is another knowledge in which the customers use to gain the maximum satisfaction of the needs of their knowledge. This use to involve a product, supplier, and market-based knowledge.

Knowledge from a customer: This is the kind of the knowledge which use to deal with suppliers, products as well as markets. It further supports organization to use the knowledge in an adequate manner by improving services and products.

Knowledge of suppliers: This knowledge is directly concerned with the supplier that needs and involve forecasts, production's needs, customers, inventory, and markets.

Knowledge from suppliers: The suppliers use to gather the knowledge so that they deal properly with organizations.

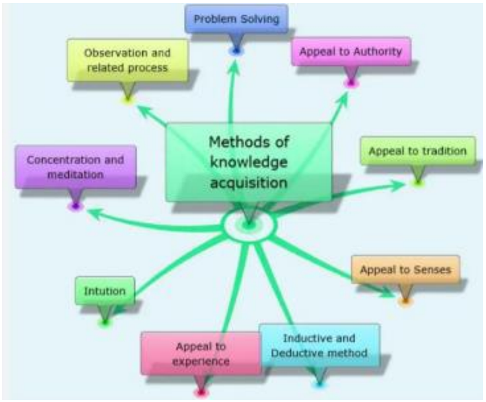


Fig.3: Knowledge Acquisition Methods

Knowledge Dissemination

Given its critical role in assuring the timely provision and accessibility of vital knowledge resources to satisfy organizational demands, the dissemination of knowledge stands as an integral component within the context of organizational knowledge management. This dissemination process is not just a normal task; rather, it is a purposeful strategy that calls for a commitment to upholding high standards and a contextual awareness. By ensuring that the dissemination plans are carried out meticulously and methodically, the efficacy and efficiency of the organization are maximized. When a company chooses to use knowledge dissemination, it is crucial to convey messages simply and succinctly, using a simplified strategy that encourages proactive and beneficial action. This simplified method highlights the importance of clearly communicating information and demystifying complicated ideas to promote quick and informed decision-making. The careful dissemination of strategies inside the business is essential because it not only permits effective implementation but also allows the organization to precisely analyze their direct influence, permitting the thorough evaluation of the overall success trajectory.

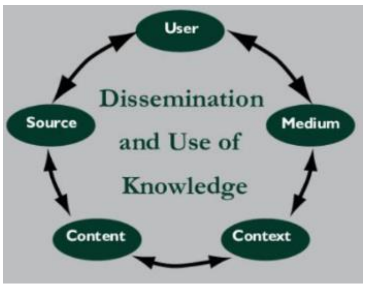


Fig.4: Knowledge Dissemination

Responsiveness to Knowledge

Within a framework that is knowledge-centric, the capacity to respond to knowledge is essential for coordinating the cautious gathering and accurate filtration of significant information. The main goal of this knowledge responsiveness is to promote a thorough awareness of the collective or individual knowledge of an organization, consequently influencing the overall effectiveness of knowledge usage. Additionally, this responsiveness to knowledge emphasizes the need to make it easier for people to convert, acquire, defend, and use knowledge, as each of these processes is essential to the responsiveness to knowledge paradigm's overall efficacy. This openness to new information forms the basis of knowledge management, assisting in the careful evaluation of an organization's skills and competencies within a changing environment and ultimately raising organizational performance to new heights. In order to utilize key capabilities and maintain a competitive advantage, it becomes more important for businesses to adapt and evolve their knowledge base. They must see it as a concrete asset that merits strategic attention and comprehensive investment. Adopting this holistic strategy enables firms to not only respond to industry changes early on but also ensures that organizational performance is continually improved (Oriarewo, 2014).

Organizational Capabilities

The concept of organizational capability, as highlighted by Spanos and Prastacos (2004), encompasses a company's aptitude in efficiently managing its range of resources, including its employees, to achieve a significant competitive edge within the dynamic marketplace. It is the responsibility of the company to direct its attention toward developing these talents and making sure they are in line with the needs and preferences of its clientele. The development of a distinctive organizational perspective, which enables the business to traverse the competitive landscape with resiliency and creativity, is an essential component of this strategy. An corporation can orchestrate major business changes by strategically utilizing its resources, creating a strategic environment that opens the door for long-term competitive advantage.

According to Bititci and GurkanInan (2015), a strong portfolio of skills enables an organization to operate efficiently within the market, permitting the continuous development and upgrading of current competencies to successfully resist competitive forces. These capabilities cover a wide range, including product licenses, knowledge assets, and innovative designs. As a result, an adaptive strategy is required that prioritizes the ongoing development of a workforce with knowledge-based skills in a flexible work environment, leading to successful business domain transformations.

Furthermore, Martelo (2013) explains how organizational qualities are closely related to developing strong customer relationships, underlining the necessity of ongoing competition and market expansion. The development of employee capabilities, which have a substantial impact on the organization's reputation, sales success, and customer loyalty, is essential for building good customer relationships. A harmonious workplace that is geared to addressing the changing requirements and expectations of customers in a timely and effective manner is crucial. Within the organizational framework, both existing and new customer interactions serve as important drivers of overall growth.

Learning Orientation

According to Wang's (2008) observations, the idea of a learning organization entails an organizational paradigm that places a high priority on the acquisition and dissemination of information with the goal of causing positive market transformations by staying tuned in to the changing needs and expectations of customers, competitor behavior, technological advancements, and other relevant factors. The creation of novel, superior goods or services, which secures a competitive edge through a strong grasp of numerous situational aspects, with stakeholders playing a crucial role among these determinants, is at the center of this process.

Within the organization, this learning orientation plays a crucial function as a catalyst for improving competencies through specialized training programs and educational activities. It includes a number of crucial elements, such as motives, beliefs, abilities, and self-control, all of which are intricately intertwined to produce concrete learning outcomes. This learning orientation supports the accomplishment of predetermined goals within the corporate context, fostering an environment that is conducive to individuals' experience learning. The constructivist approach, which emphasizes the need of dynamic interactions within difficult situations as a way to achieve and maintain a competitive edge, is also perfectly aligned with it (Keskin, 2006).

Calantone and Cavusgil (2002) emphasize the need for modern businesses to foster a strong learning orientation by describing it as a crucial instrument for obtaining long-term benefits. The foundation of this learning orientation, according to a large body of research, is made up of four essential elements: a strong commitment to learning, the development of a common vision, the encouragement of intra-organizational knowledge sharing, and an innate openness to new ideas and viewpoints. This transformative learning orientation is a cutting-edge idea with a significant and immediate effect on an organization's general performance levels.

Organizational Performance

According to Tzabbar and Baruch (2017), the idea of organizational performance encompasses the thorough assessment of a company's effectiveness in achieving its set goals in the competitive marketplace. As a result, it is essential to continuously evaluate and review the organizational performance, which forms a crucial part of the larger strategic management viewpoint. A clear understanding of performance within the operational framework of any business is extremely valuable to stakeholders, empowering them to take well-informed decisions and put those decisions into action whenever necessary to support continuing improvements. It is critical to understand that organizational performance is a complex and nuanced idea that requires constant observation and assessment throughout time in order to pinpoint areas that could be improved.

Fig.5: Sustainable High Performance Organizational

(Source: https://www.insidehr.com.au/how-to-build-a-sustainable-high-Performance-organisation/)

The efficacy of organizational performance is closely related to the common vision that is articulated to and accepted by all levels of the workforce and serves as a compass for group strategic initiatives. Employee performance directly affects how smoothly tasks are carried out at each organizational level, underlining how crucial it is for each team member to strategically contribute to the overall goal. A culture of active involvement and reciprocal cooperation is established when the company, its administrative staff, employees, and other stakeholders work together in a structured and coordinated manner. A systematic strategy is necessary for the development of a successful organizational performance landscape, ensuring that work activities are streamlined and coordinated in an orderly manner. The preservation and enhancement of organizational performance remain dependent on the seamless integration of organizational learning efforts and the availability of a skilled workforce, despite the fact that the dynamic character of business settings frequently necessitates quick recalibrations and adaptations. According to Devece, Palacios, and Simarro (2017), this proactive approach enables the timely implementation of critical adjustments, enabling the company to maintain and improve performance standards over time.

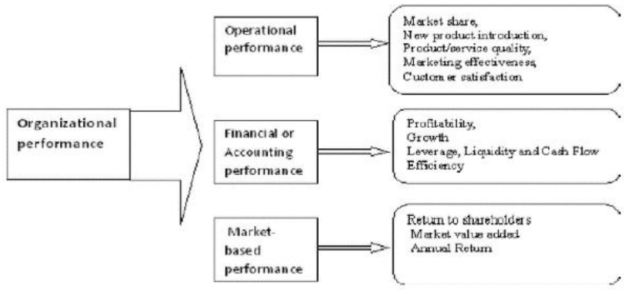


Figure 6: Measuring OP

(Source: DOI:10.5897/AJBM11.1768)

According to observations made by Loosemore (2017), organizational performance emerges as a continuous and dynamic process that forms the basis for protecting and distributing resources in accordance with an organization's broad goals. The nurturing of staff development initiatives, a crucial path that thrives via the facilitation of effective learning mechanisms, is integral to this process. The active participation of managerial and executive personnel, who supervise the creation of customized developmental strategies and keep an eye on workforce activities to support overall development and productivity levels inside the firm, is closely linked to this learning imperative. As a greater emphasis on comprehensive learning efforts invariably converts into a similarly increased performance standard within the cutthroat marketplace, the symbiotic relationship between organizational learning and performance becomes clear. The combination of learning-driven processes and a proactive dedication to supporting employee development strengthens the basis for long-term organizational success.

Fig.7: Key Organizational Performance/Effectiveness Indicators

(Source: https://www.beringer.net/beringerblog/why-does-my-organization-need-key-Performance-indicators-kpis/)

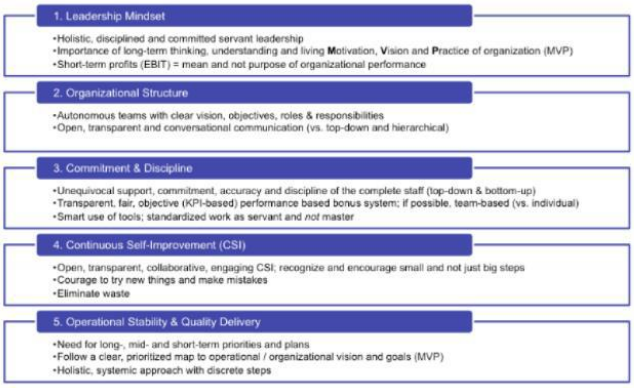


Fig.8: Principles of Organizational Performance/ Effectiveness

(Source: https://motivate2b.com/principles-for-org-Performance/)

III. METHODOLOGY

The use of a carefully designed research methodology plays a crucial part in aiding the study's effective conclusion. This specific study approach has been painstakingly created to carefully monitor and examine the complex interactions between knowledge management and the subsequent effects on organizational performance. This research methodology, which is quantitative in nature and heavily depends on primary data sources, will be compiled and processed using the SPSS software to enable a thorough analysis of the complex dynamics underlying the relationship between knowledge management and organizational performance. The inclusion of different variables stands as a crucial requirement for this study. Following are the research methodology (RM) phases:

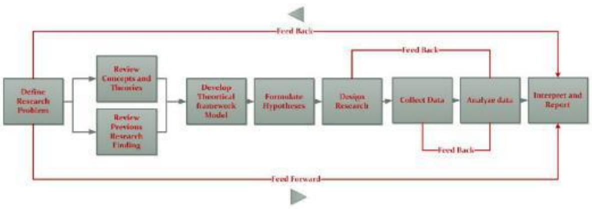


Fig.9: RM - Phases

The study process is divided into a number of connected steps, each of which is closely tied to the one before it. Determining the scope of the research problem is the first step in the process, and it is here that it is emphasized how crucial it is to give the problem a clear definition within the context of existing research because this will serve as the foundation for the study.

Next phase is the reviewing concept, theories as well as prior research findings. This component will be known as literature review. The creation of the study's theoretical framework model will be referred to as the third step. The formulation and conceptualization of the study's hypotheses, based on the theoretical framework model, will be greatly aided by the fourth phase. Fifth phase will be research design. It is considered that in the research design focus will be laid on the transformation of the knowledge, idea as well as information about the knowledge management for improving overall organizational performance into the meaningful aspect. Sixth phase is collect data through Information source considered from the primary data. Information source considered from the primary data includes questionnaire techniques. Seventh phase will be conducting analysis of the data with the assistance of the SPSS business software (Tanner, Emily & Elizabeth, 2014). In the end, researcher will develop the interpret report for improving knowledge management to examining within current system of organization.

The creation and development of a model for KM & its impact on organizational Performance are related to research methodology. Quantitative methods will be used in the investigation. For the purpose of data collection, information from the main data will be used as a source, and SPSS software will be used to process the data. The steps of research technique are numerous. Overall, each stage of the research technique would be connected to the stage before it. The formulation of the research problem is the initial stage of methodology. The attention has been placed on the precise definition of the issue within the context of current research, which is regarded as the basis of the investigation.

Fig.10: Research Framework

The review of concepts, hypotheses, and previous study findings comes next. The literature review component will be known as such. The development of the theoretical model framework will be referred to as the third phase. It will be quite helpful to create and formulate hypotheses during the fourth step. The theoretical foundation of the investigation will serve as a guide for designing hypotheses.

Research design will be the fifth phase. It is anticipated that the research design will place special emphasis on how knowledge, ideas, and information concerning knowledge management may be transformed into significant organizational Performance improvements. The sixth stage involves gathering data from sources that are taken into account while using primary data. Questionnaire methods are one information source from the basic data taken into consideration. The data analysis process will be carried out in the seventh step with the aid of SPSS (Statistical Package for the Social Sciences) tool.

Research Design

The basis for the research's design was knowledge management's potential to boost organizational performance. The emphasis will be on carefully examining ideas concerning knowledge management that have been successfully applied within a particular company, in this case Pakistan Tabaco Company, PTC.

Data Collection Tools

Information source considered from the primary data will be utilized for the process of data collection (Questionnaires distributed among Engro Foods, Nestle Pakistan, P & G Pakistan and Coca-Cola Pakistan employees) acting as a tool for investigation. SPSS (Statistical Package for the Social Sciences) tool will be used for analysis.

Part 1: Personal Information

Section I		
Your Organization (Tick 1 or zero):	Government = 1	2. Private = 0
Your gender (Tick 1 or zero):	Male = 1	2. Female = 0
Your age (in years like 25 years, 29 years.)		
Your education (actual total years of schooling, like 14 years; 18 years)		
Your area of specialization:		
Your job title in this organization:		
Experience: Working years in this organization:		

Part 2: Instructions

Strongly Agree(SA)	Agree (A)	Neutral (N)	Disagreed (D)	Strongly Disagree(SD)
1	2	3	4	5

Section A: Knowledge Management and acquisition

N		A			D
	Knowledge management and acquisition policies in the organization are really important, relevant and latest.				
	Organization can easily accept or share useful knowledge with other organizations.				
	Knowledge management and acquisition procedures that used in organization are friendly, easy, relevant and latest.				
	Staff is encouraged to transfer their professional knowledge to less experience or new employees.				

Section B: Knowledge Dissemination

N		A			D
	Use of IT in KM dissemination and implementation is very great.				
	Your library staff has basic IT knowledge that is required to implement the KM dissemination and practices.				
	Internet and KM software are the tools that are frequently used for obtaining relevant knowledge dissemination.				
	Library does encourage the staff to effectively use the network and web for the research purpose and solving of problems.				
	Software used for KM practices and dissemination should be updated when required.				

Section C: Responsiveness to knowledge

N		A			D
	Responsiveness to the value of KM as compare to public with private institutions.				
	Public and private organizations face more obstacles than implementing KM practices.				
	Organization should focus more on complete knowledge process (i.e. storage, retrieval, transfer, sharing, and application) than their public counterparts and/or competitors.				

Section D: Organizational capabilities

N		A			D
	Organizational capabilities is based on KM.				
	Organizational capabilities understand value of KM.				
	Lack of training is major issue in implementation of knowledge management practices.				
	Systems are complicated for the implementation and use of KM practices.				
	Troubleshooting and technical issues are hurdles in smooth operation of the KM practices.				

Section E: learning orientation

N		A			D
	Training is the key stage for implementation of learning orientation.				
	External training resources are necessary for learning orientation.				
	It is easy for me to become skillful at using the learning orientation.				
	Learning to use the organizational knowledge system is easy for me.				
	Strong and meaningful training programs are necessary for learning orientation and its implementation.				

Fig.11: Questionnaires

Sampling Size Technique

Techniques of random sampling would be used. One Hundred (100) respondents, both directly and indirectly related to the organization's knowledge management, will be the maximum sample size. Engro Foods, Nestle Pakistan, P & G Pakistan and Coca-Cola Pakistan will provide a representative sample size that is dispersed around the nation.

Statistical Instrument Development

The development of the statistical tools used in this inquiry will be based on the SPSS tool. This business software was chosen based on how well it processed, analyzed, and produced the necessary data. These results or outcomes will be examined for reliability data, demographic data, correlational analysis, and regression analysis.

Conceptualized Research Model

The researcher created his own conceptualized model for analysis based on the literature review and existing Knowledge Management and organizational Performance models (as indicated below).

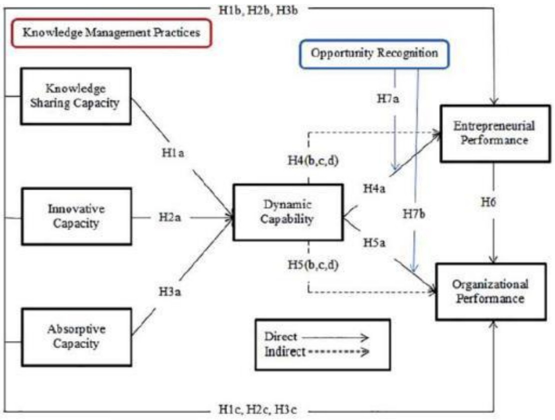


Fig.12: Influence of Knowledge Management Practices on Entrepreneurial and Organizational Performance: A Mediated-Moderation Model

(Source: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.577106/full)

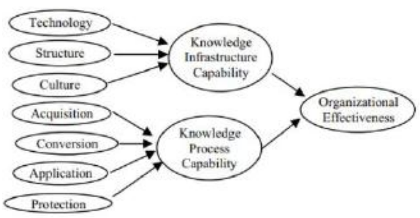


Fig.13: Knowledge Management Capabilities and Organizational Effectiveness

(Source: DOI:10.1186/s40064-016-3173-6)

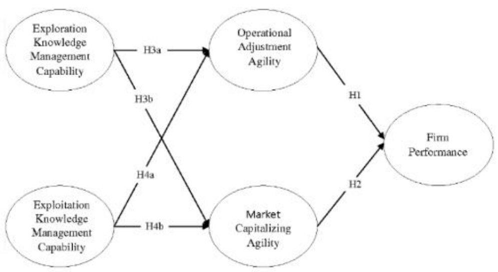


Fig.14: Knowledge Management Capability and Firm Performance: Mediating Role of Organizational Agility

(Source: https://www.semanticscholar.org/paper/Knowledge-Management-Capability-and-Firm-the-Role-Liu-Song/8592cd74513ca29c68cbc38141e14f40d9340121)

The researcher conceptualized the model for the analysis shown below based on the aforementioned and the literature review.

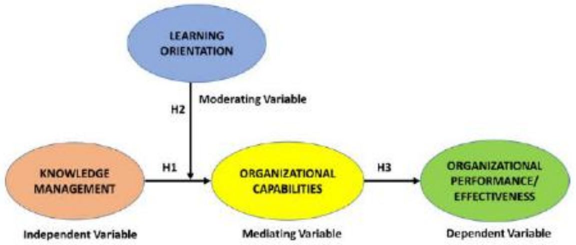


Fig.15: Researchers Conceptualized Model

IV. DATA ANALYSIS, RESULTS & INTERPRETATION

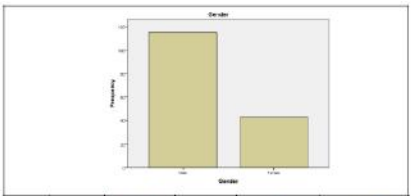
The successful conclusion of this inquiry depends heavily on the chapter devoted to data processing, outcomes, and interpretation. This section was created with the explicit goal of examining the connection between knowledge management and organizational performance. It has been observed that knowledge management plays an active role in context of any organization. Without practical implementation of knowledge management, it's very difficult for organization to accomplish their goals and objectives according to management requirements (Bhatt, 2001). The domain for measuring knowledge management is wide and complex in situations. This is the key reasons that well-known companies are using KM for overall increase their organizational performances in market and also increase high competition in market.

A variety of statistical tests are included in the chapter on data analysis, outcomes, and interpretation. These tests entail analyzing user demographic data, using correlational analysis, presenting a summary evaluating hypotheses, as well as actually using multiple regression analysis models and mediation analysis. In the context of this investigation, these approaches help to demonstrate the genuine influence of research factors on performance as a whole.

The key operative functional activities of demographic information are associated with respect to marital status of respondents, gender differentiation, employee age, employee work experience and private companies that are directly and indirectly connected with knowledge management in order to measure their performance in market. In this investigation, researchers apply correlational analysis for testing of suggested hypotheses derived from research framework model. Hypotheses assessment summary is typically design and develop by using correlational values to know the importance of research model in this study. The multiple regression analysis model's main job is to show the variations present in the current research model and to evaluate the impact of all independent variables on the dependent variable. Mediation analysis is also applied in this investigation. The key main functionality of mediation analysis is to check the moderating effect on independent variables and dependent variable. In this investigation, main variables are in the form of knowledge management (Bhatt, 2001) and learning orientation (Asongu & Simplice , 2017) having mediation impact on organization capabilities (Keskin, 2006) that lead towards organizational performance (Malhotra & Segars, 2001). Some of the imperative outcomes of statistical tests are assumed below:

Demographic Information

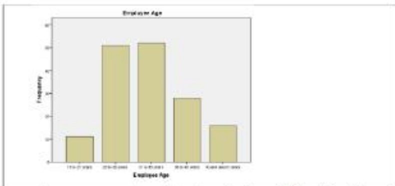
Some of the imperative demographic information with respect to KM on organizational performances is assumed below:



		F "Frequency"	%	Valid %	Cumulative %
Valid	Male	115	72.8	72.8	72.8
	Female	43	27.2	27.2	100.0
	Total	158	100.0	100.0	

Fig.16: Gender

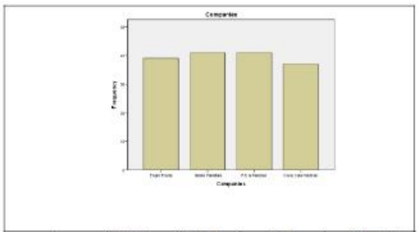
A key demographic data point for comprehending the users engaged is the gender information that is included. The binary classification of people into male and female groups is represented by two main components in this particular dataset. Male participants made up 72.8% of the sample, according to an examination of this data by gender, while female participants made up 27.2% of the entire population involved.



		F	%	Valid %	Cumulative %
Valid	18 - 25 years	11	7.0	7.0	7.0
	26 - 30 years	51	32.3	32.3	39.2
	31 - 35 years	52	32.9	32.9	72.2
	36 - 40 years	28	17.7	17.7	89.9
	40 & above Years	16	10.1	10.1	100.0
	Total	158	100.0	100.0	

Fig.17: Employee Age

In this investigation, employee age plays an active role in context of any organization. This employee age shows employees skills, abilities, knowledge and decision making powers to effectively run business operations in market. Employee age encompasses a wide range of age groups that can be divided into various unique categories. These age ranges include 18 to 25 years old, 26 to 30 years old, 31 to 35 years old, 36 to 40 years old, and over 40. According to the study of this statistics, the distribution of workers within these age groups was as follows: Those between the ages of 18 and 25 made up 7% of the workforce, those between the ages of 26 and 30 made up 32.3%, those between the ages of 31 and 35 made up 32.9%, those between the ages of 36 and 40 made up 17.7%, and those beyond the age of 40 made up 10.1% of the studied population.



		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	Single	52	32.88	32.88	32.88
	Married	106	67.19	67.19	100.0
	Total	158	100.0	100.0	

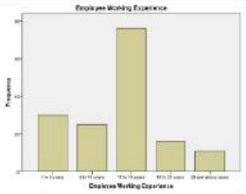
Fig.18: Marital Statistics

In order to comprehend the user population, it is essential to provide information on marital status. This dataset consists of two main parts that classify people as either single or married. According to the analysis, 32.9% of the participants were single, compared to 67.1% of the sample who were married and actively participating in the investigations.

		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	Engro Foods	39	24.7	24.7	24.7
	Nestle Pakistan	41	25.9	25.9	50.6
	P & G Pakistan	41	25.9	25.9	76.6
	Coca Cola Pakistan	37	23.4	23.4	100.0
	Total	158	100.0	100.0	

Fig.19: Companies

In order to evaluate the application of knowledge management in connection to organizational performance, the researcher worked with a variety of businesses. Engro Food, Nestle Pakistan, P & G, and Coca Cola Pakistan were among the businesses that took part in the survey. The results showed that the management of Engro Food made up 24.7% of the study's participants, Nestle Pakistan contributed 25.9%, P & G contributed 25.9%, and Coca-Cola Pakistan participated at a rate of 23.4%.



		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	1 to 5 years	30	19.0	19.0	19.0
	6 to 10 years	25	15.8	15.8	34.8
	11 to 15 years	76	48.1	48.1	82.9
	16 to 20 years	16	10.1	10.1	93.0
	20 & above Years	11	7.0	7.0	100.0
	T	158	100.0	100.0	

Fig.20: Employee Working Experience

Within organizational framework of this study, the length of an employee's employment history acquires a key significance. An employee's professional experience is evidence of their learned abilities, knowledge, and decision-making skills, all of which help to run business operations within the market effectively. The length of an employee's employment history is divided into numerous unique groups, including: 1 - 5 years, 6 - 10 years, 11 - 15 years, 16- 20 years & 20 years and above. According to the research, workers with 1 to 5 years of experience made up 19.0% of the workforce, followed by workers with 6 to 10 years of experience (15.8%), workers with 11 to 15 years of experience (48.1%), workers with 16 to 20 years of experience (10.1%), and workers with 20 years of experience or more (7.0%) of the workforce.

Reliability Statistics

In Statistics, reliability is in order to measure the inner consistency among variables. This reliability statistic is known as pilot testing of investigation.

Table 1: Reliability Statistics

RS - Reliability Statistics	
Cronbach's Alpha	Number of Items
.975	19

In reliability statistics, Cronbach's alpha having value of .975 which is considered as excellent for further proceeding of this investigation & N of items are 19. Reliability statistics values are good for further proceeding.

Correlational Analysis

Table 2: Correlational Analysis

Correlations					
		Knowledge Management	Learning Orientation	Organizational Capabilities	Organizational Performance
Knowledge Management	Pearson Correlation	1	.349**	.070	.158*
	Sig. (2-tailed)		.000	.000	.000
Learning Orientation	Pearson Correlation	.349**	1	.143	.255**
	Sig. (2-tailed)	.000		.000	.000
Organizational Capabilities	Pearson Correlation	.070	.143	1	.913**
	Sig. (2-tailed)	.385	.074		.255
Organizational Performance	Pearson Correlation	.158*	.255**	.913**	1
	Sig. (2-tailed)	.000	.000	.000	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

In the field of statistics, correlational analysis is employed to assess proposed hypotheses that stem from a theoretical framework model. The initial research hypothesis suggests a positive correlation between knowledge management and organizational performance. The correlation coefficient for knowledge management and organizational performance is .158*, indicating a positive association. The level of significance is .000, and the sample size is 158 respondents.

The second research hypothesis posits a positive correlation between learning management and organizational performance. The correlation coefficient for learning management and organizational performance is .255**, indicating a positive relationship. The level of significance is 0.000, and the sample size is 158 respondents.

Third research hypothesis is about knowledge management is positively associated with respect to organizational performance and having mediating effect of organizational capabilities. The correlation value of knowledge management and organizational performance is .158* and having mediation effective of organizational capabilities is .913**, significant level is .000 and sample size n is 158 respondents.

Fourth research hypothesis is about learning management is positively associated with respect to organizational performance and having mediating effect of organizational capabilities. The level of significance is 0.000, sample size is 158 respondents, and the correlational value between learning management and organizational performance is.255**. The moderating influence of organizational capacities is.913**. As a result, the framework of this investigation is supported by all of these research theories.

Hypotheses

The hypotheses are derived by using correlational analysis. The outcome of hypotheses assessment summary is presented in the form of table are assumed below:

Table 3: Hypotheses Assessment Summary

Hypotheses	Correlational Value	Significant Level	Remarks (Admit / Reject
Knowledge Management Is positively associated with respect To organizational performance.	.158*	0.000	Admit
Learning Management Is positively associated	.255**	0.000	Admit
With respect to organizational performance.			
Knowledge Management is Positively associated With respect to organizational performance and Having mediating Effect of organizational capabilities.	.158* and .913**	0.000	Admit
Learning Management is Positively associated With respect to organizational performance and Having mediating Effect of organizational capabilities.	.255** and .913**	0.000	Admit

Research hypotheses, correlational values, levels of significance, and statements designating acceptance or rejection are only a few of the important components that make up the summary of hypotheses evaluation.

According to the first research hypothesis, knowledge management and organizational performance are positively correlated. Knowledge management and organizational performance have a.158* correlation value, which indicates a favorable link. The related comment recommends acceptance, and the level of relevance is noted as.000.

According to the second research hypothesis, learning management and organizational performance are positively correlated. Learning management and organizational performance have a.255** correlational value, which indicates a very significant positive link. The significance level is shown as 0.000, and the comment that follows denotes approval.

According to the third study hypothesis, organizational capabilities also have a mediating role in the relationship between knowledge management and organizational performance. Knowledge management and organizational performance have a.158* correlation value, and organizational capabilities have a.913** mediating influence. The comment indicates acceptance and specifies the level of relevance as.000.

According to the fourth study hypothesis, organizational capacities have a mediating role in the relationship between learning management and organizational performance. Learning management and organizational performance have a.255** correlational value, and organizational capabilities have a.913** moderating influence. The related comment denotes acceptance and the level of significance is noted as 0.000. As a result, each research hypothesis is verified, supporting the investigation's theoretical framework.

Multiple Regression

Table 4: Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.367a	.135	.118	1.57184

a. Predictors: (Constant), Organizational Capabilities, Knowledge Management, Learning Orientation

Organizational performance was the dependent variable, and the findings showed that organizational capabilities, knowledge management, and learning orientation were the main predictors in the model summary. With a score of 36.7%, R indicates that a regression has occurred. The standard error of estimation is 1.57184, the R square value is 13.5%, and the adjusted R square is 11.8%. These values are regarded as acceptable and offer a strong foundation for the development of this inquiry.

Table 5: ANOVA Analysis

ANOVAb						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	59.276	3	19.759	7.997	.000a
	Residual	380.483	154	2.471		
	Total	439.759	157			

a. Predictors: (Constant), Organizational Capabilities, Knowledge Management, Learning Orientation

b. Dependent Variable: Organizational Performance

Frequency analysis is the main emphasis of this ANOVA analysis, as shown by the F value of 7.9%, which indicates that the variation within the model is significant at 0.000. These results are also supported by other related numbers. The findings show that the sum of squares and degrees of freedom are used to evaluate the regression and residual values, with values of (59.276, 380.483, and 3, 154) and mean square values of (19.759 and 2.471) correspondingly. These ANOVA analysis results give a solid foundation for continued development of this inquiry. The following results of the coefficient analysis are listed:

Table 6: Coefficient Analysis

Coefficients					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.535	.690		3. 673	.0 00
Knowledge Management	.409	.118	.278	3. 450	.0 01
Learning Orientation	.675	.158	.349	4. 289	.0 00
Organizational Capabilities	.029	.102	.022	.2 88	.7 73

a. Dependent Variable: Organizational Performance

The main goal of the coefficient analysis, which was developed using multiple regression analysis models, is to find the study variables' best predictors by using standardized coefficients. Using the Beta value, these standardized coefficients are measured. Learning orientation, with a Beta value of.349, is the first and most significant predictor, according to the results. With a Beta value of.278, the second predictor, knowledge management, follows closely behind, and subsequent predictors follow suit. All of these factors are therefore considered important and offer a solid foundation for continued development of this inquiry.

Mediation Analysis

In statistical term mediation analysis plays an active role to properly analyze the real worth of mediation in framework model. The outcome of mediation analysis is presented in the form of table are assumed below:

Table 7: Model Summary

Model Summary				
Mod El	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.399[a]	.159	.142	1.54985

a. Predictors: (Constant), Moderator Variable, Knowledge Management, Learning Orientation

According to the findings, the moderator variable, knowledge management, and learning orientation are the main predictors in the model summary, with organizational performance serving as the dependent variable. R, which represents the regression and represents 39.9%, is used. The calculated R square value is 15.9%, the adjusted R square is 14.2%, and the estimated standard error is 1.54985. These values represent a solid basis for moving this inquiry forward. The following is a summary of the ANOVA analyses' findings:

Table 8: ANOVA Analysis

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	69.848	3	23.283	9.69 3	.000 A
	Residual	369.911	154	2.402		
	Total	439.759	157			

a. Predictors: (Constant), Moderator Variable, Knowledge Management, Learning Orientation

b. Dependent Variable: Organizational Performance

The F value of 9.693%, which shows the variation within the model at a significant level of 0.000, indicates that the main purpose of this ANOVA analysis is to undertake frequency analysis. This judgment is consistent with other related values. With values of (69.848, 369.911 and 3, 154) and mean square values of (23.283 and 2.402), respectively, the sum of squares and degrees of freedom are used to evaluate regression and residual values. The results of the ANOVA analysis lay a strong foundation for the development of this inquiry. Below are the findings of the coefficient analysis:

Table 9: Coefficient Analysis

Coefficients					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.534	.610		4. 157	.0 00
Knowledge Management	.393	.116	.267	3. 377	.0 38 01
Learning Orientation	.711	.153	.367	4. 637	.0 00
Moderator Variable	.255	.120	.158	2. 118	.0 00

a. Dependent Variable: Organizational Performance

The main goal of the coefficient analysis, which was built using mediation analysis models, is to determine the study variables' best predictors using standardized coefficients. The Beta value is a representation of these standardized coefficients. The results show that learning orientation, which has a significant Beta value of.367, is the main and most important predictor. Knowledge management, the second predictor, follows closely behind with a Beta value of.267, and successive predictors continue this trend. All of these factors are therefore regarded as crucial and provide a strong foundation for the development of this inquiry.

V. CONCLUSION, RECOMMENDATION AND FUTURE RESEARCH

Conclusions

It has been concluded that the concept of knowledge management plays an active role in context of any organization. Position of knowledge management cannot be overlooked at any cost, typically in background to well perform business internal and external operation in market. Knowledge management is considered as a source of energy to well perform business activities and also increase high competition in market. The domain for measuring knowledge management is always considered as complex tasks for management to accomplish organizational goals and objectives within set time framework model. This is the key reasons that management should emphasize for increasing the term of knowledge management within their current business setup. Importance of knowledge management is highly dependent upon effective use of operational knowledge management approaches; use the sources of strategic knowledge management, practical implementation of market and strategy, use people skills and abilities for creating more innovation, promotes the real concepts of knowledge and system that lead towards effectively managing and directing structure and parameter in state. The outcome of this investigation demonstrated that knowledge management is always acting of getting people together to accomplish desired organizational goals.

It has been concluded that learning orientation is considered as a part of knowledge management. The concept of learning orientation is increase due to knowledge management to well perform business tasks and meet consumer's obligations. The main operative functional activities of learning orientation are in procedural of focus on present tasks, in order to measure or sort seek new and broaden existing knowledge, use the concepts of actively experiment that directly lead towards seek feedback and reflect in environment. Currently, in the presence of high competitive business environment management of well-known companies are emphasize on learning orientation to create awareness among people for development of new products or services and also improve their existing products or services. It has been observed that failure or success of any companies is highly dependent upon learning orientation of their developed products. This is the key reasons that management should need to develop and establish various organizational strategies for speedup their processes and capturing more consumer's attentions towards their services.

It has been concluded that management of well-known organizations such as Engro Foods, Nestle Pakistan, P & G Pakistan and Coca Cola Pakistan are using the concepts of knowledge management to well execute their product development. The concept of knowledge management is working in procedural of organizational capabilities that directly and indirectly lead towards more organizational performance all around the globe. Knowledge management is known as emerging concept of management. This knowledge management involves within the area of business strategies and practices in order to sort or measure enterprise to create and represent practical implementation of insights and experiences. Management should need to practical implemented organizational capabilities model that shows their value and worth in state. This organizational capabilities of innovation work through creative abrasion, creative agility and create resolution. The key operative functional activities of creative abrasion are the ability to generate ideas by using discourse and debate. Management should need to use creative agility in order to measure the ability to test and experiment by using quick pursuit and adjustment. Creative resolution is known as the ability in order to make integrative decision making powers that combine disparate and opposing ideas as well.

Recommendations

It has been highly recommended that the term knowledge management is considered as an important part of any organizations. Without positive implementation of knowledge management, it's very difficult for management to accomplish organizational goals, tasks and objectives within set time framework model. The domain for measuring the real importance of knowledge management is wide and complex in state. Based on outcome demonstrated that private companies of Pakistan is to be seem within current area of appreciated the potential and value of KM needs. This knowledge management need is to be evaluated in terms of further education in context of principles and specific methodology as best to leverage their knowledge in their organization to evolve transform into learning organization.

It has been high recommended that in order to measure or create a knowledge sharing culture that make a visible connection among sharing knowledge and use effective source of business practical goals and problems. Human resource network is considered as one of the main source of vehicles for sharing knowledge. The source of knowledge management is very helpful tool in order to sort or measure builds a sharing culture and also enhances networks that already exist in state. The outcome of this investigation is associated with respect to the term of knowledge management shows organizational real performance in market. It has been investigated that knowledge management is composed of three key stages. Knowledge management implementation consists of three main stages: the preparatory phase, which occurs before knowledge management is started, the active phase, which occurs when knowledge management is put into practice, and the post-process phase, which includes tasks related to the ongoing management of knowledge. Through the proper use of knowledge management approaches, knowledge management strategies serve as essential tools for effectively managing business operations and developing a competitive edge in the market. These tactics not only help company networks run smoothly, but they also considerably increase competition and support ongoing growth within the changing market environment.

It has been highly recommended that for creating improvement in current business setup management should need to use knowledge auditor services for increasing their overall outcome in market. This knowledge audit is that should be conducted as a pilot study in context of targeted business area. This target business area is very helpful tools for management to capturing more consumers' attentions and on the other side companies increases their value and worth in market by using business sharing knowledge concepts. This term of business sharing knowledge concept is highly dependent upon expert employees by using their skills, knowledge and abilities to accomplish organizational goals according to management requirements.

Future Research

Research "Using Knowledge Management to Enhance Organizational Performance and Effectiveness" limelight and reflects the influence of the knowledge management to well perform business operations in market. Position of knowledge management cannot be overlooked at any cost. However, in future, more researches needs to be conducted on the similar domain researching on the other sectors such as governmental and NGO's as well.

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INFOGAIN PUBLICATION

International Journal of Advanced Engineering, Management and Science (IJAEMS)

Peer-Reviewed Journal

ISSN: 2454-1311 | Vol-9, Issue-11; Nov, 2023

Journal Home Page: https://ijaems.com/

DOI: https://dx.doi.org/10.22161/ijaems.911.2

Performance Enhancement of 5G Networks: Remodeling Power Domain Scheme Through NOMA-MIMO Technologies Integration

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Received: 19 Sep 2023; Received in revised form: 28 Oct 2023; Accepted: 06 Nov 2023; Available online: 13 Nov 2023

Abstract— *The integration of multiple-input multiple-output (MIMO) and non-orthogonal multiple access (NOMA) technologies addresses critical challenges such as massive connectivity, low latency, and high dependability in 5G cellular systems and beyond. However, resolving these issues required additional research, particularly in the case of 5G networks employing MIMO. This involved enhancing and reevaluating parameters like bit error rate, downlink spectrum efficiency, average capacity rate, and uplink transmission outage probability to optimize performance. The devised model utilized Quadrature Phase Shift Keying modulation on selected frequency channels, accommodating users with diverse power location coefficients, signal-to-noise ratios, transmit powers, and bandwidths. Evaluating the proposed model's effectiveness involved testing and comparing results to previous research. Download transmission results demonstrated that MIMO-NOMA significantly improved the bit error rate performance and transmitting power for the best-evaluated user. For uplink transmission, the average capacity rate was used to assess performance, indicating an increase in the average capacity rate for the best user and a decrease in outage probability. Closed-form formulas for bit error rate, spectrum efficiency, average capacity rate, and outage probability for both downlink and uplink NOMA, with and without MIMO, were derived. In essence, adopting MIMO-NOMA led to a remarkable improvement in the performance of all users, even those facing challenges such as interference or fading channels.*

Keywords— ***Multiple-input multiple-output (MIMO), Non-orthogonal multiple access (NOMA); spectrum efficiency (SE); Bit Error Rate (BER); Outage Probability (OP).***

I. BACKGROUND

In recent decades, wireless communication has undergone a significant technological transformation. The evolution from basic voice communication to highly interactive communication has necessitated high data rates and uninterrupted connectivity. Additionally, there is a surging demand for mobile devices. To address future requirements, researchers are actively developing fifth-generation (5G) and beyond-fifth-generation (B5G) wireless communication networks. Non-orthogonal multiple access (NOMA) emerges as a promising scheme for these networks, capable of meeting the escalating needs of a vast user base, connectivity demands, cost-effectiveness, limited bandwidth, and extensive coverage requirements. However, the implementation of NOMA in wireless communication networks comes with both challenges and advantages.

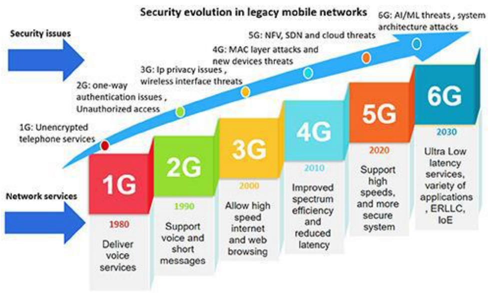

Fig.1.1: Evolution from 1G to 6G (B5G)

In order to address the limitations of 5G and beyond fifth-generation technologies and establish innovative technological pathways for spectrum efficiency and energy efficiency at minimal costs, exploring multiple-access systems becomes imperative to partially mitigate these challenges. The conventional orthogonal multiple access (OMA) schemes employed in 1G through 4G cellular networks, allocating different frequencies, resource blocks, time slots, or codes to individual users, prove insufficient to handle the anticipated high demands for network traffic and user density in the future. The fundamental advantage of orthogonality lies in assigning various resources to users, ensuring zero interference while accessing network resources (Kalra and Chauhan, 2014) [1].

In NOMA, numerous users within the same cell simultaneously share a single frequency channel, offering advantages such as improved cell-edge throughput, enhanced spectrum efficiency, loose channel feedback, and reduced transmission delay. NOMA outperforms conventional OMA by servicing multiple customers simultaneously using the same frequency resource and employing successive interference cancellation to reduce interference and achieve superior spectral efficiency. It facilitates large-scale connectivity, accommodating a vast number of users. The simultaneous transmission nature of NOMA enforces a set time period for information delivery, reducing latency. NOMA's flexible power control between strong and weak users ensures user fairness and accommodates different quality of service (QoS) requirements (Ahmad, 2016) [2], ultimately leading to a superior user experience and enhanced cell-edge throughput.

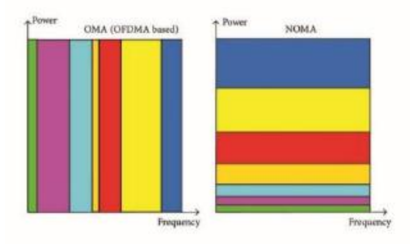

Fig.1.2: Comparison of OMA and NOMA

NOMA has garnered considerable attention as a multiple access method for long-term evolution (LTE) systems. Various NOMA applications are under scrutiny within the third-generation collaboration project (3GPP). In LTE Release 12, NOMA was incorporated for inter-cell-interference (ICI) mitigation as an extension of the network-assisted interference cancellation and suppression (NAICS) (3GPP, 2014).

The goals of achieving user connections, system capacity, and service latency can all be realized through NOMA. Recent advancements in standardization, a unified transceiver design framework, and intriguing use cases in future cellular networks form the basis of the improved NOMA transmission approach. Notably, ongoing 3GPP research, initiated in LTE Release-13, predominantly focuses on downlink transmission. Release-15 shifts the focus to uplink transmissions, emphasizing newly defined grant-free transmission processes with high reliability, low latency, and extensive connectivity in NOMA schemes (Chen et al., 2018) [3].

Despite the numerous benefits of NOMA-assisted wireless communication, several challenges must be addressed to establish an effective communication environment (Vaezi et al., 2019b) [4]. Receiver complexity poses a concern, as each user, even with the worst channel conditions, is required to decode the information of every other user, potentially leading to a more sophisticated and energy-intensive receiver. Serving the maximum number of users encounters hurdles due to increased error risks while decoding information from all users, limiting the serviceable user count. Achieving the intended functionality of the power domain concept in NOMA necessitates sufficient channel gain differences among users. (Vaezi et al., 2019b) [4].

Dai et al. (2018a) [5] provide a comprehensive review of

NOMA fundamentals, contrasting it with OMA and comparing power domain-NOMA (PD-NOMA) and code domain-NOMA (CD-NOMA) in terms of spectrum efficiency, complexity, and performance. Islam et al. (2018) [6] delve into various aspects of downlink PD-NOMA, including different user pairing methods, power allocation, and practical considerations. Lu et al. (2017) [7] conduct an extensive examination of NOMA fundamentals, recent developments, and future research trends, with a focus on comparing NOMA and OMA from an information theory perspective. Vaezi et al. (2019a) [8] cover the flexible integration of NOMA with MIMO, mmWave, CC, CR, security, and energy harvesting.

NOMA (Non-Orthogonal Multiple Access) is poised to shape the future of network technology, finding applications in 5G and beyond. It outperforms OMA, particularly in serving more clients by employing multiplexing in power and code domains. SC and CIC techniques in the receiver facilitate power-domain multiplexing in the transmitter. NOMA aims to enhance spectrum efficiency while ensuring fairness for all users. The grant-free NOMA uplink holds promise for reducing latency, communication overhead, and terminal power consumption in low-traffic or free applications. NOMA, along with tiny cells, contributes to increasing 5G capacity, making it a key player in future network evolution [10].

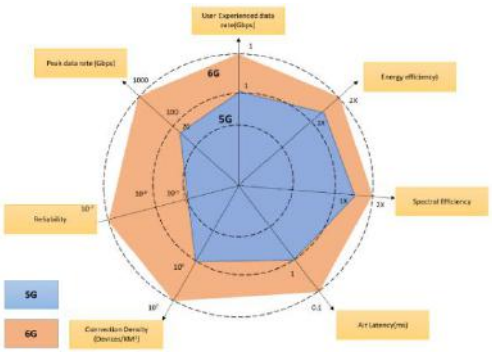

Fig.1.3: Performance requirements between 5G and 6G [24]

In the context of power regulation and allocation mechanisms, the deployment of small cells proves instrumental in managing network traffic load, thereby enhancing Quality of Service (QoS) [11]. Furthermore, the introduction of the "New Radio" (NR) principle in new radio access technologies contributes solutions to address 5G-related challenges. 5G incorporates additional enhancements such as new operational frequency bands, Multiple Input Multiple Output (MIMO), Millimeter Wave (mmWave), and Non-Orthogonal Multiple Access (NOMA). NOMA is particularly favored over Orthogonal Multiple Access (OMA) due to its capability to handle a comparatively higher number of subscribers [11]. The categorization of NOMA under multiple access schemes is presented below:

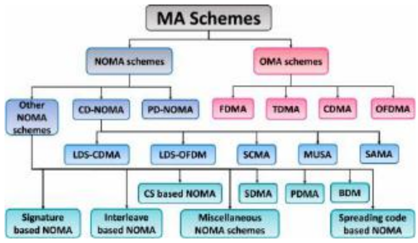

Fig.1.4: NOMA Classification Schemes

NOMA B5G (Beyond 5G)/6G Systems Applications

The impact of technology on human lifestyle is profound, with wireless technologies transforming various aspects such as businesses, infrastructure, and living conditions. The constant search for innovative solutions and avenues for progress has driven the evolution of wireless communication from 1G to 5G, and the journey continues with efforts towards 5G and Beyond 5G (B5G) connectivity by dedicated researchers.

Over a brief span of five years, from 2016 to 2021, mobile data traffic has surged sevenfold, highlighting the rapid pace of development (Benisha et al., 2019) [12]. However, the exacerbation of congestion on a daily basis underscores the inadequacy of available spectrum to meet these escalating demands. The existing network generations—1G, 2G, 3G, and 4G—fall short in ensuring seamless connectivity, leading to the exploration of innovative approaches such as Non-Orthogonal Multiple Access (NOMA).

In recent decades, numerous NOMA schemes have emerged, addressing various applications and use cases. The implementation of NOMA holds promise for enhancing Energy Efficiency (EE) and spectral efficiency in upcoming 5G and B5G wireless communication networks.

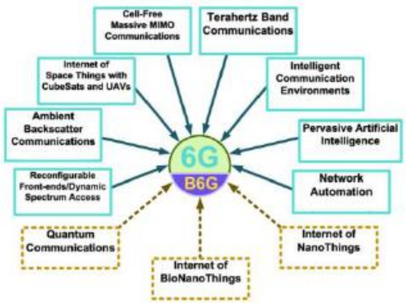

Fig.1.5: Enabling Technologies for 6G and beyond wireless communications systems [25]

The exponential growth of users has led to an increased demand for data rates and connectivity. Addressing these needs can be achieved through cutting-edge technical trends, such as NOMA-assisted Base Stations (BS) [13]. As fifth-generation (5G) mobile communication technology is currently widely accessible, attention is shifting towards the next generation, B5G. The new B5G applications are expected to have additional demands and a larger network capacity compared to current 5G networks. Therefore, the future wireless networks, particularly in the form of sixth-generation (6G) applications, are anticipated to play a key role in various aspects of our lifestyle, economic sectors, and social structures [13]. The wireless networks will serve as the communication channel between people and intelligent machines, emphasizing the need for enhancement and collaboration between the scientific community and industry [13]. By 2030, wireless networks are expected to accommodate increased needs, supporting demanding applications like virtual, augmented, and mixed reality, as well as remote control of delicate operations.

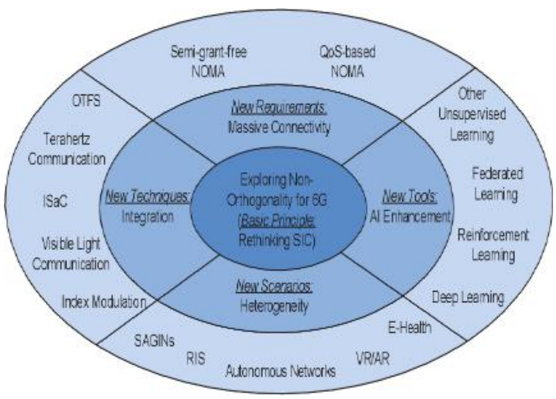

Fig.1.6: Application of NOMA in B5G Networks [26]

Until the year 2030, a plethora of new application possibilities will continue to surface, categorized into three groups: intelligent production, intelligent life, and intelligent society. [14] These categories serve to organize various scenarios, with post-2030 use cases being exemplary instances as identified by Sodhro et al. (2020) and Khan et al. (2020).

- ***Smart Production***

By integrating emerging technologies into business and agriculture, the digital economy has the potential to expand significantly. B5G will leverage information technology to achieve intelligent manufacturing.

- ***Smart Life***

In 2030, the network connecting twin physical locations, coupled with online synesthesia and intelligent interaction, is anticipated to revolutionize our way of life.

- ***Smart Society***

By 2030, the widespread coverage network is expected to substantially extend public service coverage, effectively eliminating regional digital divides. The implementation of a 6G network is poised to enhance overall social governance, establishing the foundation for a more stable society. The applications of B5G are detailed in the table below.

Table 1.1: Beyond 5G/6G Applications [15]

	5G	Use Cases	6G	Use Cases
Data Rate	1 – 10 *Gb/s*	Telemedicine	100 *Gb/s* – 1 *Tb/s*	3D holographic AR/VR Robotics Arm
Coverage Extension	0.1 km	The limited scale of IoT network	3D coverage scenarios (10000 m (Sky, 200NM (sea)	Terrestrial, aerial, space and sea domain, massive-scale IoT network
Power Consumption	10 years battery life	IoT devices	50 times improvements compared to 5G, nearly (1 Tb/J)	Wearable user devices Zero energy devices
End-to-End Latency	1–5 *ms*	Vehicular Networks Military Services	< 1 *ms*	Healthcare Networks AR/VR Unmanned Ariel Vehicle (UAV) Robotics Arm
Reliable Communication	99.9%	Vehicular Networks Telemedicine	~ 99.9999%	Healthcare Networks AR/VR Unmanned Ariel Vehicle (UAV) Robotics Arm
Massive Connectivity and Sensing	1 $milliondevice/km^2$	IoT devices	10 $milliondevice/km^2$	Wearable user devices AR/VR IoE
Frequency Extension and Improved Spectrum	3 – 300 *GHz*	mmWave for fixed access	Up to 1 *THz*	mmWave Sub-6 GHzExploration of THz bands (above 300 GHz) high-definition imaging and frequencyNon-RF (e.g., optical, VLC) spectroscopy localization
Mobility and speed supportive	500 *km/hr*	Vehicular Networks	1000 *km/hr*	Terrestrial, space, sea, aerial, and airline

NOMA-MIMO Technologies

To expedite the development of future intelligent wireless systems, it is imperative to design an energy-efficient Massive multiple-input-multiple-output (MIMO)-non-orthogonal multiple access (NOMA)-aided Internet of Things (IoT) network. Such a network should be capable of accommodating a large number of distributed users and IoT devices, ensuring seamless data transfer and connectivity. The distinctive features of Massive MIMO make it a suitable technology for implementing an energy-efficient IoT network in beyond 5G (B5G) communications, given its utilization of a substantial number of antennas. However, the challenge lies in providing swift data transfer and maintaining hyper-connectivity between IoT devices in B5G communications, posing an energy challenge.

Numerous studies have demonstrated that Non-Orthogonal Multiple Access (NOMA) outperforms Orthogonal Multiple Access (OMA) in terms of performance. NOMA excels in meeting high-demand requirements, including extremely low latency, high spectral efficiency, increased network capacity, and elevated connectivity demand. Additionally, MIMO is acknowledged as a highly adaptable technology capable of enhancing capacity by increasing the potential data rate. In comparison to the combination of MIMO and OMA, MIMO and NOMA (MIMO-NOMA) are anticipated to achieve a higher capacity than MIMO and OMA (MIMO - OMA) [27].

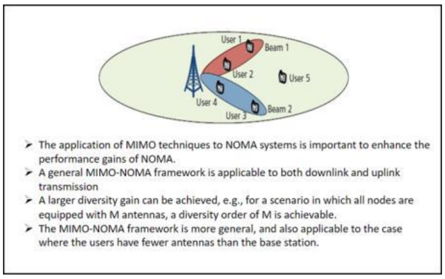

Fig.1.7: NOMA in Massive MIMO System [30]

The requirements for next-generation technology encompass high data rates, substantial spectrum efficiency, successive interference cancellation (SIC), and ultra-reliable low latency (URLL). In the domain of next-generation technologies, the non-orthogonal multiple access (NOMA) scheme is favored over the orthogonal multiple access (OMA) scheme. NOMA presents advantages such as multi-user scaling (multiplexing), optimal spectral efficiency (SE), notable user-pairing improvement, and the capability for multiple users to share a single resource block. To identify the optimal power allocation algorithm for multiple-input multiple-output-NOMA (MIMO-NOMA) technology, researchers conducted comparative analyses of various power allocation algorithms [28].

A multiple input multiple output (MIMO) structure can enhance the overall capacity of modern communication networks without requiring excessive power or bandwidth. To meet the demands for higher user data rates and improved spectrum efficiency, the non-orthogonal multiple access (NOMA) configuration is a fitting candidate for integration with the MIMO structure. The dynamic uniform channel gain difference (DUCGD) user pairing technique plays a significant role in maximizing the capacity of all paired and served users [29]. In summary, the depiction of NOMA in B5G Systems using the MIMO Technique is presented in the figure below.

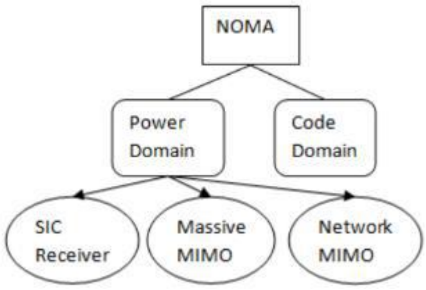

Fig.1.8: NOMA in B5G Systems using MIMO Technique [31]

NOMA technology has been predominantly categorized by researchers into two types: the power domain and the code domain. In the power domain, additional subcategories include the SIC Receiver and Massive MIMO. In Massive MIMO, multiple antennas are employed at both the source and destination points of wireless communication [31].

Artificial Intelligence application to NOMA implementation

Cellular devices and emerging wireless applications are experiencing explosive growth within wireless systems. To support extensive connectivity and high data speeds in constrained environments, research into advanced multiple access technologies, including next-generation multiple access (NGMA), is essential [16]. Non-orthogonal multiple access (NOMA), identified as a potential multiple access method, is considered a crucial component of NGMA. Particularly, the integration of NOMA and multiple-antenna technology has garnered significant interest, revealing substantial connectivity potential [17] [18].

Despite the potential of NGMA, the intricate multi-domain multiplexing makes interference suppression and system optimization more challenging. The communication design of next-generation NOMA systems often leads to a highly complex nonconvex mixed-integer nonlinear programming (MINLP) problem, with the globally optimal solution being extremely difficult to obtain. Recent advances in AI offer opportunities to overcome these challenges, providing automated communication designs to combat the overwhelming complexities [19] – [22]. This has led to investigations into promising and advanced machine learning (ML) methods to empower NGMA through AI. The integration of AI/ML in the planning process of mobile networks is illustrated below.

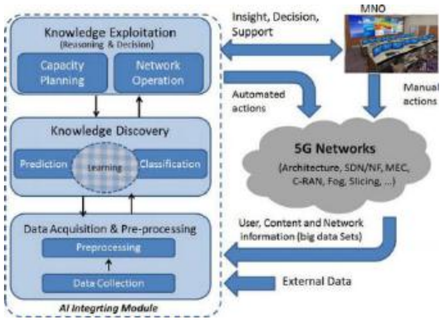

Fig.1.9: Integrating AI/ML in the planning process of mobile networks [32]

AI has the capability to train deep neural networks (DNNs) to approximate optimal solutions for challenging problems, leveraging the exceptional ability of deep models to fit arbitrary functions. The optimal solutions, considered as a non-convex function mapping the system state to optimization variables, can be learned automatically by AI, eliminating the need for expert knowledge and hand-engineered parameter initialization required by traditional optimization methods [23].

Supervised learning, focused on approximating pre-labeled solutions, and unsupervised learning, directly minimizing unsupervised variables, are two main approaches. Common machine learning models in wireless communications include the multi-layer perceptron (MLP) and convolutional neural network (CNN). Reinforcement learning is typically employed for long-term optimization problems modeled using the Markov decision process (MDP). Each base station (BS) is treated as an autonomous agent interacting with its environment to continually enhance decisions through trial and error. It observes the system state at each time slot to determine the optimization variables (actions) and maximize the accumulated discount reward.

The emerging AutoML paradigm [23], which includes hyper-parameter optimization (HO), neural architecture search (NAS), and meta-learning, can be combined to automate the configuration of learning models, significantly reducing human interventions and improving performance. NAS can automatically optimize hyperparameters and neural architecture, while meta-learning aims to create a general initial model quickly adapting to previously unseen communication scenarios. These AutoML techniques can serve as add-on modules to assist NGMA communications based on the requirements of different application scenarios. The figure below illustrates the applications of AI (deep learning) in various layers of B5G Systems.

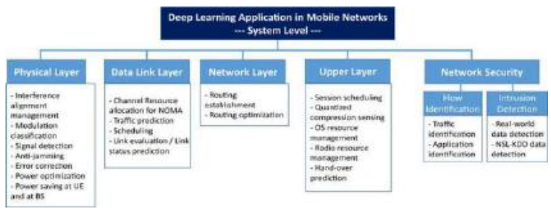

Fig.1.10: Applications of AI (deep learning) in different layers of B5G Systems [33]

To extend the scope of current multiple-antenna NOMA schemes, a novel AI-powered cluster-free NOMA framework has been suggested by researchers. This framework facilitates highly flexible Successive Interference Cancellation (SIC) operations. Nevertheless, the exploration of AI-enabled Next-Generation Multiple Access (NGMA) is still in its initial phases.

Model-based constrained ML for NGMA

NGMA communication design frequently involves non-convex, coupled, and mixed-integer constraints. Learning algorithms often address constraint violations by converting them into loss functions or employing projection operations to discover feasible solutions, even though their capacity to strictly enforce these constraints is limited. Recently, the introduction of the Lagrangian dual method and the interior point method for model-based machine learning has demonstrated the potential of guiding machine learning with constrained optimization theory. This has sparked researchers' interest in exploring model-based constrained machine learning for NGMA communication design.

ML empowered dynamic multi-objective optimization for NGMA

As next-generation wireless systems exhibit time-variant and heterogeneous characteristics, communication design will encounter various competing optimizations, such as system rate objectives, energy consumption, traffic latency, outage probability, and more. Moreover, the dynamic nature of wireless environments can cause these competing objectives and constraints to evolve over time, challenging the prediction of the changing Pareto optimal front. To facilitate dynamic multi-objective optimization, it is essential to explore efficient multitask machine learning methods.

Accelerating AutoML for NGMA

Although machine learning can forecast favorable solutions efficiently through low-complexity forward propagation, the training phase, typically carried out via back-propagation, often demands substantial datasets and imposes notable computational demands. When incorporating AutoML techniques like meta-learning and NAS, the training process can become even more time-consuming and computationally intensive. The challenge lies in addressing the critical research problem of constructing high-performance lightweight models and enhancing AutoML to mitigate training costs for Next-Generation Multiple Access (NGMA).

Problem Statement

In the context of the hybrid technology environment, the integration of MIMO and NOMA technologies is essential to tackle numerous challenges in 5G and B5G cellular systems, addressing issues related to massive connectivity, low latency, and high dependability. The performance of users is particularly affected by interference and fading in the channels, which can hinder connections. However, an increase in the number of antennas and bandwidth in a 5G network, without concurrent improvements in fading characteristics, may lead to performance degradation. This can manifest as a higher bit error rate (BER) and lower spectrum efficiency (SE) for the downlink, as well as a reduced average capacity rate and increased outage probability (OP) for the uplink.

Purpose of the Study

The existing research is focused on achieving improvements in these parameters, and the study will address these objectives.

• Developing an integrated network architecture that combines multiple-input multiple-output (MIMO) and non-orthogonal multiple access (NOMA) technologies in a hybrid configuration.

• Creating a network model focused on achieving massive connectivity, low latency, and high dependability by implementing MIMO-NOMA to address challenges related to near/far user scenarios.

• Enhancing the performance of a B5G network by addressing bit error rate, spectrum efficiency (downlink), average capacity rate, and outage probability (uplink) through the utilization of MIMO technology.

• Analyzing the performance of downlink NOMA in terms of bit error rate and spectral efficiency for different distances, power location coefficients, transmitted power, and bandwidths.

• Analyzing the performance of uplink NOMA in terms of average capacity rate and outage probability for various distances, signal-to-noise ratio, and bandwidth.

II. BACKGROUND LITERATURE

Wireless Communication

Wireless communication has rapidly progressed in the last decade, driven by the widespread use of smart mobile devices and engaging multimedia applications [34,35]. A promising approach to achieve enhanced performance has been proposed: non-orthogonal multiple access (NOMA), aiming to preserve spectral efficiency and ensure widespread accessibility [36,37]. NOMA employs successive interference cancellation (SIC) in receivers with noise, allowing the reception of signals while adjusting the power levels of overlay user signals at the transmitter. This approach limits bandwidth usage for undesired channels and optimizes user rates for desirable channels [38-41].

Non-orthogonal multiple access (NOMA)

Because NOMA involves sequential interference cancellation, SIC is implemented at the power user level, enabling the detection and exclusion of users with stronger channel conditions. Emphasis is placed on extracting data from users with superior channel conditions and weaker interfering users [42]. In the NOMA downlink (DL) system, where power fields are multiplexed, multiple users share the same time, coding, and frequency resources. Each user receives an overlay signal from the base station (BS), encompassing signals for all users [43]. By eliminating the need for users to wait for an orthogonal resource block, NOMA supports extensive connections while significantly reducing transmission delay [44].

In the context of the next-generation communication system, NOMA with SIC stands out as a promising multiple-access strategy [45]. NOMA, as a wireless technology, can meet the demands of the current wireless environment [46]. The assessment of various access technologies is an evolving area [47], and as new features continue to emerge, the primary research focus is on determining spectrum efficiency [48,49].

In uplink (UL) NOMA, multiple users simultaneously transmit signals to their respective BS [50,51]. Consequently, intra-cluster interference impacts a user's received signal, influenced by the channel data of other users [52]. Minimizing interference is crucial, and the BS decodes communications via SIC. Successful application of the SIC approach requires separate message signals with sufficient strength variance to reach the BS receiver. This is typically managed by using various scales at the transmitter in the DL. However, in the UL, the channel gains already provide adequate signal separation, making such adjustments unnecessary. The UL standard emphasizes power control, which is not recommended for UL NOMA broadcasts, as it could compromise channel distinctness to balance the received signal levels of users [53–57].

Multiple-input multiple-output (MIMO)

The capacity of a radio communication channel can be significantly enhanced by deploying multiple antennas in both the transmitter and receiver. In other words, multiple-input multiple-output (MIMO) technology allows the management of numerous independent channels within the same bandwidth, provided the propagation environment is sufficiently rich, but this holds true only with specific antennas [58,59]. While the use of MIMO techniques introduces a new dimension for improving efficiency, recent research has shown considerable interest in the integration of MIMO and NOMA [59,60].

The bit error rate (BER) of the downlink (DL) NOMA network, created in a closed form for BPSK modulation in both perfect and deficient successive interference cancellation (SIC) states, was explored using additive white Gaussian noise (AWGN) and Rayleigh fading channels. Notably, this exploration did not incorporate BER-influencing variables such as distance and power location coefficients [61]. To maximize the power allocated to each NOMA, three power assignment algorithms are proposed in [62,63].

Bandwidth, Average Capacity Rate, Outage Probability, Bit Error Rate & Spectrum Efficiency

Researchers investigated the impact of varying bandwidth and the number of antennas in a 5G network on the uplink's average capacity rate and outage probability (OP), as well as the downlink's bit error rate (BER) and spectrum efficiency (SE), revealing the influence of Rayleigh fading on the network. Analytical processes yielded integral expressions for BER, SE, capacity rate, and OP, and modeling was employed to explore all conceivable system configurations. The study proposed and examined different bandwidths (BWs) for the NOMA system across a Rayleigh fading channel. System enhancements were observed when NOMA and MIMO were integrated to support users. The research focused on the NOMA approach, a fundamental element of 5G technology, with the central idea being the redesign of NOMA-MIMO in the power domain to enhance data rate, capacity, and throughput. This was achieved by proposing a novel NOMA-MIMO power domain architecture.

Proposed Research Literature

As per the author in [65], NOMA systems employ multiple beams forming with a single carrier to accommodate multiple users, utilizing a two-stage beamforming solution with modular beamforming vectors. The design addresses the challenge of shaping transmission packets overall, aiming to identify the power and packet-shaping vectors of users.

MIMO-NOMA Performance

The potential of NOMA can be realized even when users have comparable initial channel conditions, as demonstrated by the author in [66], who devised effective precoding and detection processes to create a significant difference in users' effective channel gains. The performance of MIMO-NOMA was explored when multiple users were combined into a single group, revealing that MIMO-NOMA outperforms MIMO-OMA in terms of total channel capacity and overall practical capacity [67]. The research in [63] addressed the ergodic capacity maximization problem for selective Rayleigh fading MIMO-NOMA systems, utilizing statistical channel state information at the transmitter. The results indicated that MIMO-NOMA techniques exhibit significantly better performance than traditional OMA schemes.

An experimental evaluation in [68] assessed the performance of NOMA downlink integrated with MIMO in real-world scenarios, exploring the integration of NOMA downlink with MIMO as a concept for user connection in the uplink. The author considered various defined power allocation approaches in [69] and demonstrated that NOMA with the proposed user pair strategy performs better than NOMA with the previously discussed signal realignment method. [70] examined multiple NOMA downlink and uplink user power field-based communication systems with various fading conditions for all users adhering to one of several feasible distributions. Analytical formulations of the outage probability (OP) for NOMA downlink and uplink systems were developed, particularly when signal-to-noise ratios (SNRs) are high.

Analytical expressions of OP were further explored in [71], focusing on an unmanned aerial vehicle-assisted NOMA network with uplink and downlink transmissions. The author investigated a unique uplink/downlink NOMA system with a uniform relay and set decoding to enhance fairness and application using statistical channel state information [72].

Correlation Similarity for NOMA Effectiveness

In [73], a strategy for identifying correlation similarity is proposed. The author examined the effectiveness of various NOMA schemes over the tapping delay line channel, considering both regular and high-speed user equipment (UE) mobility, and explored correlation-level modeling in [73-75]. Different NOMA techniques and UE rapid speed operate in distinctive manners.

The potential of NOMA for 5G cellular networks was originally discovered by Saito et al. [76], who also demonstrated that NOMA outperforms OMA in terms of capacity and user fairness. Since then, researchers worldwide have started investigating the application of the NOMA principle to the next generation. Early NOMA research focused on single-input single-output (SISO), where user fairness and power allocation were primary concerns. NOMA's power distribution strategy considers user fairness and sum rate while maximizing the sum rate. This approach ensures that the powerful user does not dominate completely if the goal is to maximize the sum. The dynamic power allocation scheme presented in [77] guarantees that individual rates for both strong and weak users in NOMA are higher than their counterparts in OMA. [78] considers max-min data rate and min-max outage probability, respectively, focusing on user fairness.

Combining MIMO and NOMA

The rapid evolution of wireless communication in recent years has been fueled by the widespread adoption of smart mobile devices and multimedia applications. A promising multiple-access strategy for the next-generation communication system is non-orthogonal multiple access (NOMA) with successive interference cancellation (SIC). Despite ongoing evaluations of various access technologies, research groups are still working to determine the most efficient use of spectrum as new features continue to emerge.

Combining NOMA with multi-input multi-output (MIMO) technology can further enhance performance. In MIMO-NOMA, users are grouped into clusters, and NOMA is exclusively employed within those clusters. Although finding the optimal user pairing necessitates an exhaustive search, [79] employs random pairing to reduce computational costs. Furthermore, [80] suggests a greedy user pairing method, leveraging channel correlation and gain differences to achieve performance close to the ideal scenario. Users within the same cluster share a common precoding vector in MIMO-NOMA, dividing the MIMO channel into multiple parallel single-input single-output (SISO) channels. Consequently, NOMA maintains superiority over orthogonal multiple access (OMA) [81]. [80] explores a comprehensive MIMO-NOMA framework utilizing zero-forcing precoding and signal alignment-based detection to eliminate inter-cluster interference. The paper assumes perfect instantaneous channel state information (CSI) for MIMO settings, acknowledging that this assumption may not be feasible to achieve in practice. Sun et al. investigate optimum and low-complexity suboptimal power distribution strategies to enhance power efficiency. Additionally, [82] analyzes the ergodic capacity of a two-user MIMO-NOMA system, considering total transmit power and the minimum rate constraint of the weaker user. [83] proposes a NOMA strategy for a large MIMO system while considering limitations on feedback channels.

The aforementioned research has primarily focused on single-cell systems, with multi-cell networks introducing the challenge of inter-cell interference (ICI). Researchers are beginning to explore the performance of NOMA in multi-cell networks, suggesting synchronized beamforming strategies in [84] to address ICI in a two-cell MIMO-NOMA network. NOMA also shows promise for communications using visible light [86] and millimeter-wave (mmWave) [85].

III. RESEARCH METHODOLOGY

Research methodology followed a series of steps, including formulating research questions, developing a research design with the selection of a research method, analyzing data through diverse methods, drawing conclusions based on the results, and communicating findings. The primary objective is to integrate multiple-input multiple-output (MIMO) and non-orthogonal multiple access (NOMA) technologies to address challenges faced by B5G cellular systems, including massive connectivity, low latency, and high dependability. However, a literature gap exists concerning the impact of MIMO on parameters like bit error rate (BER), downlink spectrum efficiency (SE), average capacity rate, and uplink outage probability (OP) for B5G. Current research focuses on achieving improvements in these parameters. The research aims to design an integrated network architecture based on MIMO and NOMA, enhancing BER, downlink SE, average capacity rate, and uplink OP in B5G networks. The study will also analyze downlink NOMA performance for various conditions and uplink NOMA performance under different scenarios.

The role of the researcher involves evaluating the performance of DL and UL NOMA PD in a 5G network with and without 64 x 64 MIMO technologies. The study analyzes BER and SE performance of DL NOMA under various parameters and examines average capacity rate and OP performance of UL NOMA in different conditions. The introduction of 64 x 64 MIMO technology enhances DL NOMA performance, addressing near-far user issues and improving overall user performance. The researcher contributes by leveraging MIMO technology, significantly improving the performance of all users.

In the methodology section, NOMA systems using multiple beams and a two-stage beam forming solution are described. Researchers have developed effective precoding and detecting techniques to create a significant gap in effective channel gains, enabling optimal NOMA performance. Studies on MIMO-NOMA reveal superior performance compared to MIMO-OMA in terms of total channel capacity and practical capacity. Ergodic capacity maximization for selective Rayleigh fading MIMO-NOMA systems is explored using statistical channel state information. Experiments evaluate NOMA DL integrated with MIMO and analyze UL NOMA with various power allocation techniques. Additionally, unmanned aerial vehicle-assisted NOMA networks and a novel UL/DL NOMA system are examined. Another method for finding correlation similarity is proposed, exploring NOMA plots under diverse UE speeds and correlation-level modeling.

In this research, the researcher came up with two scenarios.

- Downlink (DL) Scenario
- Uplink (UL) Scenario

- ***Data Collection - Downlink (DL) Scenario***

Shown below is the Downlink (DL) Design.

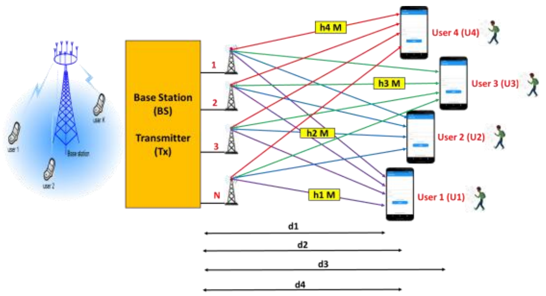

Fig.3.1: Wireless Network - 4 Users (64 × 64 MIMO-DL-NOMA) Power Domain

The table below shows various parameters of the conceptualized design. hT1

Table 3.1: Design Parameters

S/No	Design Parameters	Notation
1	Bandwidth	80 MHz, 200 M
2	Users (4 Users)	U1, U2, U3, U4
3	Distance of Users from the Base Station (BS)	d1, d2, d3, d4
4	Rayleigh Fading Coefficients	hT1, hT2, hT3, I

The distances from the base station vary, with users positioned at different proximities to the base station. The formulas employed for these calculations are presented below, along with references indicating their sources or utilization:

Table 3.2: Design Formulas (DL)

S/No	Description	Formula	Referenc
1	* Total Rayleigh fading channel (each user)	$h_{Ti} = \sum_{i=1}^{M} h_{Ti}$	[87]
2	* Base Stations Encoded Overlay Signal	$x = \sqrt{P}(\sqrt{\alpha_1}x_1 + \sqrt{\alpha_2}x_2 + \sqrt{\alpha_3}x_3 + \sqrt{\alpha_4}x_4)$	[88 - 89
3	* U Rate R1	$R_1 = \log_2\left(1 + \frac{\alpha_1 P\|h_{T1}\|^2}{\alpha_2 P\|h_{T1}\|^2 + \alpha_3 P\|h_{T1}\|^2 + \alpha_4 P\|h_{T1}\|^2 + \sigma^2}\right)$	[88]
4	* U Rate R2	$R_2 = \log_2\left(1 + \frac{\alpha_2 P\|h_{T2}\|^2}{\alpha_3 P\|h_{T2}\|^2 + \alpha_4 P\|h_{T2}\|^2 + \sigma^2}\right)$	[88]
5	* U Rate R3	$R_3 = \log_2\left(1 + \frac{\alpha_3 P\|h_{T3}\|^2}{\alpha_4 P\|h_{T3}\|^2 + \sigma^2}\right)$	[88]
6	* U Rate R4	$R_4 = \log_2\left(1 + \frac{\alpha_4 P\|h_{T4}\|^2}{\sigma^2}\right)$	[88]
7	* Spectrum Efficiency	$SE = \frac{Th}{BW}$	[88]

*Where;

i = 1, 2, 3, 4

M (No of Channels) = 64

Power Coefficients = α1, α2, α3, α4 where α1 > α2 > α3 > α4

QPSK Formed Messages = x1, x2, x3, x4

R = U Rate

P = Maximum Power

SIC = Successive Interference Cancellation

SE = Spectrum Efficiency

Th = Throughput

BW = Bandwidth

Conceptualized wireless network consists of a 64 x 64 MIMO system and four DL NOMA users, namely U1, U2, U3, and U4, each with different bandwidths of 80 and 200 MHz. Various distances of the users from the base station are represented by d1, d2, d3, and d4, where d1 > d2 > d3 > d4, indicating the preferred order. Depending on the distance, U1 is considered the weak/far user, while U4 is regarded as the strong/near user from the base station. The selective Rayleigh fading coefficients are identified as hT1, hT2, hT3, and hT4 correspond to |hT1|2 < |hT2|2 < |hT3|2 < |hT4|2.

- ***Data Collection - Uplink (UL) Scenario***

The power domain multiplexing approach in uplink NOMA differs notably from downlink NOMA. In downlink NOMA, the base station (BS) employs superposition coding to achieve power domain multiplexing. In contrast, for uplink NOMA, users are only limited by their battery capacity, enabling both users to transmit at full strength. As a result, fluctuations in the users' channel gains lead to variations in the power domain observed by the BS receiver.

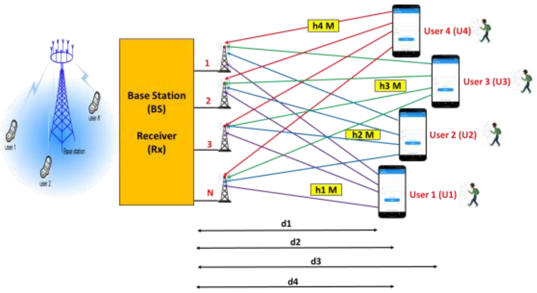

Fig.3.2: Wireless Network - 4 Users (64 × 64 MIMO-UL-NOMA) Power Domain

Assuming a 64x64 MIMO system and a bandwidth of 80 MHz in a wireless network, let x1, x2, x3 and x4 denote the messages that will be transmitted by four UL NOMA users - U1, U2, U3, and U4 - respectively, with both users' signals having the same strength. The various distances of the users from the base station (BS) are represented by d1 > d2 > d3 > d4, with d1 > d2 > d3 > d4 being the preferred order. Depending on the distance, U1 is the weak/far user from the BS, while U4 is the strong/near user. The selective Rayleigh fading coefficients are identified as hT1, hT2, hT3, and hT4 where |hT1|2 < |hT2|2 < |hT3|2 < |hT4|2, indicating the relationship between the coefficients and the users. The formulas used for the calculations are shown below along with their references from where these were taken or used:

Table 3.3: Design Formulas (UL)

S/No	Description	Formula	Referenc
1	* Total Rayleigh fading channel (each user)	$h_{jT} = \sum_{i=1}^{N} h_{iT}$	[87]
2	* Signal Received at the Base Station	$y = \sqrt{P_{1T}}h_{1T} + \sqrt{P_{2T}}h_{2T} + \sqrt{P_{3T}}h_{3T} + \sqrt{P_{4T}}h_{4T} + w$	[88] [89 [90]
3	* Maximum rate User 4	$R_{U4} = \log_2\left(1 + \frac{P\|h_{4T}\|^2}{P\|h_{3T}\|^2 + P\|h_{2T}\|^2 + P\|h_{1T}\|^2 + \sigma^2}\right)$	[91] [92
4	* Maximum rate User 3	$R_{U3} = \log_2\left(1 + \frac{P\|h_{3T}\|^2}{P\|h_{2T}\|^2 + P\|h_{1T}\|^2 + \sigma^2}\right)$	[91] [92
5	* Maximum rate User 2	$R_{U2} = \log_2\left(1 + \frac{P\|h_{2T}\|^2}{P\|h_{1T}\|^2 + \sigma^2}\right)$	[91] [92
6	* Maximum rate User 1	$R_{U1} = \log_2\left(1 + \frac{P\|h_{1T}\|^2}{\sigma^2}\right)$	[91] [92
7	* Capacity U4 (specific target rate)	$C_4 = \sum_{i=1}^{N} \log_2\left(1 + \frac{P\|h_4\|}{P\|h_3\| + P\|h_2\| + P\|h_1\| + N_0}\right)$	[91] [92
8	* Capacity U3 (specific target rate)	$C_3 = \sum_{i=1}^{N} \log_2\left(1 + \frac{P\|h_3\|}{P\|h_2\| + P\|h_1\| + N_0}\right)$	[91] [92
9	* Capacity U2 (specific target rate)	$C_2 = \sum_{i=1}^{N} \log_2\left(1 + \frac{P\|h_2\|}{P\|h_1\| + N_0}\right)$	[91] [92
10	* Capacity U1 (specific target rate)	$C_1 = \sum_{i=1}^{N} \log_2\left(1 + \frac{P\|h_1\|}{N_0}\right)$	[91] [92
11	* Outage Probability Condition U1	[illegible]	[91] [92
12	* Outage Probability U1	[illegible]	[91] [92
13	* Outage Probability Condition U2	$P_r(C_2(k) < r_2) \| P_r(C_3(k) < r_3) \| P_r(C_4(k) < r_4)) < r$	[91] [92
14	* Outage Probability U2	[illegible]	[91] [92
15	* Outage Probability Condition U3	$P_r(C_3(k) < r_3) \| P_r(C_4(k) < r_4)) < r$	[91] [92
16	* Outage Probability U3	$Pr(U3) = (\sum_{k=1}^{N} P_r(C_3(k) < r_3) \| P_r(C_4(k) < r_4))/N$	[91] [92
17	* Outage Probability Condition U3	$P_r(C_4(k) < r_4)) < r_4$	[91] [92
18	* Outage Probability U3	$Pr(U4) = (\sum_{k=1}^{N} P_r(C_4(k) < r_4))/N$	[91] [92

*Where;

j = 1, 2, 3, 4

N (No of Channels) = 64

y = Received Signal

w = Noise Power

RU4 = Maximum rate at which BS can decode the data of a nearby user (User 4)

RU3 = Maximum rate at which BS can decode the data of a nearby user (User 3)

RU2 = Maximum rate at which BS can decode the data of a nearby user (User 2)

RU1 = Maximum rate at which BS can decode the data of a nearby user (User 1)

OP = Outage Probability

r = User with different target rates (r1 =1, r2 =2, r3 =3, r4 =4)

C = Capacity of users with different target rates.

C1 = Capacity of user 1 with specific target rate.

C2 = Capacity of user 2 with specific target rate.

C3 = Capacity of user 3 with specific target rate.

C4 = Capacity of user 4 with specific target rate.

Pr = Outage Probability

N = Number of Transferred Samples

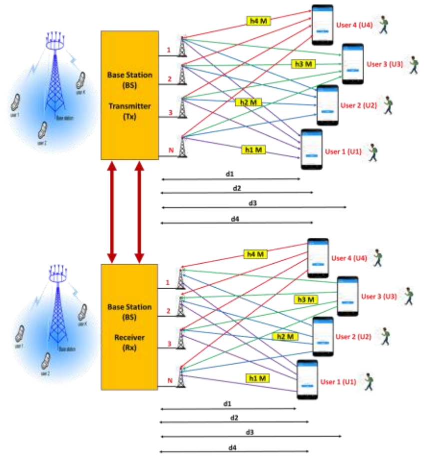

Fig.3.3: Wireless Network - 4 Users (64 × 64 MIMO-DL-UL-NOMA) Power Domain

Simulation Parameters

Using the MATLAB software program, the simulation parameters for the DL and UL NOMA power domains in 5G networks were incorporated, with and without MIMO. Tables 1 and 2 display the simulation parameters that were appropriately taken into account in the simulation model.

Table 3.4: Simulator Parameters for Downlink (DL) Scenario

S/No	Parameters	Values		
Downlink Scenario				
1	Number of Users		4	
2	Transmit Power		0 to 40 dBm	
3	Bandwidth	BW1		80 MHz
		BW2		200 MHz
4	Distances	User 1		900 m
		User 2		700 m
		User 3		400 m
		User 4		200 m
5	Power Coefficients	User 1		0.843
		User 2		0.219
		User 3		0.062
		User 4		0.022
6	Path Loss Exponent		4	
7	MIMO		64 X 64	
8	Modulation		QPSK	

Table 3.5: Simulator Parameters for Uplink (UL) Scenario

S/No	Parameters	Values		
Uplink Scenario				
1	Number of Users		4	
2	Transmit Power		-30 to 30 dBm	
3	Bandwidth	BW1		80 MHz
		BW2		200 MHz
4	Distances	User 1		900 m
		User 2		700 m
		User 3		400 m
		User 4		200 m
5	Path Loss Exponent		4	
6	MIMO		64 X 64	

The researcher employed MATLAB for the analysis in this study.

IV. RESULTS AND DISCUSSION

- ***Downlink Results & Discussion***

According to the Downlink (DL) NOMA system results, adopting 64 X 64 MIMO came up with the following results:

- Enhanced Bit Error Rate (BER) Performance.
- Enhanced Spectral Efficiency (SE) performance.
- The near-far user problem solved.

For varied power location coefficients, transmitted power, and distance parameters when compared without MIMO DL NOMA performance, the performance of all user's approaches that of the other users. Performance of the DL NOMA Bit Error Rate (BER) versus transmitted power at 80 MHz BW is shown below in Fig 4.1.

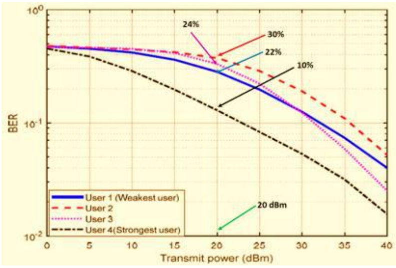

Fig.4.1: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 80 MHz Bandwidth

The results show that;

- As transmitted power rises, BER performance declines.
- As U4 is the closest, its BER performance is the best for all users.
- BER rates for U1, U2, U3, and U4 are determined to be 22%, 30%, 24%, and 10%, respectively, at a transmitter power of 20 dBm.
- BER performance declines as transmitted power increases.

Figure 4.2 below compares the DL NOMA BER performance against transmitted power at 200 MHz BW.

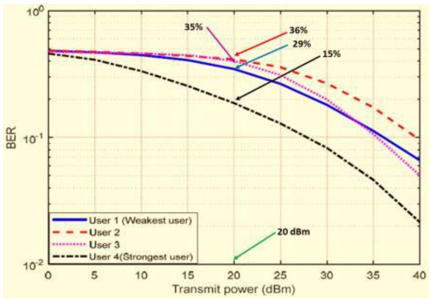

Fig.4.2: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 200 MHz Bandwidth

The results found that U4 being the closest user, its BER performance is the best when compared to all other users. BER rates for U1, U2, U3, and U4 are determined to be 29%, 38%, 35%, and 15%, respectively, at a transmit power of 20 dBm. Best user U4 from the 64 x 64 MIMO DL NOMA improves BER performance from 10-1.48 to 10-4.93 at 200 MHz BW at a transmitter strength of 40 dBm and then from 10-1.68 to 10-5.1 at 80 MHz. In contrast, with a transmitter power of 40 dBm, the Spectrum Efficiency (SE) performance for the best user U4 is enhanced by 8 x 10-2.9 bps/Hz for 80 MHz BW and by 10-1.9 bps/Hz for 200 MHz BW.

UL NOMA systems' results with 64 x 64 MIMO were improved the Outage probability (OP) for 80 MHz BW at Signal to Noise Ratio (SNR) of 1 dB was lowered by 14 x 10-2.9 and the average capacity rate performance increased by 11 bps/Hz. Figure 4.3 below displays the DL NOMA BER performance as a function of transmitted power at 80 MHz BW and 64 x 64 MIMO. The BER rates for U1, U2, U3, and U4 are determined to be 18 x 10-3.8, 17 x 10-3.8, 7 x 10-3.8, and 4 x 10-3.9 at 20 dBm of transmitted power, respectively.

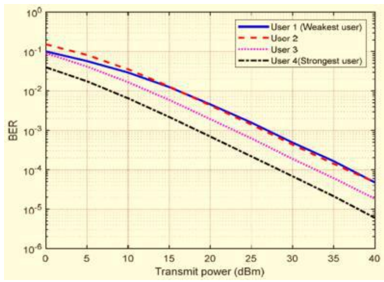

Fig.4.3: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 80 MHz Bandwidth with 64 x 64 for DL NOMA

A transmitted power of 20 dBm, the DL NOMA BER performance at 200 MHz BW and 64 x 64 MIMO is shown in Figure 4.4 below. The BER rates for U1, U2, U3, and U4 are determined to be 45 x 10-3.7, 42 x 10-3.8, 18 x 10-3.6, and 6 x 10-3.8, respectively. The MIMO system improves BER efficiency.

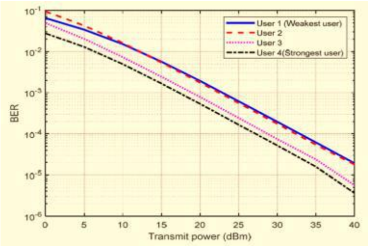

Fig.4.4: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 200 MHz Bandwidth with 64 x 64 for DL NOMA

Figure 4.5 plots the DL NOMA Spectral Efficiency (SE) performance against transmitted power at 80 MHz BW. The results reveal that SE performance improves with increasing transmitted power. The U4 BER performance is therefore the best for all users because it is closest one. Up until the transmitted power reaches 5 dBm, all users' SE performance is clearly distinct from one another.

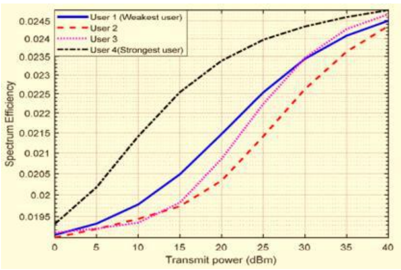

Fig.4.5: Spectral Efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) at 80 MHz Bandwidth for DL NOMA

Figure 4.6 shows the relationship between DL NOMA SE performance and transmitted power at 200 MHz BW. The results show that SE performance improves as transmitted power increases. The finest is U4 SE performance considering that U4 is the closest user as compared to all other users. With an improvement rate of 10-2.2 in the BER, the results are better than those of the best U2 users.

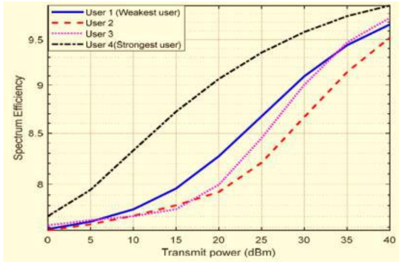

Fig.4.6: Spectral Efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) at 200 MHz Bandwidth for DL NOMA

Figure 4.7 displays the DL NOMA SE's performance in terms of transmitted power at 80 MHz BW and 64 x 64 MIMO. The SE is fairly close for all users at 5 dBm of broadcast power.

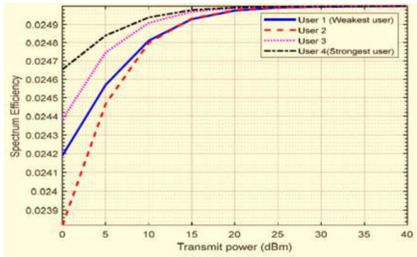

Fig.4.7: Spectral Efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for DL NOMA

Figure 4.8 shows the performance of the DL NOMA SE vs transmission. power at 64 x 64 MIMO and 200 MHz BW. At 15 dBm of transmitter strength, the SE for all users is reasonably near. The SE performed is better; thanks to MIMO.

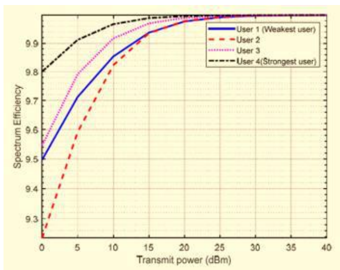

Fig.4.8: Spectral Efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for DL NOMA

- ***Uplink Results & Discussion***

Figure 4.9 shows the UL NOMA average capacity rate vs. SNR at 80 MHz BW. Because U4 is the closest, the result demonstrates that the average capacity rate for U4 is best for all users. The average capacity rate for U1, U2, U3, and U4 is found to be 1.6873, 2.8718, 6.4960 and 12.7814 respectively.

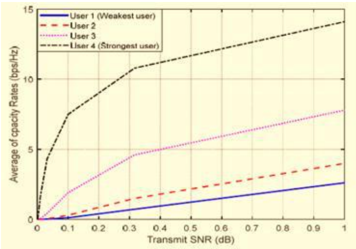

Fig.4.9: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) and 80 MHz Bandwidth for UL NOMA

Figure 4.10 shows the UL average capacity rate at 200 MHz BW. Average capacity rates for U1, U2, U3, and U4 are found to be 2.5923, 3.89479, 7.7821, and 14.0972, respectively at SNR of 1 dB. The findings show that the average capacity rate performance increases along with an increase in SNR. The performance of the capacity average rate was enhanced by 64 x 64 MIMO by 11 bps/Hz and decreased the OP by 11 x 10-2.9 for 200 MHz BW at 0.18 dB SNR for user U4, and reduced the OP by 14 x 10-2.8 for 80 MHz BW at SNR of 1 dB. In general, an increase in BW decreases OP and SE while increasing BER and the capacity average rate. MIMO greatly increases each user's throughput.

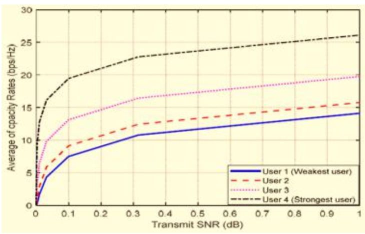

Fig.4.10: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) and 200 MHz Bandwidth for UL NOMA

Figure 4.11 shows the average capacity rate performance for UL NOMA versus SNR at 80 MHz BW and 64 x 64 MIMO. The outcome for the four users were found to be four users is 12.8732, 14.3921, 18.4489, and 24.7714 respectively.

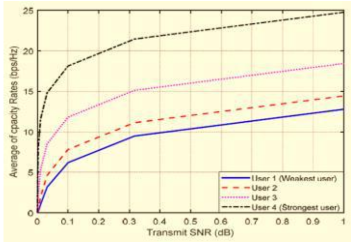

Fig.4.11: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for UL NOMA

Figure 4.12 depicts average capacity rate performance in relation to SNR for 64 x 64 MIMO and 200 MHz BW UL NOMA. The findings indicate that when SNR rises, average capacity rate performance gets better. According to data gathered for four users at the SNR of 1 dB, the values were found to be 14.0921, 15.7563, 19.7586, and 26.1820 respectively. U4's average capacity rate performance is the best. Furthermore, BW and average capacity rate are positively correlated i.e. rising BW translating into rising average capacity rate. When system is improved utilizing MIMO technique, the average capacity rate rises sharply.

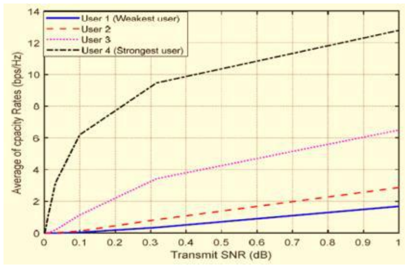

Fig.4.12: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for UL NOMA

Figure 4.13 shows 80 MHz BW plot displaying the association between the UL NOMA of OP and SNR. The values for U1, U2, U3, and U4 are 98.8 x 10-1.9, 97.7 x 10-1.8, 43.3 x 10-1.9, and 14 x 10-3, respectively, when SNR is 0.169 dB.

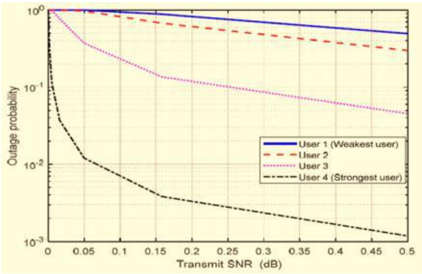

Fig.4.13: OP vs SNR (4 Users, Varied Distances & Power Coefficients) and 80 MHz Bandwidth for UL NOMA

The UL NOMA of OP versus the SNR is shown in Figure 4.14 at 200 MHz BW. The values for U1, U2, U3, and U4 are 0.9746, 0.9744, 0.2809, and 0.0173, respectively, at an SNR of 0.169 dB. The results demonstrate that the OP performance degrades as the SNR increases. Results obtained are better than those of the top U2 users and have increase in average capacity rate.

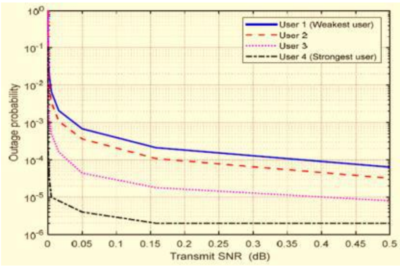

Fig.4.14: OP vs SNR (4 Users, Varied Distances & Power Coefficients) and 200 MHz Bandwidth for UL NOMA

The UL NOMA of OP vs. SNR is shown in Figure 4.15 at 80 MHz BW with 64 x 64 MIMO. The results for U1, U2, U3, and U4 are 0.0061, 0.0026, 0.0002, and 0.0001 at an SNR of 0.169 dB.

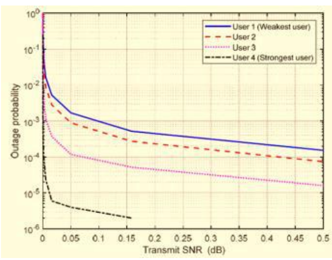

Fig.4.15: OP vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for UL NOMA

The UL NOMA of OP vs. 64 x 64 MIMO at 200 MHz BW is shown in Figure 4.16. The values for U1, U2, U3, and U4 are 20 x 10-3.8, 10-3.9, 10-3.7, and 10-4.8 at an SNR of 0.169 dB. According to the results, the performance of the OP degrades as the SNR rises. A rise in BW causes a decrease in OP, and the two variables are inversely related. When the system is optimized using the MIMO approach, the OP drops significantly. The outcomes are better since there was an improvement rate of 10-1.8 in OP.

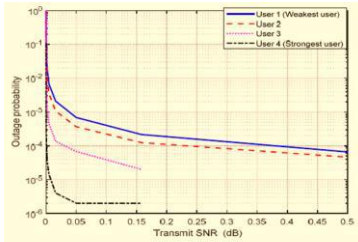

Fig.4.16: OP vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for UL NOMA

V. CONCLUSIONS AND FUTURE WORK

The study underscores the potential advantages of combining MIMO and NOMA technologies within B5G cellular systems, offering valuable insights into optimal configurations for improving performance across diverse parameters. Drawing conclusions from the investigation into the integration of multiple-input multiple-output (MIMO) and non-orthogonal multiple access (NOMA) technologies in B5G cellular systems, the findings are presented.

• Integrating MIMO and NOMA technologies offers a solution to various challenges encountered by B5G cellular systems, encompassing issues such as massive connectivity, low latency, and high dependability.

• The collaborative deployment of MIMO with NOMA leads to notable improvements in key parameters, including bit error rate (BER), spectrum efficiency (SE), average capacity rate, and outage probability (OP).

• The amalgamation of MIMO and NOMA effectively addresses the near-far user's predicament in downlink NOMA. This enhancement is manifested through improved BER and SE performance, aligning the performance of all users more closely.

• Implementation of 64 x 64 MIMO technology in downlink NOMA results in significant enhancements in BER for the best user. Simultaneously, in uplink NOMA, it improves average capacity rate performance and diminishes outage probability for the best user.

• An augmentation in bandwidth correlates with an increase in BER and average capacity rate, accompanied by a reduction in spectrum efficiency and outage probability.

The study exhibited the efficacy of Downlink (DL) and Uplink (UL) NOMA Power Domain (PD) in a 5G network, considering both scenarios with and without 64 x 64 MIMO technology. The following procedures were executed, accompanied by corresponding observations:

• Investigation and assessment of the Bit Error Rate (BER) and Spectral Efficiency (SE) performance of Downlink (DL) NOMA for varying distances and power location coefficients.

• Examination of the Average Capacity Rate and Outage Probability (OP) performance of Uplink (UL) NOMA under different conditions, including varied distances, Signal-to-Noise Ratio (SNR), and Bandwidth (BW).

• Results from the DL NOMA system indicated that the introduction of 64 x 64 Multiple-Input Multiple-Output (MIMO) technology not only enhanced BER and SE performance but also effectively addressed the near-far user's challenge, aligning the performance of each user closely with others.

• Comparative analysis between DL NOMA with and without MIMO revealed that, under factors such as different transmitted power, distance, and power location coefficients, the 64 x 64 MIMO DL NOMA, at 80 MHz BW and 200 MHz BW (with a transmitter power of 40 dBm), improved BER performance for the best user U4 from 10^-1.7 to 10^-5.2.

• In contrast, with a transmitter power of 40 dBm, the SE performance for the best user U4 witnessed an improvement of 0.8% bps/Hz for 80 MHz BW and 1.01% bps/Hz for 200 MHz BW. The results from UL NOMA systems, employing 64 x 64 MIMO, demonstrated notable enhancements.

• For the best user U4, the average capacity rate performance improved by 12 bps/Hz, the OP decreased by 0.0120 for 200 MHz BW at an SNR of 0.17 dB, and the OP decreased by 0.0150 for 80 MHz BW at an SNR of 1 dB.

• An increase in BW led to a reduction in SE and OP while increasing BER and average capacity rate.

• MIMO technology significantly improved the performance of each user.

Future Research

This research seeks to make a valuable contribution to the existing literature by introducing an integrated network architecture based on hybrid technologies, incorporating Multiple-Input Multiple-Output (MIMO) and Non-Orthogonal Multiple Access (NOMA). The objective is to address challenges related to massive connectivity, low latency, and high dependability while effectively resolving issues associated with near/far users. It is important to note that this study did not delve into the collaborative potential of MIMO cooperative NOMA and cognitive radio. Future research endeavors can explore this unexplored avenue to unlock further enhancements in network performance.

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International Journal of Advanced Engineering, Management and Science (IJAEMS)
Peer-Reviewed Journal
ISSN: 2454-1311 | Vol-9, Issue-11; Nov, 2023
Journal Home Page: https://ijaems.com/
DOI: https://dx.doi.org/10.22161/ijaems.911.3

Optimum Location of Seismic Isolation for Manavgat Cable-Stayed Bridge

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Received: 08 Oct 2023; Received in revised form: 10 Nov 2023; Accepted: 20 Nov 2023; Available online: 30 Nov 2023

Abstract: *Seismic isolation strategies have been extensively implemented to mitigate the risk of damage in cable-stayed bridges (CSBs). The effectiveness of seismic isolation has received a great deal of attention from a number of researchers. This paper focuses on studying the seismic performance of a single pylon cable-stayed bridge with a single concave friction pendulum (SCFP) at various locations under bi-directional seismic excitations. A 3D numerical model was created using the prototype of a single pylon cable-stayed bridge located in Antalya, Turkey in order to study its seismic response. SCFP was installed at the bridge's deck-abutment, deck-pylon and pylon-foundation connection to study the reduction of the dynamic response when subjected to various seismic excitations. The efficiency of SCFP is evaluated by monitoring and controlling the displacement of the deck, acceleration, and the base of the pylon. The analytical results indicate that SCFP can effectively diminish both the base shear and the displacement of the pylon. However, the effectiveness of SCFP is significantly influenced by its location and ground motion.*

Keywords: ***Seismic isolation, Single Concave Friction Pendulum (SCFP), Structure control, Cable-stayed bridges, Nonlinear dynamic analysis.***

I. INTRODUCTION

Cable-stayed bridges are renowned for their architectural appeal. They can include various cable arrangements, fan, harp, semi-fan, etc. Studies conducted on past-earthquakes damages or destruction have revealed that a bridge's behavior is mainly influenced by two factors: structural control methods and dynamic loadings (wind and earthquakes). In order to resolve these challenges, advanced strategies such as structural control approaches have emerged. These approaches can be categorized as active, semi-active, passive, and hybrid control approaches [1]. The adoption of control approaches in the structural design community has been gradual due to perceived complexity, large scale, and high costs associated with these systems. Recently, technological advancements have made control methods more practical for new bridge construction projects as well as retrofitting existing ones.

In the past three decades, many studies have focused on mitigating the structural response induced by dynamic effects. This led to the development and implementation of various structural control concepts [2]. Ali and Abdel-Ghaffar [3,4] conducted initial studies focused on utilizing isolation techniques to enhance the seismic behavior of cable-stayed bridges. Constantinou et al. [5,6] performed experimental evaluations on a seismic isolation system for cable-stayed bridges. This system comprised of multi-directional Teflon bearings, which served to account for thermal shifts and provided isolation. Additionally, control devices served the dual purpose of both restoring the bridge under seismic excitation and, offering energy dissipation capacity and structural rigidity for service loading. The seismic behavior of cable-stayed bridges was examined by Iemura and Padrono [7] using a combination of elastomeric and hysteretic bearings. This isolation strategy included both passive and semi-active dampers to enhance seismic response. Weselowsky and Wilson [8] studied the seismic performance of cable-stayed bridges that were isolated using Lead Rubber Bearings (LRBs), particularly focusing on their behavior during near-field earthquake events. Their findings indicated the presence of an optimal level of isolation that offers limiting displacement and reduces seismic forces during earthquakes. Casciati et al. [9] evaluated the dynamic performance of a cable-stayed bridge utilizing elastomeric LRBs. They employed fragility curves as a method to assess the bridge response. A comparison was performed by Soneji and Jangid [10] in order to analyze the effectiveness of three different systems: high-damping rubber bearings (HDRBs), Lead Rubber Bearings (LRBs), and a friction pendulum system (FPS) on isolated cable-stayed bridges. They determined the optimum levels of yield strength for LRBs and the frictional coefficient for FPS that resulted in the most significant reduction of both base shear and the maximum displacement of the bridge.

Integrating isolation techniques with dampers can improve the capacity for controlling the displacement of isolated bridges. Park et al. [11] suggested the installation of a hybrid control system for cable-stayed bridges. This system incorporated LRBs to mitigate the forces generated by earthquakes. Furthermore, fluid dampers provided additional reduction in the bridge's responses. Soneji and Jangid [12] applied an additional damping mechanism using a viscous fluid damper (VFD) to reduce the seismic response of an isolated cable-stayed bridge. This approach proved effective in controlling the maximum displacement of the isolator and limiting the base shear of towers. Ismail and Casas [13,14] conducted a study focused on the seismic behavior of a cable-stayed bridge equipped with a novel isolator for controlling the displacement, accelerations, and internal forces of a bridge. They specifically investigated the bridge's response to near-fault ground motions. Cámara and Astiz [15] investigated retrofitting solutions for cable-stayed bridges. They explored the implementation of supplemental damping devices that establish a connection between the deck and the tower in the transverse direction. Elkady et al. [16, 17] conducted a study using a Tuned Mass Damper (TMD) on a scale model of Dongshuimen Bridge to simulate the earthquake excitations and evaluate the efficiency of the TMD. To enhance the seismic response of Dongshuimen bridge, Alshaer et al. [18] investigated how a Single-Tuned Mass Damper (STMD) can improve the efficiency of cable-stayed bridges under various ground motions. Additionally, they determined the ideal value of TMD mass ratio. The safety of cable-stayed bridges during earthquakes is of paramount importance because of their long spans. However, the seismic excitations affecting these bridges may not be spatially synchronous.

Based on literature reviews and studies, base isolation has been proven as an effective and economical method for mitigating structural response and damage during earthquakes. Many full-scale bridges have different base isolation systems [19]. Sliding isolators operate on the friction principle. It is assumed that as the friction coefficient decreases, the transmission of shear also decreases [20]. The base isolation technology used in this study is the single concave friction pendulum (SCFP).

SCFP bearings have been studied since 1990 [21-23]. SCFP is mainly composed of an articulated slider and a concave spherical surface. The sliding surfaces are coated with a low-friction material. Based on the pendulum function, the superstructure period is determined by the curvature radius of the SCFP bearing. Because of the concave surface, re-centering forces proportional to superstructure weight are introduced. In the last few decades, sliding bearings with adaptive seismic response have been presented [24-26]. As a response to the need for earthquake-resistant structures, several studies have been conducted to develop flexible and cost-effective isolation systems. One such system is the friction pendulum, which has garnered significant attention. In this regard, the double concave friction pendulum (DCFP) and triple concave friction pendulum (TCFP) were developed to provide enhanced seismic performance and structural stability [27-31]. For example, Tsopelas et al. [32], Kim and Yun [33], Tsai et al. [34], and Soni et al. [35] studied the effect of friction pendulum bearings on the seismic behavior of cable-stayed bridges.

The seismic behavior of a single-pylon cable-stayed bridge is significantly influenced by the method of connection between the deck and the pylon. An example of this is the Chi-Lu Bridge, a single-tower cable-stayed bridge that suffered damage during the 1999 Chi-Chi Earthquake in Taiwan [36]. Chadwell [37] performed numerical investigations aimed at evaluating the effectiveness of an isolation system designed to protect the Chi-Lu cable-stayed bridge. The collapse of the Benten Viaduct occurred during the Hanshin Earthquake in Japan in 1995. In its reconstruction, the implementation of base-isolation technology included the installation of lead rubber bearings (LRB) at the bottom of the piers [38]. Ates and Constantinou [39] conducted an examination of a curved bridge that was isolated using friction pendulum bearings positioned between the deck and the piers. Atmaca et al. [40] conducted nonlinear time history analyses to investigate the seismic behavior of the Manavgat cable-stayed bridge. The bridge was isolated using SCFP implemented between the pylon base and the foundation. Javanmardi et al. [41] studied an existing cable-stayed bridge under bi-directional seismic excitation using LRBs at the base of the pylon. Previous numerical studies primarily centered on examining the seismic behavior of cable-stayed bridges that were isolated using sliding bearings. However, the optimal placement of bearings in single-pylon cable-stayed bridges has not been extensively explored.

The present study contains nonlinear dynamic analyses for single pylon cable-stayed bridge under bi-directional seismic excitation. The objectives of the study are to: (1) investigate the seismic performance of a single pylon cable-stayed bridge with the installation of SCFP at various locations, (2) evaluate the effectiveness of SCFP on the seismic behavior of a single pylon cable-stayed bridge; and (3) determine the optimum location of SCFP to enhance the seismic behavior of single pylon cable-stayed bridges.

II. ESCRIPTION OF MANAVGAT BRIDGE

Manavgat bridge was constructed in 2009 in Antalya, Turkey using the balanced cantilever construction method. The total length of the bridge is 202m, and it features a lambda-shaped steel tower positioned at the mid-span of the bridge as shown in Fig.1. Fig.2 shows the general layout of Manavgat cable-stayed bridge, including typical cross-sections at various locations.

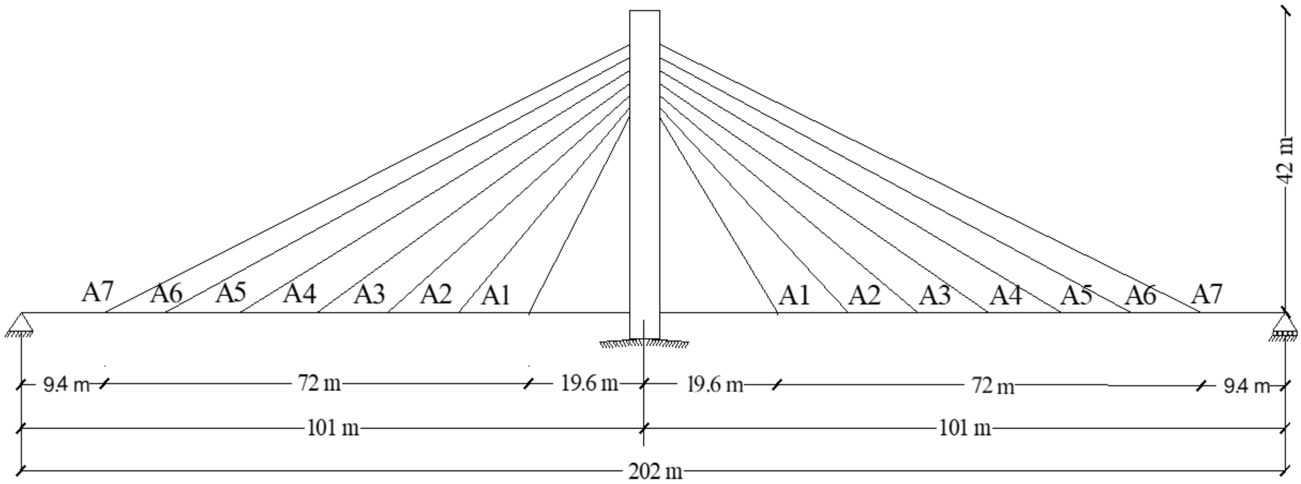
Fig. 1. Manavgat cable-stayed bridge(https://structurae.net/en/structures/manavgat-antalya-bridge)

The bridge has two equal spans of 101m and a width of 13.7m. It is designed to accommodate two lanes of traffic. The cross-section of the 42m steel tower is hollow and hexagonal. The bridge deck is a composite section consisting of a 25cm thick layer of concrete supported by cross girders placed at a regular spacing of 3m. Additionally, there are two main girders positioned at the outer edges of the deck with an average depth of 1.8m.

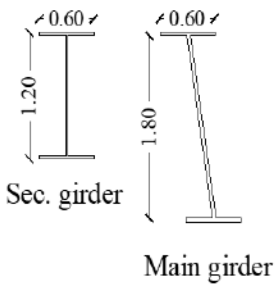
The pylon connects to 28 stay cables with a semi-fan arrangement that supports the bridge deck. The centermost cable attaches to the deck 19.6m away from the pylon, while the gap along the deck between each additional cable measures 12m. The last cable attaches to the deck 9.4m away from the shore supports [40]. It is assumed that the bridge deck is continuous from one end to the other. Tables 1,2 describe the bridge's material properties, cable properties, and general description.

Table 1. Material properties of the bridge.

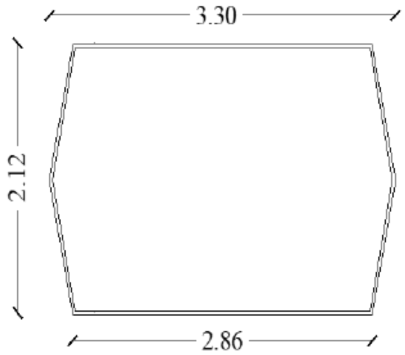
Material	Unit Weight (KN/ m^3)	Strength (MPa)	Modules of Elasticity (MPa)	Poisson Ratio
Deck Concrete	25.0	40	34000	0.2
Structural Steel	78.5	450	200000	0.3
Strand	78.5	1860	197000	0.3



(a) Elevation of the bridge.



(b) Deck cross section.



(c) Pylon cross section.

Fig. 2. General layout of Manavgat cable stayed bridge (a) Elevation of the bridge; (b) Deck cross section; (c) Pylon cross section.

Table 2. Properties of the stay cables.

Cable No	No. of Strands	Approximate angle to horizontal	Diameter of Strand(mm)	Cross Section area of Stay Cable(mm^2)
A1	15	56	15.2	2100
A2	16	45	15.2	2240
A3	19	37	15.2	2660
A4	19	33	15.2	2660
A5	22	29	15.2	3080
A6	19	26	15.2	2660
A7	24	24	15.2	3360

III. ANALYTICAL MODEL OF THE BRIDGE

A finite-element model (FEM) of the bridge was developed using SAP2000 software. The model consists of 1102 beam elements, 28 truss elements, and 1980 shell elements. A beam element is used to model the pylon and steel I-beam profile (part of the deck). The deck is modeled as a four-node shell element. The cables are modeled as truss elements, capable of withstanding only tensile forces. The support condition at the base of the pylon is fixed, preventing both rotational and translational movement. The right abutment is modeled as a roller, facilitating longitudinal movement while restricting vertical and transverse translation ($U_Y = U_Z = 0$). The left abutment is hinged, which allows the abutment to rotate around longitudinal and transverse axes without permitting any translation ($U_X = U_Y = U_Z = 0$). The FEM of the bridge is shown in Fig.3.

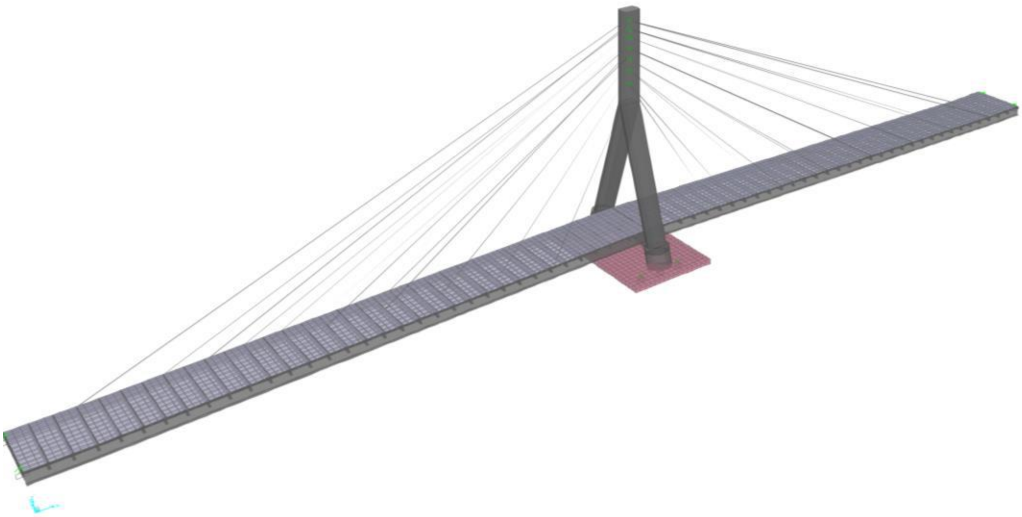


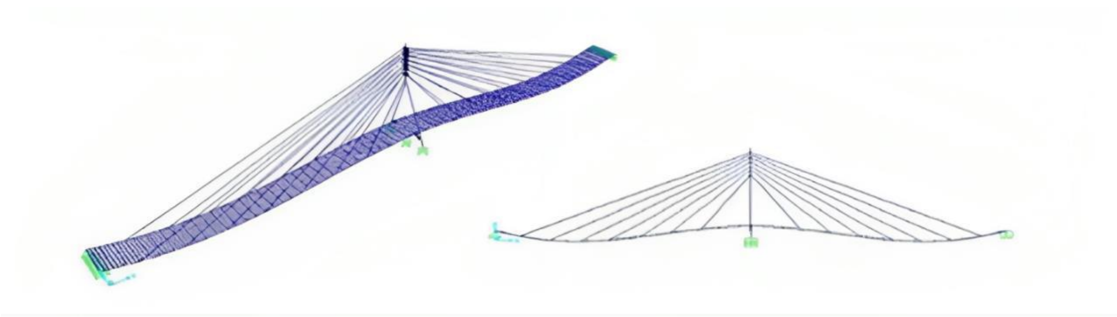
Fig. 3. FEM of the bridge.

The geometric nonlinearity response of cable-stayed bridges depends on (i) large displacements (P-D effect), (ii) beam-column effect, and (iii) cable sag. [42]. It is generally recognized that the third factor takes the most significance. Numerous finite element models have been presented to account for cable behavior while taking cable sag into consideration [43-46]. One approach involves the linearization of cable stiffness by employing a modified modulus of elasticity that is lower than the actual modulus. This concept was initially introduced by Ernst and is expressed by:[47]

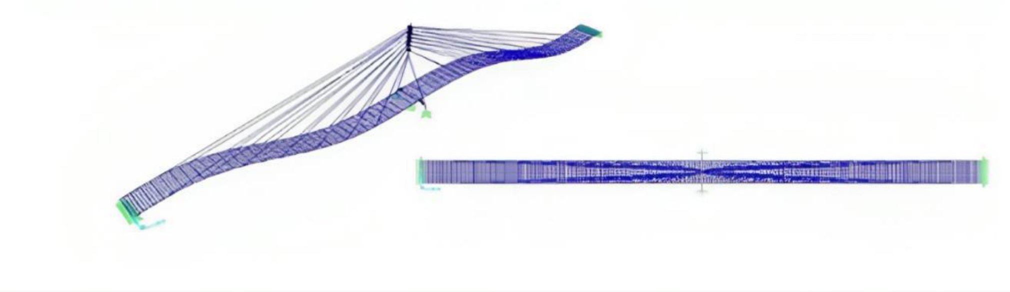
$$E_{modi} = \frac{E_C}{1 + \frac{(WL_x)^2 (EA)_C}{12{T_0}^3}} \qquad (1)$$

Where E_C is the modulus of elasticity of the material, L_x is the projected length in plane, A_C is the area of the cross-section, W is unit weight, and T_C is the tension in the cable. Wilson and Gravelle [48] mentioned that the equivalent modulus value is nearly identical to the actual modulus of elasticity. Therefore, the impact of nonlinearity attributed to cable sag was disregarded within this investigation. In this study, the cables were considered to exhibit a purely linear relationship between force and deformation, described by the material modulus.

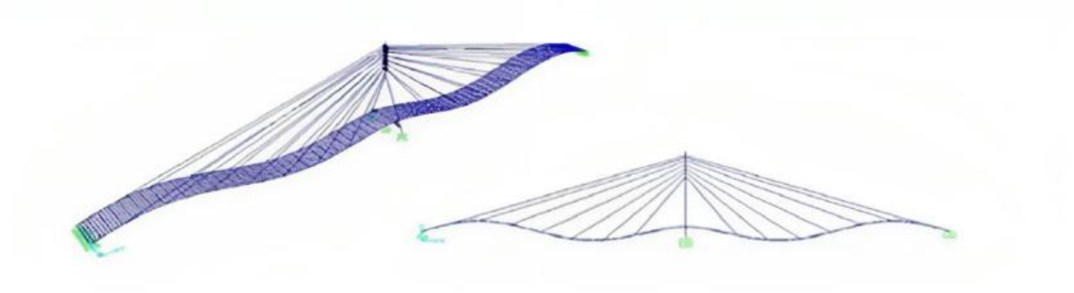
Preliminary verification was conducted to evaluate the model's ability to accurately simulate the bridge. The results were compared against prior results determined by Atmaca et al. [40]. Fig.4 illustrates the first five modes of the bridge, including longitudinal, lateral, vertical, and torsional modes. Table 3 shows a summary of the vibrational properties of the bridge, including natural periods, participating mass ratios, and a description of each mode. The first five natural periods obtained from the FEM analysis (0.831, 0.498, and, 0.436 seconds) are in agreement with the prior results (0.825, 0.536, and 0.452 seconds). It is clear that the comparison is satisfactory and represents the ability of the FEM to express the actual behavior of the Manavgat cable-stayed bridge.



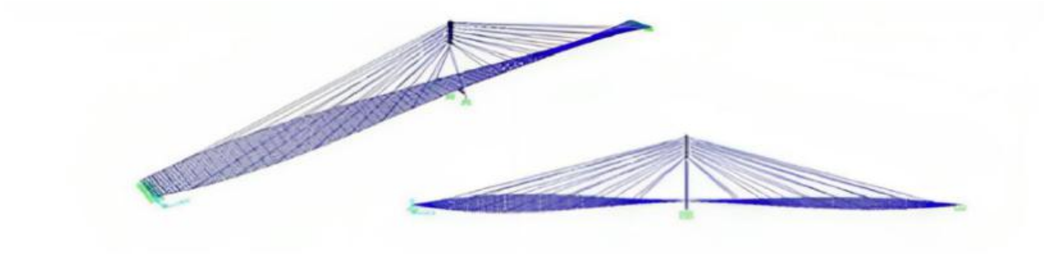
The Frist Mode (T= 0.831 Sec)



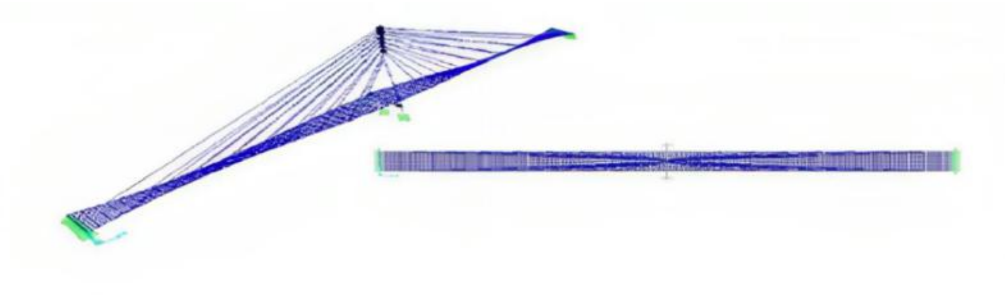
The Second Mode (T= 0.498 Sec)



The Third Mode (T= 0.436 Sec)



The Fourth Mode (T= 0.310 Sec)



The Fifth Mode (T=0.309 Sec)

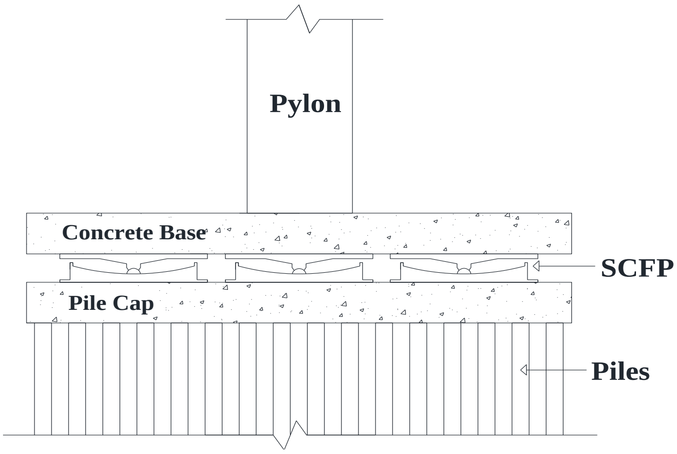
Fig. 4. Analytical modes of vibration of the bridge.

Table 3. A summary of the vibration properties of the bridge.

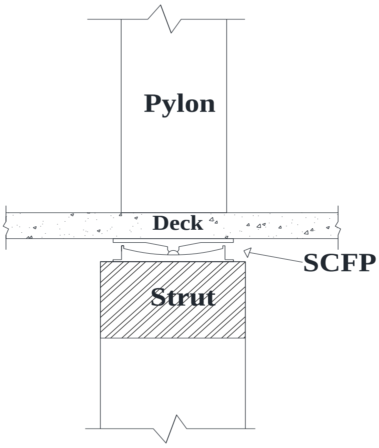
Mode No	Period (Sec)	Modal participating mass ratios (%)						
		Longitudinal Direction	Longitudinal Direction (Cumulative)	Lateral Direction	Lateral Direction (Cumulative)	Vertical Direction	Vertical Direction (Cumulative)	Vibration mode
1	0.831	0.003	0.003	0.000	0.000	0.596	0.596	1st Vertical
2	0.498	0.001	0.003	0.000	0.000	0.000	0.596	1st Transverse bending
3	0.436	0.000	0.003	0.000	0.000	0.031	0.627	2nd Vertical
4	0.310	0.000	0.003	0.000	0.000	0.000	0.627	1st Longitudinal bending
5	0.309	0.000	0.003	0.000	0.000	0.000	0.627	2nd Longitudinal bending
6	0.280	0.000	0.003	0.000	0.000	0.000	0.627	3rd Transverse bending
7	0.253	0.000	0.003	0.000	0.000	0.092	0.719	3rd Vertical
8	0.231	0.000	0.003	0.000	0.000	0.000	0.719	3rd Longitudinal bending
9	0.220	0.000	0.003	0.001	0.001	0.000	0.719	4th Longitudinal bending
10	0.212	0.000	0.003	0.065	0.066	0.000	0.719	5th Longitudinal bending

IV. SINGLE CONCAVE FRICTION PENDULUM

Nonlinear dynamic analysis was performed by comparing the performance of the CSB under different excitation records to select the optimum location of SCFP. Two groups were created to use in this study; Group I SCFP is applied between the pylon and the foundation, while Group II SCFP is applied between the deck and strut attached to pylon as shown in Fig.5.



(a) Pylon-foundation connections (Group I)

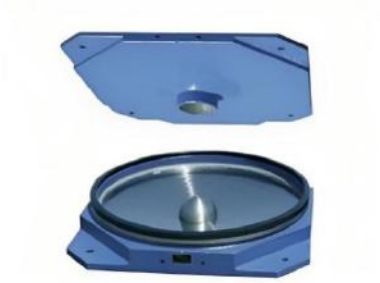


(b) Pylon-deck connections (Group II)

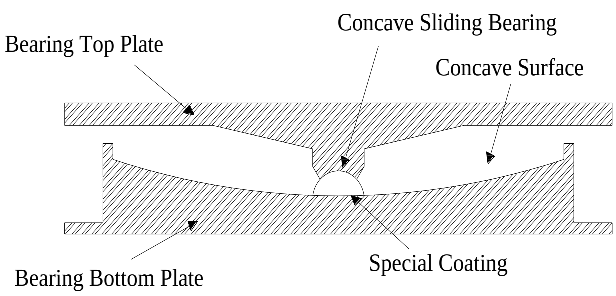
Fig. 5. Schematic of the setup proposed for SCFP.

Description of single concave friction pendulum

The SCFP system is comprised of three distinct components: the upper spherical concave surface, the lower spherical concave surface, and the articulated slider. The articulated slider is coated with PTFE (polytetrafluoroethylene), a type of non-stick material known for its low coefficient of friction. This coating allowing for smooth sliding between the slider and concave surfaces. Fig.6 illustrates a cross-section view of the SCFP [49,50].



(a)



(b)

Fig. 6. Single friction pendulum bearing (SCFP) (a) three-dimensional view;(b) cross section view.

When a supported structure is excited by horizontal motion, the SCFP bearings induce a pendular trajectory. The uplift of the displaced structure serves as a restorative force due to gravity. The period of the isolated structure behaves similarly to a pendulum and remains independent of the structural mass [51]. Without considering the effects of friction, the period of a rigid structure isolated with SCFP bearings can be determined by:

$$T = 2\pi\sqrt{\frac{R}{g}} \quad (2)$$

Where R represents the radius of the sliding surface, g represents the gravitational constant. The flexibility and energy dissipation mechanisms in SCFP bearings are separate. The structure's design stiffness is determined by determining the radius of curvature of the sliding surface. The level of energy dissipation is dependent on three key design factors: the arrangement of the sliders, the level of pressure at the overlay-slider interface, and the level of concavity of the surface finish. By adjusting these factors, the desired friction coefficient is obtained.

Table 4. Various locations of single concave friction pendulums

NO	Case	Location
Group I	Case IA	Two isolators are installed at each abutment, while six isolators are located between the pylon base and the foundation.
	Case IB	Two isolators are installed at the right abutment, while six isolators are located between the pylon base and the foundation.
	Case IC	Two isolators are installed at the left abutment, while six isolators are located between the pylon base and the foundation.
	Case ID	Six isolators are located between the pylon base and the foundation only.
Group II	Case IIA	Two isolators are installed at each abutment, while three isolators are located between the deck and strut attached to the pylon.
	Case IIB	Two isolators are installed at the right abutment, while three isolators are located between the deck and strut attached to the pylon.
	Case IIC	Two isolators are installed at the left abutment, while three isolators are located between the deck and strut attached to the pylon.
	Case IID	Three isolators are located between the deck and strut attached to the pylon only.

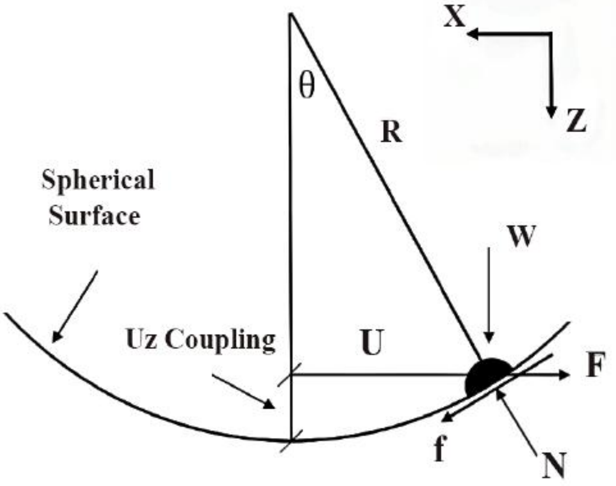


Fig.7. Forces acting on the articulated slider in SCFP bearings.

The bi-directional motion of an SCFP bearing is derived below using equilibrium equations. The SCFP bearing's resistance force is described by balancing the forces acting on the articulated slider as shown in Fig.7. The lateral force F acting at displacement u can be calculated by:

$$F = N sin\theta + f cos\theta \quad (3)$$

Where:

N is the normal force between the sliding surfaces;

f is the friction force at the sliding surface;

θ is the angle.

Similarly, the applied weight W can be calculated by:

$$W = N cos\theta + f sin\theta \quad (4)$$

The angle θ satisfies the following relationships:

$$Sin\theta = \frac{u}{R} \quad and \quad Cos\theta = \frac{\sqrt{R^2 - u^2}}{R} \quad (5)$$

Where:

u represents the displacement;

R is the radius of the spherical surface.

The friction force is commonly dependent on multiple variables, with velocity and pressure being the most influential factors [52].

In the case of Coulomb friction, the friction force (f) can be expressed as:

$$f = \mu N \quad (6)$$

The force-displacement behavior of SCFP can be described by the following equation:

$$F = N\frac{u}{R} + \mu N sgn(\dot{u}) \cos\theta = (W\frac{u}{R} + \mu W\, cos\theta)(\frac{1}{cos\theta + \mu\, sin\theta}) \quad (7)$$

Where:

μ represents a constant coefficient of friction;

N is the normal force between the sliding surfaces.

sgn(.) is the signum function used to determine the correct sign of the friction force. SCFP bearings have displacement capacities of less than 20% of R ($u/R < 0.2$), and the minimum value of cosθ is 0.98 while the maximum value of sinθ is 0.20. The simplified equation is as follows:

$$F = W\frac{u}{R} + \mu\, W\, sgn(\dot{u}) \quad (8)$$

In the literature, it is common to express Eq. 7 in terms of N, assuming that N≈W. This approximation assumes that cosθ is approximately equal to 1.0 and that the horizontal axial load on the bearings is specified as illustrated in Fig.8.

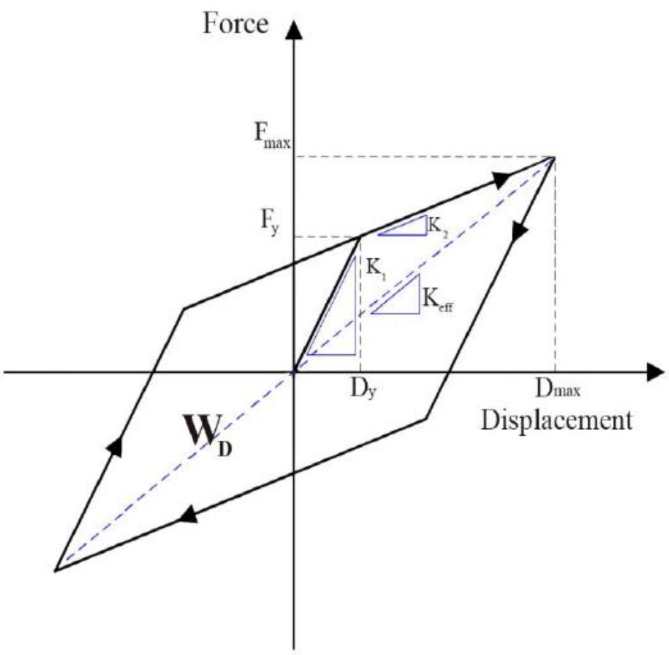


Fig.8. Idealized force-deformation relation of SCFP bearing.

Modeling of single concave friction pendulum

SAP 2000 was used to model the SCFP bearing. The bearing was selected as an isolator device, and was simulated as a direct link. Two sliding systems were considered in this model: SCFP1 and SCFP 2. The former is a placement at the abutments, and the latter is a placement between the pylon base and foundation as shown in Table 4. The parameters of each are listed below in Table 5 [40].

Table 5. Parameters of single concave friction pendulums.

Parameters	SCFP1	SCFP2
Vertical Stiffness (Kn/m)	87964594	87964594
Effective Stiffness (Kn/m)	1014.43	10806.48
Elastic Stiffness (Kn/m)	48600	517725
Friction Coefficient Slow	0.09	0.09
Friction Coefficient Fast	0.045	0.045
Rate Parameter	50	50
Radius of sliding Surface (m)	1.4	1.4

V. SEISMIC RESPONSE ANALYSES

Selection of ground motions

In order to study the seismic response of the bridge under a strong earthquake, three ground motion models were used: ERZ-EW and ERZ-NS components of the Erzincan earthquake, BOL-000 and BOL-090 components of the Duzce earthquake, as well as ERCIS-EW and ERCIS-NS components of the Van-Ercis earthquake. These are listed in Table 6. The ground motions for all these events were obtained from Disaster and Emergency Management Authority (AFAD) and Pacific Earthquake Engineering Research Center (PEER) [53].

Table 6. Summary of ground motions of the Analysis.

No.	Earthquake	Components	Date	PGA (g)
01	Erzincan	EW	1992	0.496g
		NS		0.515g
02	Duzce	BOL000	1999	0.728g
		BOL090		0.822g
03	Van-Erics	NS	2011	0.173g
		EW		0.182g

Equation of motion under seismic load

The equation of motion governing the three-dimensional vibration of the bridge, under seismic load can be expressed as:

$$[M][\ddot{u}] + [C][\dot{u}] + [K][u] = 0 \quad (9)$$

Where:

M Structure quality matrix;

C Structural damping matrix;

K Structural stiffness matrix;

u Node displacement vector; $u = u_s + u_g$

u_s Displacement of unsupported joints of the structure;

u_g Displacement of the structural support node. `

Equation (9) can be expressed in a partition form as follows:

$$\begin{bmatrix} M_{ss} & M_{sg} \\ M_{gs} & M_{gg} \end{bmatrix} \begin{bmatrix} \ddot{u}_s \\ \ddot{u}_g \end{bmatrix} + \begin{bmatrix} C_{ss} & C_{sg} \\ C_{gs} & C_{gg} \end{bmatrix} \begin{bmatrix} \dot{u}_s \\ \dot{u}_g \end{bmatrix} + \begin{bmatrix} K_{ss} & K_{sg} \\ K_{gs} & K_{gg} \end{bmatrix} \begin{bmatrix} u_s \\ u_g \end{bmatrix} = 0 \quad (10)$$

If the unit mass matrix is replaced by the centralized mass matrix, the following is obtained:

$$\begin{bmatrix} M_{ss} & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \ddot{u}_s \\ \ddot{u}_g \end{bmatrix} + \begin{bmatrix} C_{ss} & C_{sg} \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \dot{u}_s \\ \dot{u}_g \end{bmatrix} + \begin{bmatrix} K_{ss} & K_{sg} \\ 0 & 0 \end{bmatrix} \begin{bmatrix} u_s \\ u_g \end{bmatrix} = 0 \quad (11)$$

Therefore,

$$M_{ss}\ddot{u}_s + C_{ss}\dot{u}_s + C_{sg}\dot{u}_g + K_{ss}u_s + K_{sg}u_g = 0 \quad (12)$$

In the seismic action of cable-stayed bridges, the node displacement can be written as:

$$M_{ss}\ddot{u}_{vs} + C_{ss}\dot{u}_{vs} + K_{ss}u_{vs} + M_{ss}\ddot{u}_{ps} + C_{ss}\dot{u}_{ps} + C_{sg}\dot{u}_{ps} - K_{ss}u_{ps} - K_{sg}u_{pg} = 0 \quad (13)$$

According to the pseudo-static displacement principle of earthquake action, it can be seen that:

$$K_{ss}\ u_{ps} + K_{sg}\ u_{pg} = 0 \quad (14)$$

The structural motion equation under earthquake is derived:

$$M_{ss}\ \ddot{u}_{vs} + C_{ss}\ \dot{u}_{vs} + \ K_{ss}u_{vs} + M_{ss}R\ddot{u}_{pg}\ = 0 \quad (15)$$

Generally, the direct integration method is used to solve the motion time history equation.

VI. RESULTS AND DISCUSSION

To evaluate the bridge's performance, the subsequent results were obtained for each analysis:

I. Maximum vertical displacements of the deck, ($U_{z,max}$).
II. Displacement of the top pylon in longitudinal and transverse directions, (U_x&U_y).
III. Acceleration of the top pylon in longitudinal and transverse direction, (A_x & A_y).
IV. Maximum pylon base shear in longitudinal and transverse directions, ($R_{x,max}$&$R_{y,max}$).

First Group (Group I)

Deck response

The Maximum vertical displacements of the deck under seismic excitation are plotted in Fig.9. The effect of isolators is approximately similar in all isolation cases except case (ID), which has slightly higher displacements. The percentage of vertical displacement for Erzincan, Duzce, and Ercis ground motions are 40%, 18.20%, and 45.30%, respectively.

Tower response

The displacement and acceleration responses at the top of the pylon are presented in Fig.10 and Fig.11, respectively. Fig.10 shows a comparison of displacement at the top of pylon, which clearly shows similar results in most isolation cases. However, Case (ID) shows significant reduction in pylon displacement compared to other cases. Reductions in longitudinal displacement for Case ID under the Erzincan, Duzce, and Van-Erics ground motions are 77.20%,78.50%, and 63.30% respectively. Reductions in the transverse direction are 76.92%, 54.50%, and 67.50% respectively. Fig.11 shows a comparison of acceleration at the top of the pylon. Longitudinal acceleration is approximately similar in most isolation cases. However, longitudinal acceleration for case (ID) approaches zero for the three ground motions. Transverse acceleration for case (ID) significantly increases compared to other cases with percentages of 65.30%, 68.88%, and 78.45% respectively.

Base shear

Fig.12 compares the base shear of the pylon. Case (ID) reduced its values more than the other cases in both the longitudinal and transverse direction. However, the responses of the isolated bridges in the longitudinal direction are less than the responses in the transverse direction because the isolation design has been done with specific targets set for the longitudinal direction. Case (ID)'s reductions in the longitudinal direction to levels of the response of Erzincan, Duzce, and Van-Erics ground motions are 27.20%,62.50%, and 12.30% respectively. Reductions of the transverse direction to levels of the response of ground motions were 78.50%, 65.20%, and 16.30% respectively.

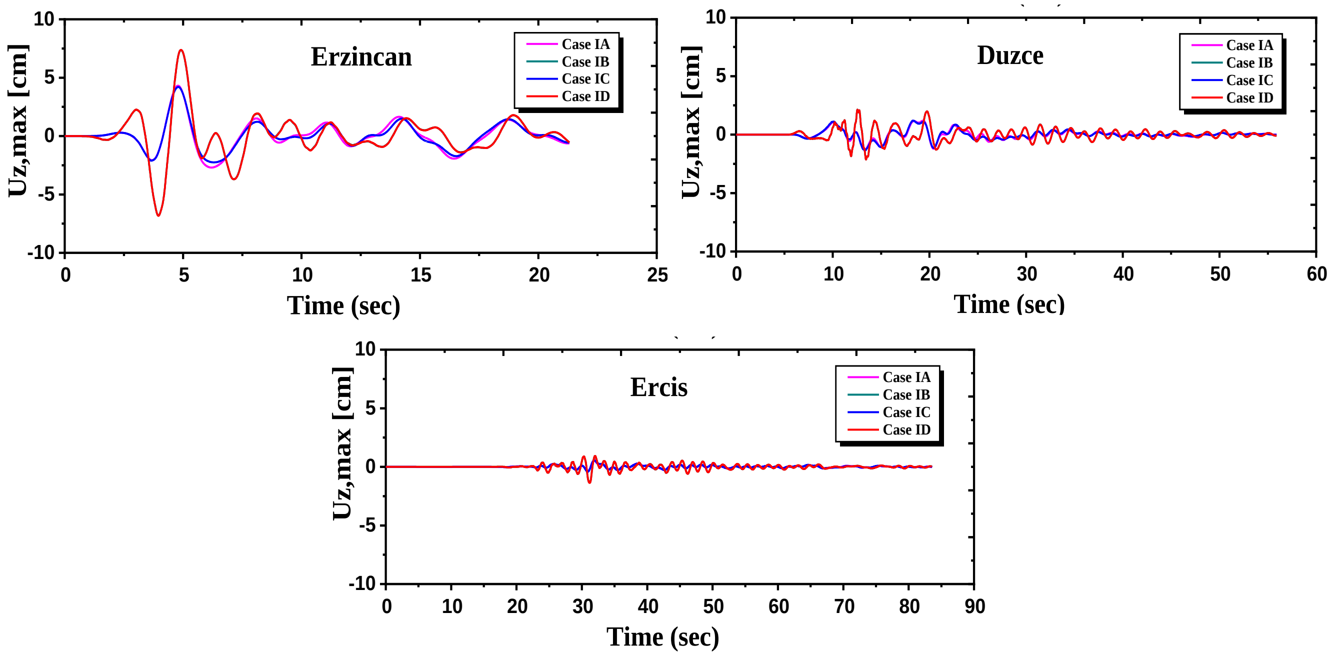
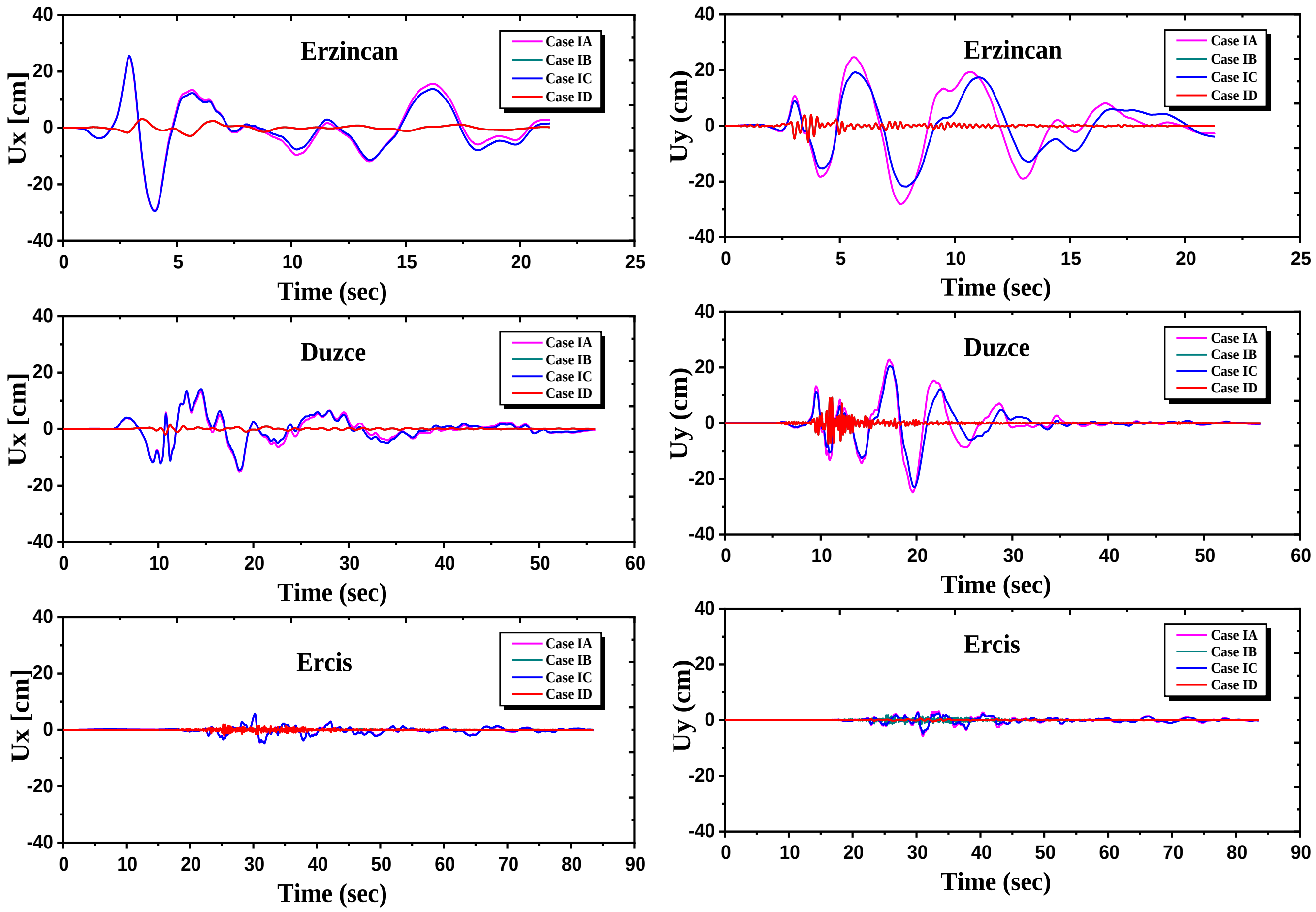
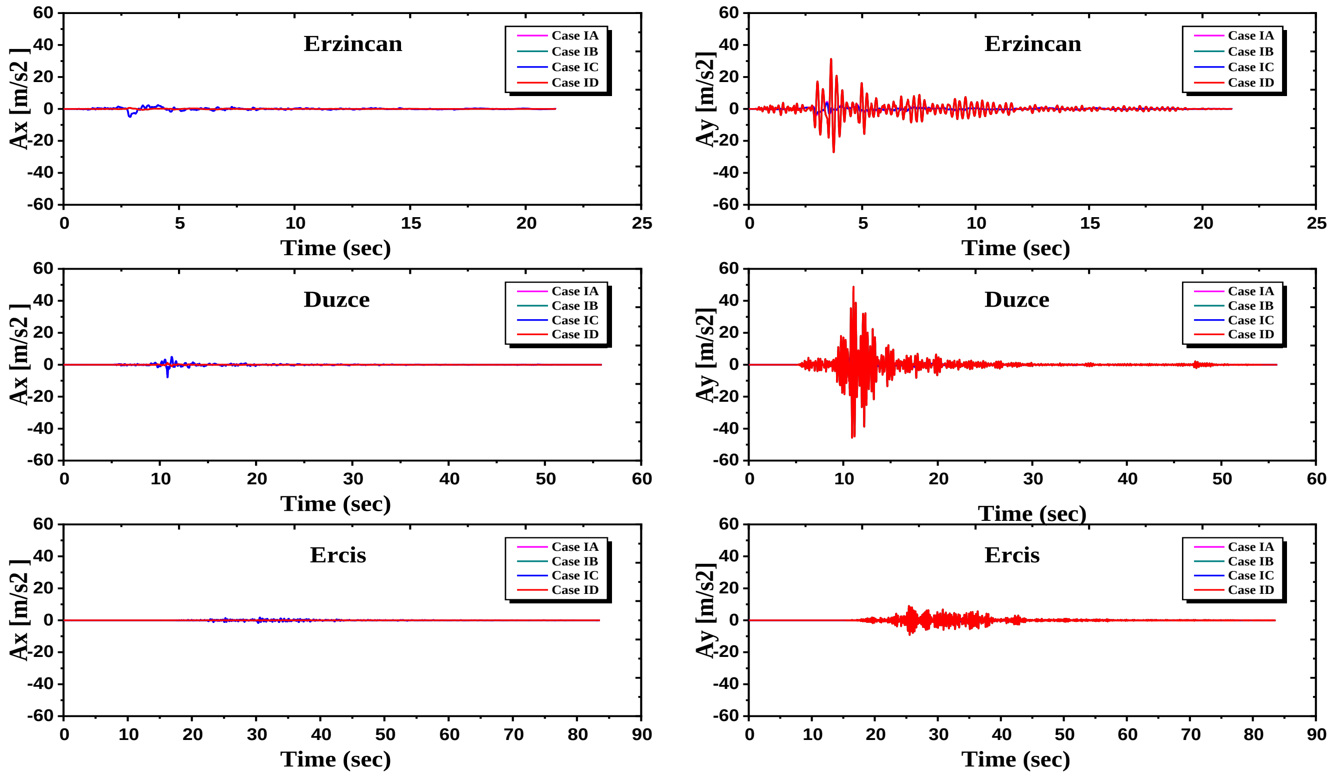


Fig. 9. Maximum vertical displacement of the deck under seismic excitations.



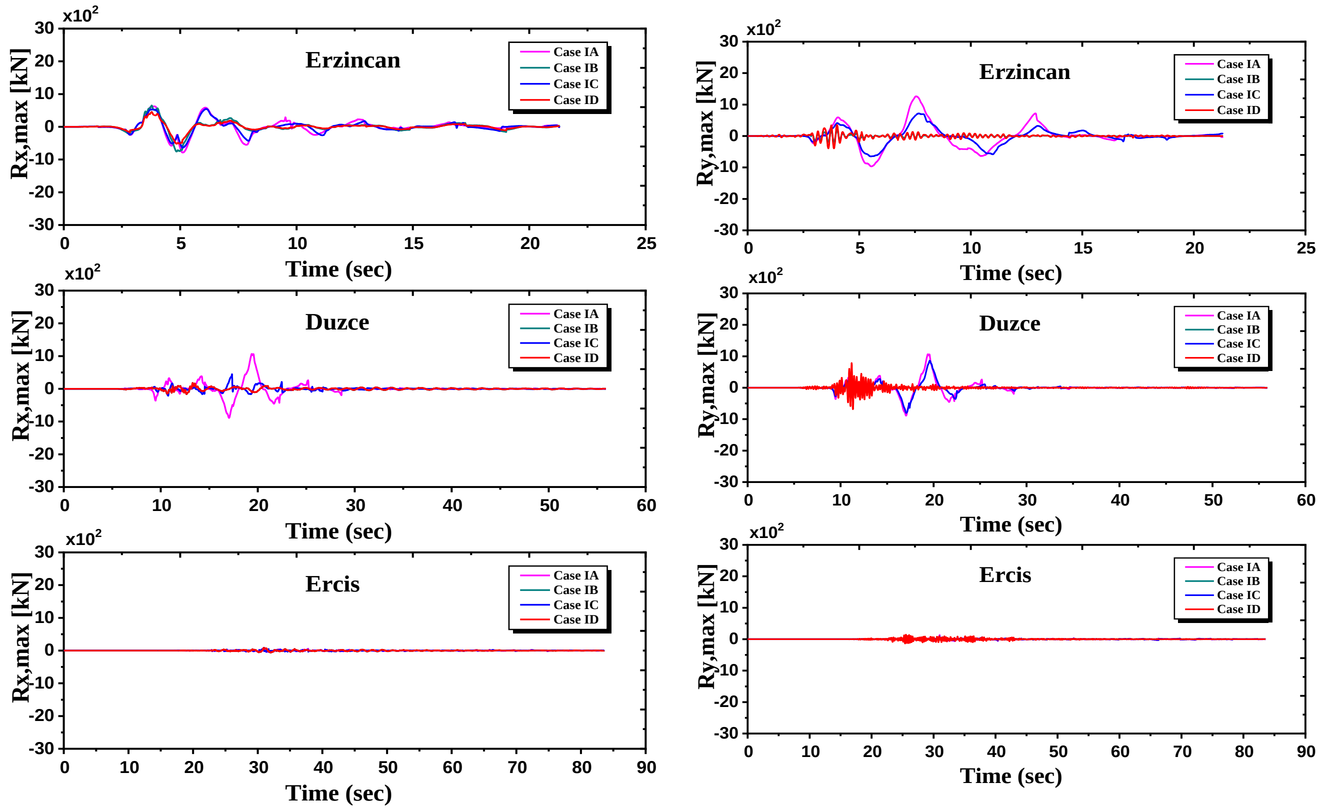
(a) Longitudinal Direction *(b)Transverse Direction*

Fig. 10. Top pylon displacement under seismic excitations.



(a) Longitudinal Direction *(b) Transverse Direction*

Fig. 11. Top pylon acceleration under seismic excitations



(a) Longitudinal Direction *(b) Transverse Direction*

Fig. 12. Pylon base shear under seismic excitations.

Second Group (Group II)

Deck response

The Maximum vertical displacements of the deck under seismic excitation are plotted in Fig.13. The effect of isolators is approximately similar in all isolation cases except case (IID), which was comparatively more effective at reducing vertical displacements. The percentage of vertical displacements for Erzincan, Duzce, and Ercis ground motions for case IID are 68.75%, 31.81%, and 44.30%, respectively.

Tower response

The displacement and acceleration responses at the top of the pylon are presented in Figs.14,15. Fig.14 clearly shows that displacements are approximately similar in most isolation cases. However, case (IID) significantly decreases displacement compared to the other cases; longitudinal reductions in response to the Erzincan, Duzce, and Van-Erics ground motions are 90.40%, 85.71%, and 62.50% respectively. Levels of response to the various ground motions reach zero in the transverse direction, occurring between the isolated bridges. Fig.15 shows that longitudinal acceleration is approximately similar in most isolation cases. However, case (IID) has nearly zero longitudinal acceleration for the three ground motions. However, transverse acceleration for case (IID) is significantly higher than other cases with percentages of 86.25%, 78.80%, and 46.65% for the Erzincan, Duzce, and Van-Erics ground motions respectively.

Base shear

Fig.16 compares the base shears of the pylon. Case (IID) reduced its values more than the other cases in both the longitudinal and transverse directions. However, the responses of the isolated bridges in the longitudinal direction are less than the responses in the transverse direction because the isolation design has been done with specific targets set for the longitudinal direction. Reductions of the longitudinal direction to levels of the response of Erzincan, Duzce, and Van-Erics ground motions are 37.5%,30.81%, and 10.44% respectively. Reductions of the transverse direction to levels of the response of ground motions were 78.57%, 75.20%, and 67.60% respectively.

Based on these results, it is clear that case (D) has significantly improved the seismic response of bridge more than all other isolation cases in the two groups (I&II). Allowing the end span to displace freely can lead to extensive damage due to pounding and excessive bending demands on the superstructure's strong axis.

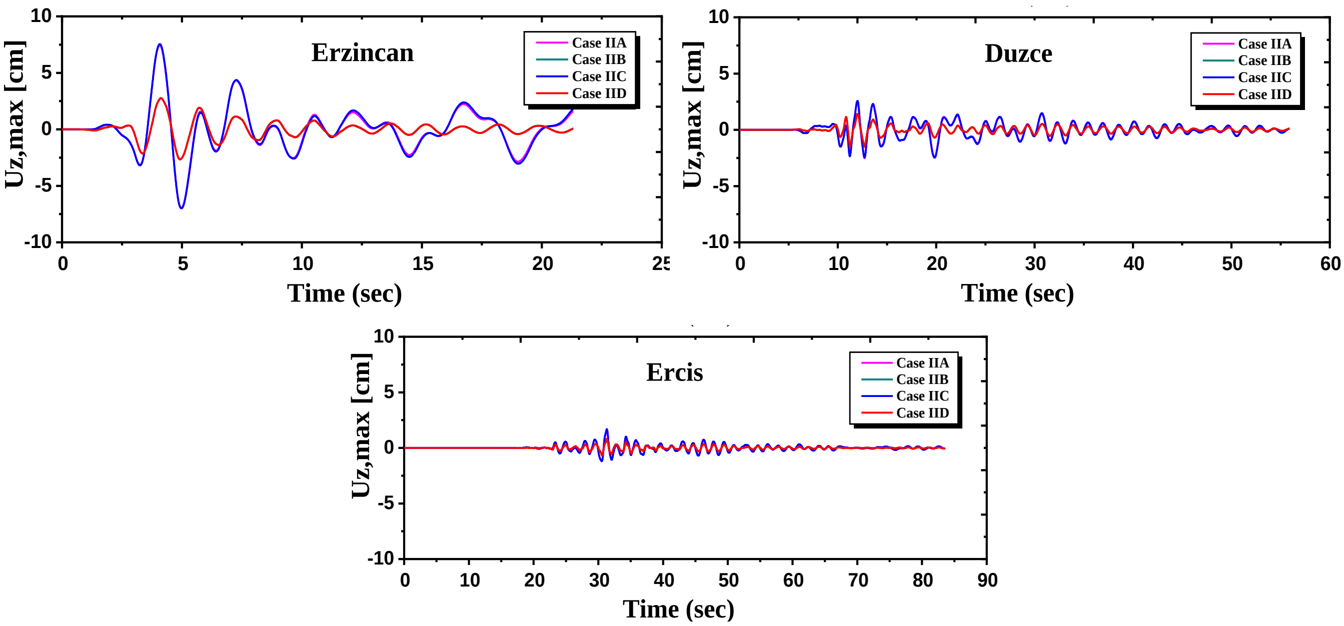
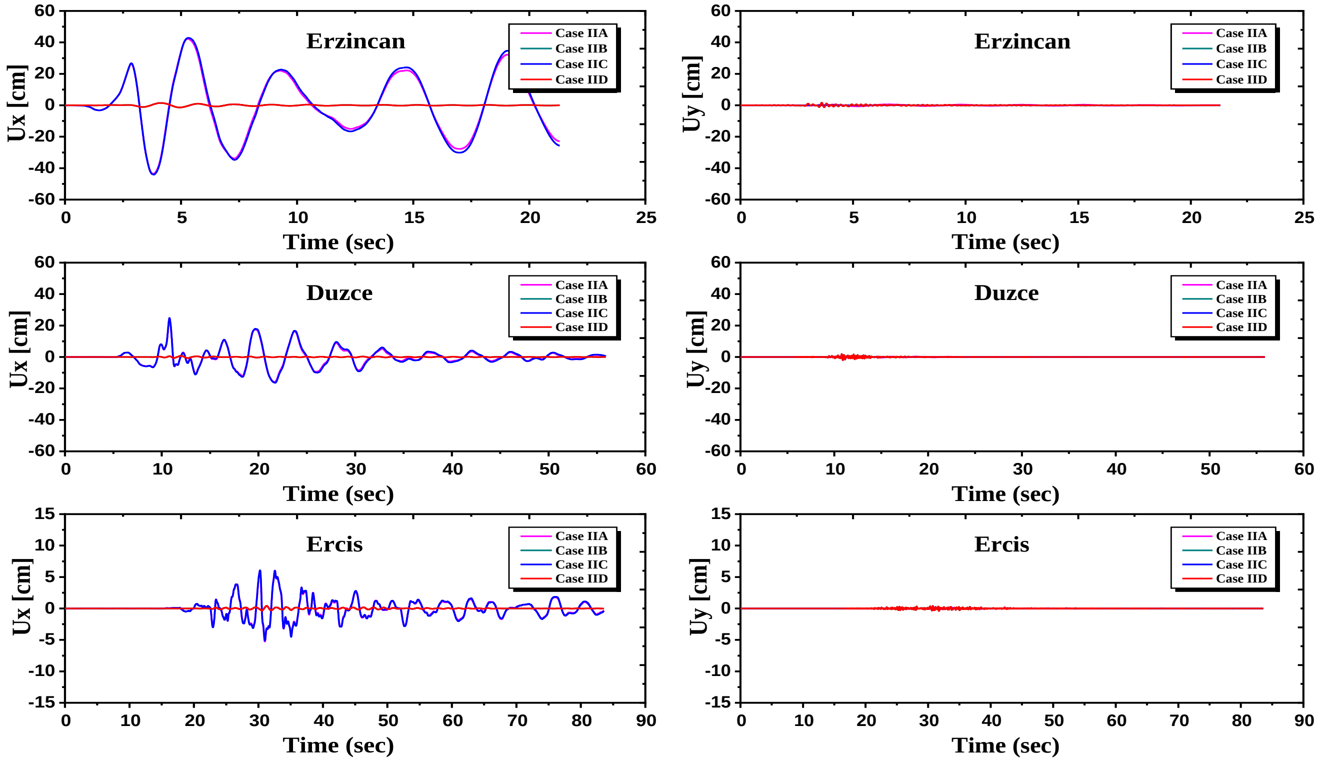
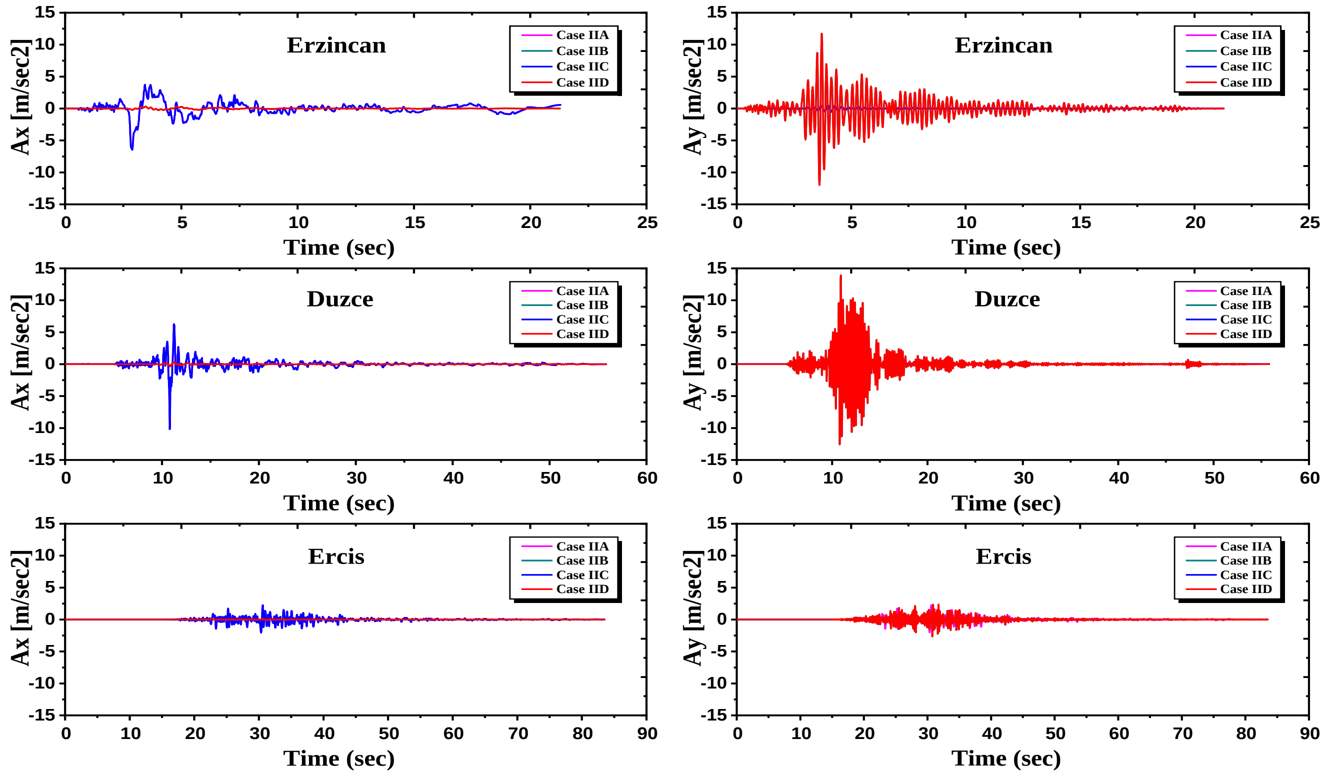


Fig. 13. Maximum vertical displacement of the deck under seismic excitations



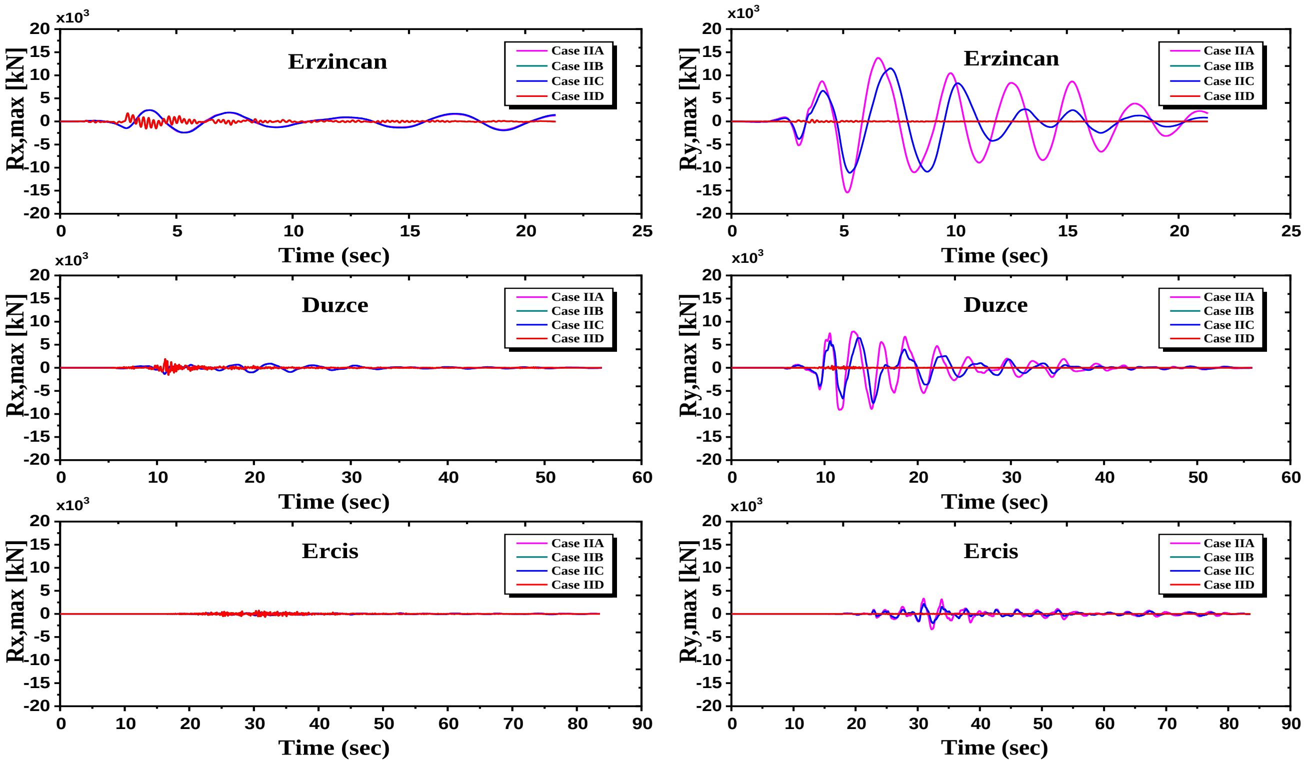
(a)Longitudinal Direction *(b)Transverse Direction*

Fig. 14. Top pylon displacement under seismic excitations.



(a) Longitudinal Direction *(b)Transverse Direction*

Fig. 15. Pylon acceleration under seismic excitations.



(a) Longitudinal Direction *(b) Transverse Direction*

Fig. 16. Top pylon base shear under seismic excitations

Optimum location

Figs. 17-20 illustrate a comparison of peak values of U_{zmax}, U_x, U_y, R_{xmax}, R_{ymax}, A_x, and A_y responses for case (D) between the two groups (I&II) under seismic excitations. It is clear that case (IID) has the capacity to decrease the seismic response more effectively compared to case (ID). Case (IID) represents three SCFP isolators located between the deck and strut attached to the pylon only. On a practical note, it is difficult to apply the pylon isolation system in engineering practice due to potential overturning and instability of the central pylon.

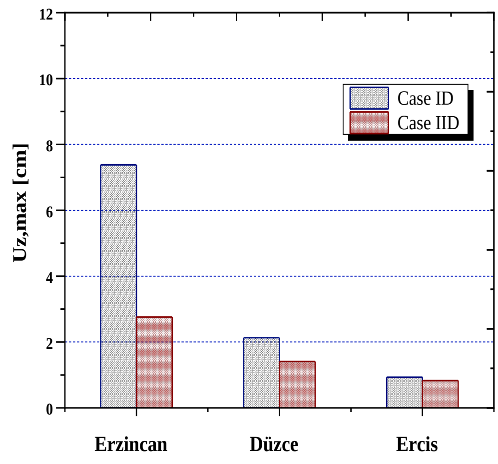


Fig. 17. Comparison between peak of maximum vertical displacement of the deck under seismic excitations

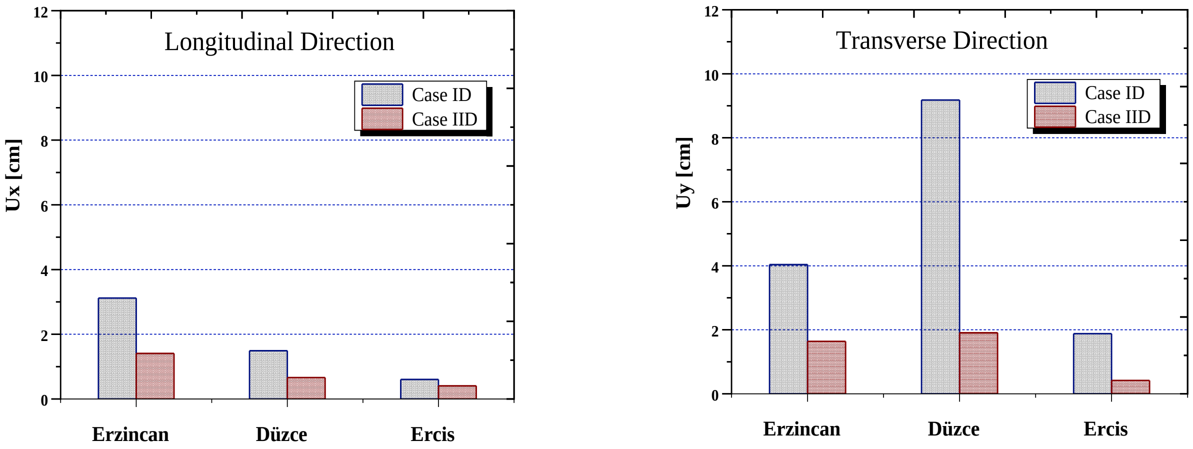


Fig. 18. Comparison between peak of top pylon displacement under seismic excitations.

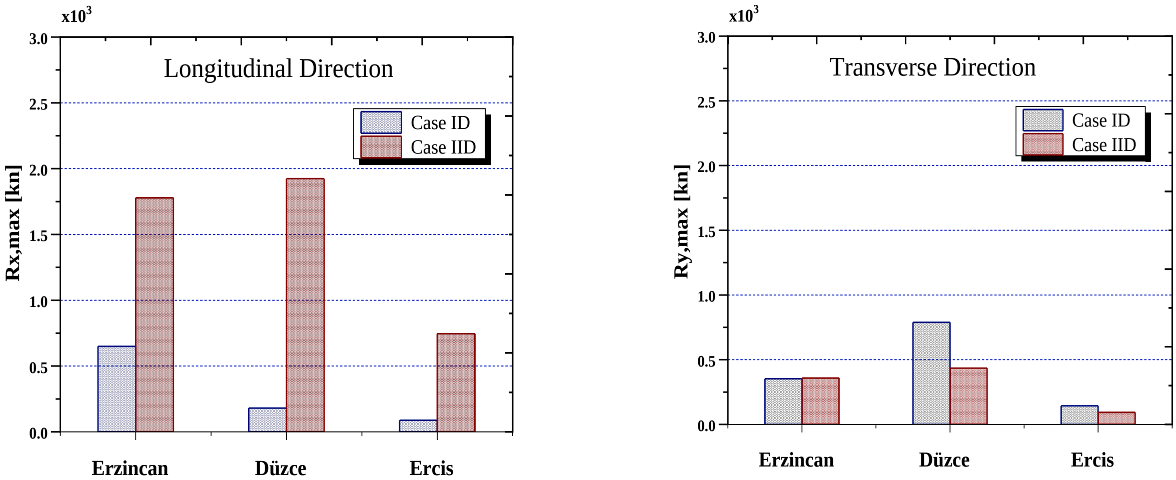


Fig. 19. Comparison between peak of maximum pylon base shear under seismic excitations.

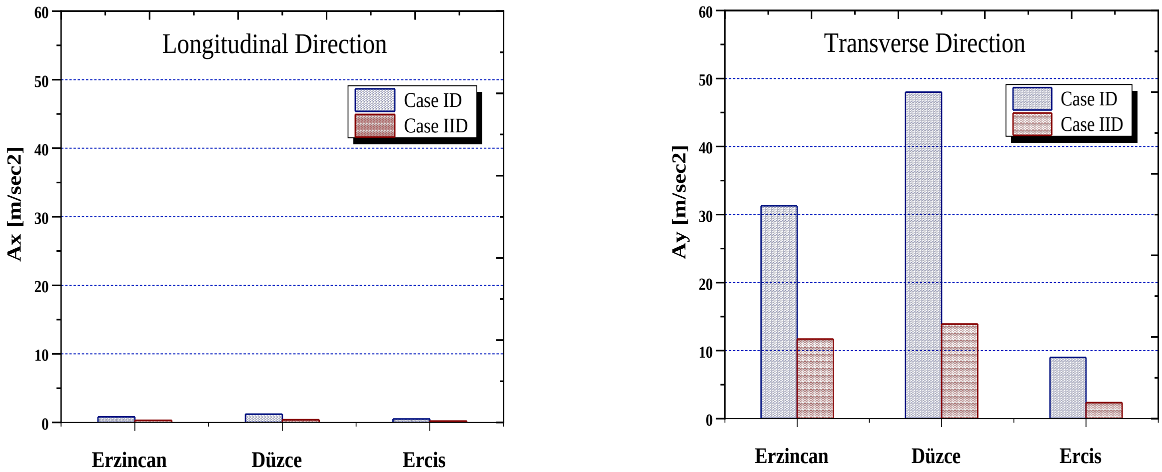


Fig. 20. Comparison between peak of top pylon acceleration under seismic excitations.

VII. SUMMARY AND CONCLUSION

The structural response of Manavgat cable-stayed bridge under seismic excitations has been studied to determine the optimum location of isolation devices (SCFP). Analytical measurements of the bridge responses were used to evaluate the performance of the bridge. The main response parameters considered were deck displacement, pylon base shear, top of pylon displacement, and top of pylon acceleration. A finite element model of the bridge was created, and its accuracy was verified using SAP2000. SCFP was applied to various locations of the bridge under three ground motions. The main conclusions of this study can be summarized as follows:

I. The isolation system is effective in increasing periods of the bridge significantly, thus decreasing the internal reactions of the bridge.
II. SCFP reduced the vertical displacement of the bridge deck, base shear, and displacement of the pylon significantly.
III. The usage of isolation devices at end spans provides some benefits to the internal forces of the bridge. However, allowing the end spans to displace can lead to extensive damage due to pounding. Therefore, the absence of isolators at the end spans is safer and more effective.
IV. The location of the isolation system between the pylon and foundation has shown some reduction in the strong axis bending demands of the superstructure. However, the isolation in this particular location is not sufficient to control the seismic bending demands on the superstructure. Finally, it is difficult to apply the pylon isolation system in engineering practice due to fear of overturning and instability of the central pylon.

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