Challenges in the Implementation of Augmented Reality for Improvement of Health and Safety in the Construction Industry of Pakistan

Final Year Project UG 2016

By

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This is to certify that the

Final Year Project, titled

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Has been accepted towards the requirements

for the award of Bachelor's degree

in

Civil Engineering

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Declaration

We certify that this research work titled "*Challenges in the implementation of Augmented Reality for improvement of health and safety in the construction Industry of Pakistan"* is our own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources; it has been properly acknowledged / referred.

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Copyright Statement

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Dedicated to Our Parents and Families

Abstract

Augmented reality is an interactive experience of a real world environment where the objects th at reside in the real world are enhanced by computer generated perceptual information, sometim es across multiplesensory modalities. The problem is that injuries and fatalities resulting from work place accidents remain a global concern within the construction and engineering sectors. There is no attention being paid to the health and safety of the employeesAdoption of a new technology such as augmented reality can reduce the number of such accidents but implement ation of such a technology is the problem in construction sector of Pakistan. This study provides an insight of the challenges for the implementation of augmented reality in the construction sector of Pakistan. Augmented Reality is helping for betterment in scheduling, defect detection in materials and employee safety training as well. Thefocus would be on improvement of health and safety in construction sector of Pakistan using augmented reality. A conceptual framework was developed for the implementation of Augmented Reality in construction industry of Pakistan for health and safety.

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CHAPTER 1

INTRODUCTION

1.1 Background

Augmented reality is defined as a way through which the real world is augmented with virtual objects (Milgramt and Kishinott, 1994). Augmented reality systems to have the following properties: to combine both the virtual and real objects in a real environment; geometrically aligning virtual objects and real ones in the real world and run interactively and in real time (Azuma and Behringer, 2001). The basic importance of augmented reality is the way in which different components of the modern digital worldare blended into any user's interpretation and perception of the real world, not only by a simple display of information, but through the integration of immersive sensations, which are perceived as components of the natural environment. The primary objective of augmented reality is to provide a rich audivisual experience despite having various implementation models and applications.

Augmented reality technology has been applied to a wide range of fields: tourism, entertainments, marketing, surgery, logistics, manufacturing, maintenance and others (Westerfield ,Mitrovic and Billinghurst, 2015). It has affected the construction industry in the same way as it has revolutionized various fields of life for the betterment of humanity. Before any project is executed, augmented reality provides teams with a walkthrough of the entire project, saving time and money and increasing the accuracy of construction projects. Project managers can easily analyze the design as they can walk through the proposed project identifying and amending any design flaws.

1.2 Problem Statement

Construction is a large, dynamic and complex sector that offers a large number of employment opportunities for millions of people worldwide. (Rostami and Sommerville, 2015) However, deadly accidents in the construction industry are higher than other sectors (Zhou, Goh and Li, 2015). These problems can be addressed by using augmented reality technology in a more effective manner by training sessions of employees and workers. Labor can be trained and guided for working in harsh conditions using augmented reality gadgets, thus, increasing productivity and reducing casualties at worksites. Resources invested for the safety of skilled and professional labor can save the reputation and assets of any company. On the other hand, use of traditional construction practices have resulted in cost overruns, construction delays

and wastage of resources which result in poor work efficiency and productivity. The quality of construction can be widely improved and make efficient through use of augmented reality. We shall be discussing how augmented reality can serve this purpose.

Secondly, we have been taught various project delivery methods but in Pakistan, most of the times, traditional method is followed. Likewise, construction firms pay less heed towards employing proper safety measures during construction. Labor is not even properly guided during large scale unique projects. Similarly, construction industries relay on traditional practices instead of innovative technology which can boost up their efficiency and productivity which will result in maximizing profit margin and reduction in cost of construction. We shall address the barriers which lie in implementing the use of augmented reality technology for the safety of labor and how it can improve the quality of construction works in Pakistan. Companies do not invest in personal protective equipment for the employees for various reasons, but they need to understand that skilled labor is a valuable asset of the firm and should use augmented reality applications for training the emp loyees. By investing in safety of workers it will automatically improve the quality of work and make construction of structure safe and sound.

Thirdly, most of the contractors in Pakistan are not aware of the fact that technological advancements can be used for safety purposes and quality improvement purposes. They need to be properly guided about the applications of augmented reality. Contractors need to be persuaded about using augmented reality for the safety of the labor, employees and for the well-being of the reputation of their construction firms.

1.3 Research Objectives

Augmented reality has vast areas of applications in construction industry from safety to construction modeling. Construction industry is a complicated environment where high accident rates are still encountered causing serious project delays and cost overruns which results in poor quality of work. Safety education and quality control is important in promoting a healthful working environment in construction industry. Main objectives of this project are briefly mentioned below:

- To identify different challenges in the adoption of augmented reality in the construction industry of Pakistan
- To develop a conceptual framework for the improvement of health and safety using augmented reality on construction sites.

1.4 Significance

The construction industry and job sites are changing. Paper sketches, drawings and design plans are being replaced by 3D models, drones and a new interactive experience called augmented reality. Augmented reality is improving construction teams by driving more accuracy, efficiency and overall confidence in their projects by combining physical and digital views. Instead of replacing employees and labor on the construction sites, augmented reality can greatly enhance the ways digital devices and humans work together.

Safety is one of the common challenges within the construction industry. Safety programs can cost a lot of money and time and are not mostly well communicated to target audience. With the help of an augmented reality headset, however, workers can be shown virtual drills, instruction, and safety scenarios. This style of direct learning not only improves their awareness of safety and provides intuitive training, but lowers training costs and downtime. Virtual models of different equipment like cranes and boom lifts are being created by exploring augmented reality. Workers shall be capable of using augmented reality headsets a nd gadgets to practice operating heavy machineryin a safe and virtual setting, further enhancing their learning and development.

One of five construction workers suffered from fatal injuries in 2017 in the US. These statistics can be potentially lowered through augmented reality by allowing contractors room for error before the actual construction work starts. One prototype demonstrates this by allowing workers to see the machinery and expected environment overlaid on anempty site. Such application of augmented reality will help teams prepare and check forsafety hazards be fore the official commencement of work. Job sites can be surveyed by the inspectors later on by comparing the real life structure and the full scale digital model. Any disparities hazardous to worker safety can be noted in this way.

CHAPTER 2

LITERATURE REVIEW

2.1 Health and Safety

We will be discussing some of the basic key terms briefly.

2.1.1 Health

"*The protection of the bodies and mind of the people from illness resulting from any materials, processes and procedures used in the workplace*" (Hughes and Ferrett, 2012).

Injuries and accidents can be prevented in workplaces during various projects. Risk should be minimized by removing hazards so as there are least possibilities of accidents to occur. In this manner, productivity and performance of the workers could be enhanced up to many folds (Alli, 2008).

2.1.2 Safety

"*The protection of people from physical injury. The borderline between health and safety is ill defined and the two words (health and safety) are normally used together to indicate concern for the physical and mental wellbeing of an individual*" (Hughes and Ferrett, 2012).

The safer the workplace, better would be the performance of the workers and engineers. All the safety concerns should be addressed effectively before the commencement of work and no negligence should be accepted in this regard.

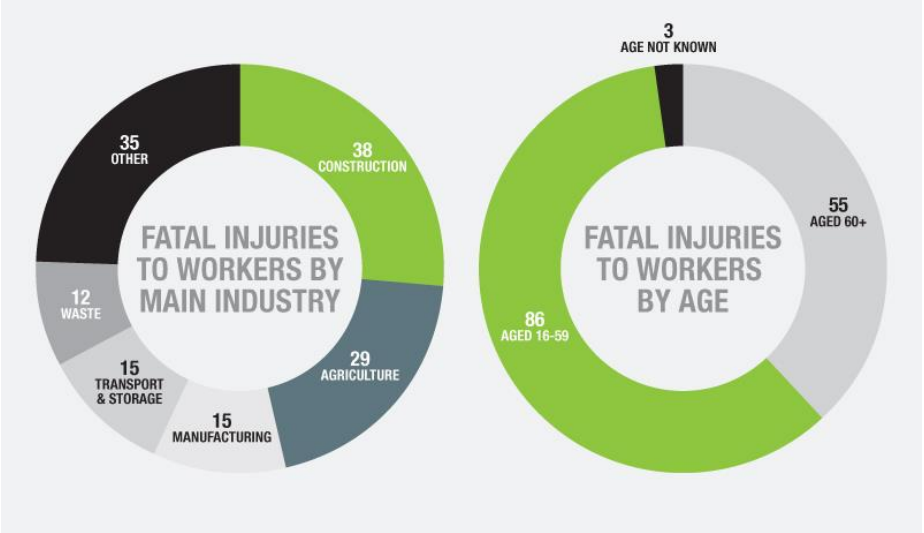
2.1.3 Accidents

"*An unplanned event which could result in mental or physical damage to people, property and environment or a loss of business opportunity*" (Hughes and Ferrett, 2012).

Accidents can badly affect the budget and timeline of any project. It disturbs the psychological health of workers which can affect their productivity. Thus, affecting the construction projects.

2.2 Importance of Health and Safety in Construction Sector

Safety managers are always trying to move towards a safer and zero-accident jobsite (Gheisari et al. 2012) but still onsite accident and injury is an occupation hazard of the Construction industry. According to the US bureau of labor statistics ((BLS) 2016) construction remains the occupation with the highest number of on-job casualties.



Rate of Injuries

2.2.1 Current Statistics

The number of casualties due to accident are also great According to the USBLS the construction industry has been identified as having the 3.6 per 10000 increase in the rate of fatal work injuries

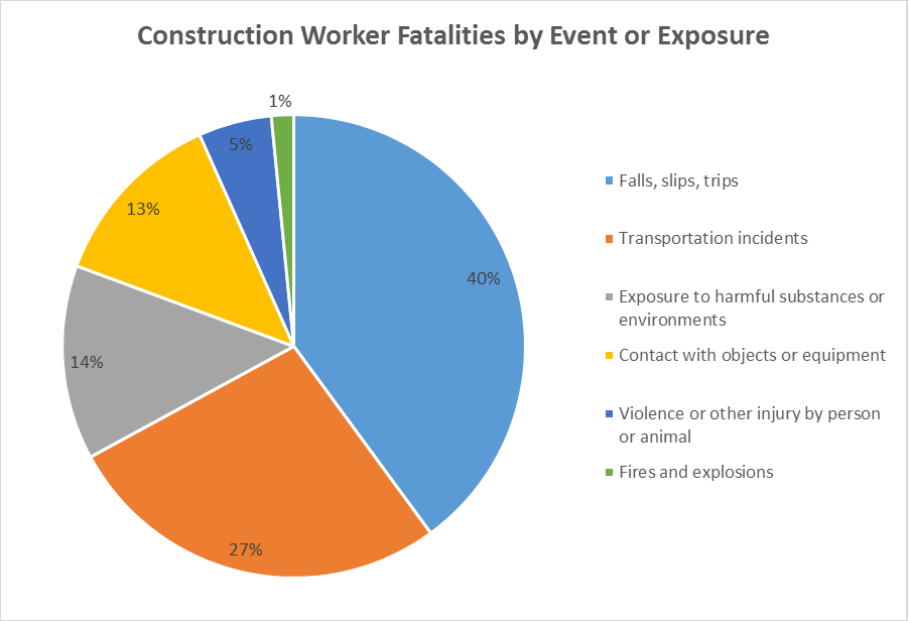
YEAR	CONSTRUCTION FATALITIES	FATALITY RATES*
2011	738	9.1
2012	806	9.9
2013	828	9.7
2014	899	9.8
2015	937	10.1
2016	991	10.1
2017	971	9.5
2018	1,008	9.5

*FATALITIES PER 100,000 FULL-TIME-EQUIVALENT WORKERS. **NOTE:** STATISTICS ARE FOR PRIVATE-SECTOR CONSTRUCTION INDUSTRY.
SOURCE: BUREAU OF LABOR STATISTICS

Workers involved in construction industry are liable to accidents that could lead to temporary or permanent disabilities and fatalities (Administration CPWR, 2018). According to United States department of labor following are major violations that occurred in 2018 which resulted in casualties on construction site

- Fall protection, construction
- Hazard communication standard, general industry
- Scaffolding, general requirements, construction
- Respiratory protection, general industry

- Control of hazardous energy (lockout/tag out), general industry
- Ladders, construction
- Powered industrial trucks, general industry (Fall Protection–Training Requirements)
- Machinery and Machine Guarding, general requirements
- Eye and Face Protection



2.2.2 Labor laws to Ensure Safety

According to Pakistan Occasional Act 2018, it addresses the labor policy 2010 of government of Pakistan which is stated as following:

- Labor Laws relating to occupational safety and health will be consolidated and rationalized to avoid overlapping and inconsistencies.
- Government shall enact suitable legislation to ensure health and safety of construction workers.
- A Tripartite Council on Health and Safety be set-up to identify health and safety hazards for workers of all economic sectors and to make recommendations for safety measures on a continuous basis.

2.2.3 Factors Compromising Health and Safety

The academia has spent a lot of time to identify which factors cause problems to health and safety of workers. (Toole, 2002) identified it as follows:

- Lack of proper training

- Safe equipment not provided
- Unsafe site conditions
- Poor attitude towards safety
- Deficient enforcement of safety
- Unsafe methods or sequencing
- Not using safety equipment provided
- Isolated or sudden events

Out of these eight factors, five factors can be monitored by observation. Hence to improve safety for all working in the construction site, safety manager need a way to efficiently observe and correct practice or action that may compromise the safety of the people working at the jobsite. One major factor that jeopardizes the health and safety that when it comes to accident prevention management is tends to be reactive rather than proactive (Borhani, 2016).

FACTORS AFFECTTING OCCUPATIONAL HEALTH AND SAFETY

2.3 Health and Safety in Construction Sector of Pakistan

2.3.1 Safety Issues

Although construction industry stakeholders/owners in Pakistan are generally aware of the priority of safety as well as its significance to the industry but lack of commitment, cooperation, expertise and familiarity with tools to implement safety culture on their projects. Formal safety management practices are infrequent among stakeholders/owners and the projects suffer from accidents resulting in productivity losses, project delays and cost overruns. Therefore it can be concluded that owners/stakeholders/owners in Pakistan construction industry, owing to lack of commitment as well as lack of systematic procedures, do not have adequate capability of maintaininga safe project. The owners are considered to be the key initiators for project safety; without owner commitment to safety, contractors are not willing to accept major responsibility for safety and hence their lack of commitment. A cultural and behavioral shift is needed in the stakeholder perception about safety management implementation and improvement on projects. The major obstacles faced by contractors to the implementation and improvement of safety includes – in decreasing order of significance –
absence of the following: worker cooperation and behavior, familiarity and expertise with safety management techniques, safety awareness and knowledge, owner commitment, and a safety regulatory framework. (Ahmed, 2008)

2.3.2 An Overview of Construction Industry in Pakistan

At the present moment there is no governing authority for work-related health and safety management in Pakistan (for example OSHA in USA). (Ali, 2006). The present engineering body of Pakistan (PEC) has yet to set down safety laws and regulations, to be implemented by all the stakeholder's in construction industry

Here are some of the statistics related to the CI of Pakistan.

- **2.5%** of GDP as per State Bank of Pakistan annual report published in 2010-11 is contributed by construction industry
- **6.29%** of total workforce is from CI as per Federal board of Statistics, 2010.
- on construction site injuries and diseases in construction industry are observed as **20 to 25% of total industry.** (Farooqui et al., 2008)
- Safety Performance Index of CI of Pakistan is observed to be **0.52.** It indicates lack of standard safety management system (Khan, 2011).

Governing Safety Laws in Pakistan

The governing laws of Health and Safety of workers in Pakistan construction industry are:

- Factories Act 1934 (chapter 3)
- Government of Pakistan Labor Policy (revised in 2010)

- Health and Safety clauses in PEC ‘s contract documents:
- Safety, Security and Protection of the Environment
- Clause 19.1 of Part-I (General Condition of Contract) of PEC
- Standard Form of Bidding Documents
- Clause 19.3 of part-II (Particular Conditions of Contract) of PEC
- Standard Form of Bidding Documents (Khan, 2011).

2.3.3 Causes of Accidents

The main demand of client is high productivity and high work efficiency at minimum cost. Primary objective of contractors is cost and time reduction in order to maximize company’s profit margin. Risky conditions and minimum safety precaution followed by labors and workers on construction site lead to accidents. On many occasion, construction industries don’t pay any attention towards necessary safety measures, safety meetings and training programs for workers and staff in order to minimize incidents that can occur on construction site (Farooqui et al., 2008).

Informal evaluations have indicated unsafe work environment on constructions site not only lead to dangerous accidents but also resulted in cost overruns, poor work efficiency, time extension and poor construction practices (Farooqui et al., 2008). Considering these outcomes rapid action should be taken by concerned authorities and construction industry towards construction safety by conducting safety seminars, onsite training and introducing new technology to detect hazards and arrange formal or informal safety education. Research (Choudhry et al., 2008b) demonstrated that constructors in the developing countries need to implement safety management systems to enhance their safety performance level.

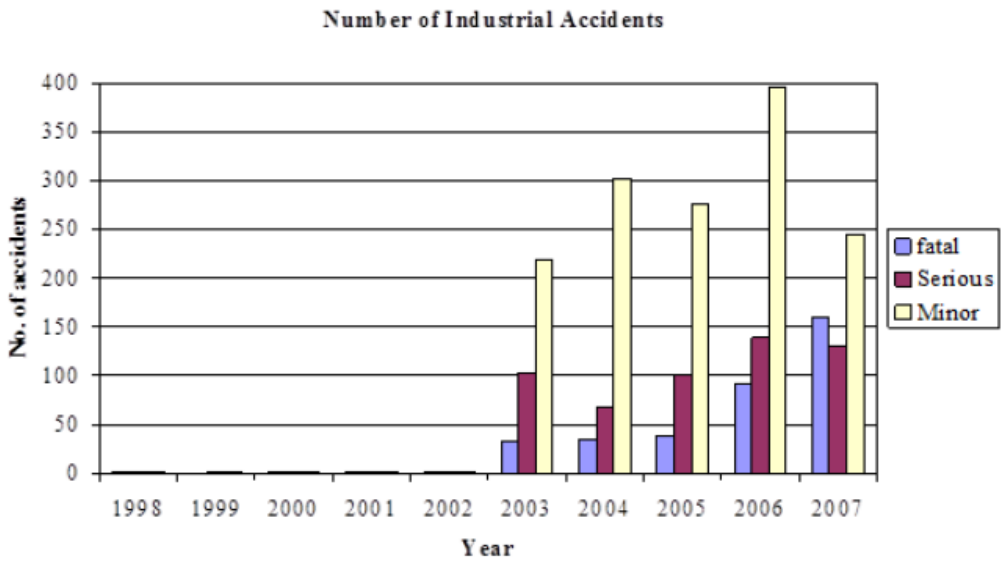


Figure shows the available data from labor division of Pakistan about the industrial accidents in factories registered under Factories Act-1934.

Following are some of the main causes of accidents which are observed during construction process.

Slips, Trips and Low Falls

Most common form of accident that usually occur on construction are trips and low falls. They may are minor accidents but they can lead towards dangerous injuries and ill health outcomes such as muscular strains and puncture wounds

Falls from height

This is one of the reason of major fatal accidents. These usually occur due to:

- Improper scaffolding
- Lack of edge protection
- Dangerous demolition work
- Inadequate use of ladders
- Unprotected openings in buildings

Crush injuries

These show up in unsafe excavations often lead to deadly accidents or serious injuries.They occur when there is inadequate support for trench sides, especially after rainfalls, or when

vehicles are operating too close to the edge. Buildings and wall may collapse when supporting structures are undermined.

Being Struck by Falling Objects, Materials or Tools

This is a potentially deadly occurrence. Such falling objects can be due to:

- The lack of toe boards on scaffolding
- Lack of tool belts for workers
- Bad storage and stacking
- Poor housekeeping

Electrocutions

This can be due to cable strikes on buried services or by contact with overhead cables.

2.4 Major Problems in Construction Sector of Pakistan

2.4.1 Quality Issues

Most stakeholders/owners feel that total quality management methods (TQM) would not be working in their organizations due to current organizational and industry culture. However they are aware of the benefits of implementing TQM in their organizations to some extent and feel that it would be favorable if it can be implemented. Most of them think that TQM is a method for improving cost estimating, warranty claims and project economy. TQM has not been implemented by any organization as their quality policy. Most of the organizations prefer periodic short-range solutions or motivational programs as compared to more formal long-term programs. Many organizations belonging to the construction industry are not giving any formal training quality management workshops to their employees.

The top 5 obstacles in the implementation of TQM program, as indicated by the respondents, are:

1. Lack of expertise/resources in TQM
2. Rigid attitude and behavior of executive management toward quality
3. Lack of top-management commitment/understanding
4. Lack of employee commitment/understanding
5. Lack of education and training to drive the improvement process

The construction firms working in Pakistan are generally neither prepared nor willing to put Total Quality Management (TQM) as a management philosophy within their organizational

cultures. Most organizations are unenthusiastic regarding TQM implementation and are unwilling to invest in it including both time and capital. Only few organizations identified the procedure for TQM implementation that should, through persistence, allow the Pakistan construction industry to adopt TQM philosophy comprehensively.

Regulatory agencies work for the organization safety management throughout the world as OSHA-Occupational Safety and Health Administration in USA. Unfortunately there is no such authority working in Pakistan. The primary construction regulatory body in Pakistan is the Pakistan Engineering Council (PEC) which has yet to lay down safety laws and regulations that will be adopted by the stakeholders/owners in order to implement safety practices throughout the country.PEC has rated each contractor against a number of components but still it does not incorporate contractor safety performance.

If safety performance is incorporated as a factor in contractor rating, it would encourage the contractors to adopt safety management practices in their companies. Construction management should be emphasized at all times no matter how fast the construction needs to be completed and under what budget constraints. The contractors should integrate management training programs with other practices according to their budget. Training can be provided in many ways: on-
site training, meetings before the start of any work; large size contractors may develop separate training departments. Contractors should encourage their project managers to develop detailed project plans and schedules incorporating risk, safety and quality.

2.4.2 Rework and Shortage of Skilled Labor

Results based on a survey conducted for analyzing the risk factors in construction sector of Pakistan are shared which can be solved by augmented reality technology. All of these issues could not be discussed so only few of them have been selected for analysis. A questionnaire was sent out to point out the causes which were responsible for project delays and increased costs. The results were further classified on the basis of three critical factors.

Table 5. RII results from questionnaire.

S. No	Factors	RII cost over run	Rank	RII quality	Rank	RII time	Rank
1	Poor site management	0.7495	3	0.6141	20	0.7515	4
2	Poor supervision	0.6465	19	0.804	1	0.6727	33
3	Lack of safety precaution	0.5838	45	0.4465	53	0.5677	68
4	Inadequate planning and scheduling	0.6788	10	0.4727	48	0.697	20
5	Underestimation of costs of projects	0.7354	4	0.6242	15	0.6768	30
6	Underestimation of complexity of projects	0.6222	30	0.4545	52	0.6626	39
7	Underestimation of time of completion	0.7818	2	0.5111	39	0.7172	12
8	Financial Instability of contractor	0.6343	25	0.5677	31	0.6707	35
9	Lack of continuous improvement culture	0.5778	49	0.4626	50	0.6242	50
10	Lack of acquiring new equipment's	0.596	41	0.5879	25	0.6141	54
11	Acquire outdate machinery	0.6566	14	0.6364	12	0.7374	6
12	Low Bid	0.6949	7	0.7091	5	0.6687	37
13	Delays in contractors payment to sub contractors	0.5818	46	0.4747	47	0.6162	51
14	Lack of trust with supplier	0.4667	69	0.4263	55	0.4949	72
15	Poor performance by procurement department	0.4949	66	0.4869	44	0.5232	69
16	Rework due to error	0.804	1	0.6242	15	0.7636	3
17	Poor site investigation	0.6687	12	0.7051	7	0.6162	51
18	Conflict between consultant and design Engineer	0.6444	21	0.697	9	0.6061	56
19	Lack of consultant experience	0.6687	12	0.7374	3	0.6444	46
20	Delay in approving major changes of work	0.6364	23	0.5657	32	0.6949	23
21	Delay in performing inspection in testing	0.6343	25	0.4	57	0.6465	45
22	In accurate site investigation	0.5737	50	0.7051	7	0.604	57
23	In adequate project management	0.7051	6	0.503	42	0.8909	1
24	Poor communication and coordination	0.602	39	0.4667	49	0.6485	44
25	Owner Interference	0.5232	62	0.5172	38	0.697	20
26	Slow decision making	0.4545	70	0.4606	51	0.6747	32
27	Change in specification by owner	0.5798	47	0.5697	29	0.6586	40
28	Poor communication and coordination	0.4545	70	0.4465	53	0.6727	33
29	Suspension of work by owner	0.6465	19	0.503	42	0.7071	15
30	Late funding	0.5677	53	0.5576	34	0.8485	2
31	No incentives	0.3899	73	0.3697	61	0.5091	70
32	Unclear definition of quality	0.4687	68	0.7253	4	0.5737	67
33	Mistakes in design	0.6263	28	0.6081	21	0.7051	17
34	Delays in design documentation	0.5919	43	0.5475	35	0.7273	11
35	Unclear and inadequate details and drawing	0.5859	44	0.6061	22	0.7172	12
36	Complexity in design project	0.6081	36	0.598	23	0.6929	25
37	Insufficient survey for design	0.6768	11	0.6222	17	0.7374	6
38	Misunderstanding in owner requirement by design engineer	0.6505	16	0.5859	27	0.7051	17
39	Lack of experience	0.6364	23	0.6162	19	0.7071	15
40	Poor communication and coordination with contractor	0.6343	25	0.5616	33	0.6667	38
41	Outdated machinery	0.6081	36	0.6687	11	0.5859	65
42	Shortage of work force	0.4727	67	0.5071	41	0.6949	23
43	Poor management	0.5293	61	0.5939	24	0.7374	6
44	Shortages of Materials on Site / Market	0.602	39	0.5879	25	0.6768	30
45	Defective Materials provided by supplier	0.5717	51	0.7475	2	0.7091	14
46	Late delivery of Material	0.6566	14	0.4768	46	0.7434	5
47	Late procurement of material	0.6162	32	0.5111	39	0.6545	43
48	Fluctuation in material prices	0.7192	5	0.4848	45	0.6707	35
49	Shortage of Mangers / Engineers	0.5636	54	0.7091	5	0.6263	48
50	Shortage of Skilled labors	0.6485	17	0.6263	14	0.7051	17
51	Shortage of Unskilled labors	0.6242	29	0.6202	18	0.6808	29
52	Lack of technological Construction Machinery	0.6101	35	0.6303	13	0.5859	65
53	Equipment failure or breakdown	0.6889	8	0.5313	37	0.7333	9
54	Unskilled equipment Operators	0.5697	52	0.6889	10	0.6283	47
55	Late deliverers	0.5394	59	0.3535	64	0.6162	51
56	Bad weather conditions	0.6485	17	0.5697	29	0.697	20
57	Natural disaster / Unfavorable site conditions	0.5939	42	0.3899	59	0.6889	26
58	Delays in obtaining permit from Govt. authorities	0.6889	8	0.2707	70	0.7293	10

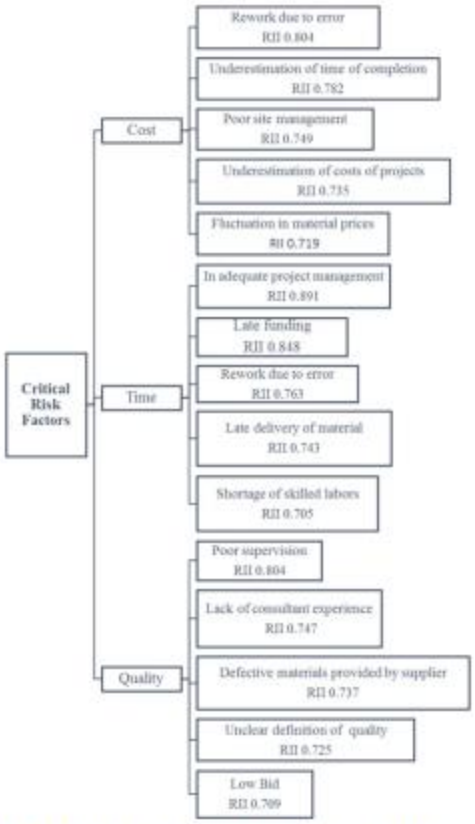


Figure 3. Objective wise break down of top risks factors.

The third highest critical risk factor which has affected project duration in a negative way was reworks done due to error. Rework of any quantum and kind disturbs the project in a negative aspect not only financially but also in terms of time. Rework almost increases the duration on any activity by three times therefore is a very critical risk and shall be avoided on first place to avoid some delays.

The fifth factor on the list of highest critical risk factors was shortage of skilled labor resulting in time overruns at construction projects in Pakistan. Skilled labor is of great significance and a very critical resource in any project as they can directly hamper the project performance in terms of time, quality and capital. Unskilled labor when execut -ing any activity shall always take more time for completion of that particular work. Moreover, additional time will be required for its rectification causing major time losses.

According to the survey results, rework due to error (RII 0.804) was rated as the most critical risk factor that disturbs the project cost in Pakistan. Rework due to error can be because of various reasons that may be due to inexperience of the labor or site overseeing staff and can

also be due to malfunction of construction equipment like shuttering, batching plant etc. Rework not only doubles the material and labor cost of any activity but also additional manpower is required for removal of the defected work that further negatively dents the project cash flow. (Asad Kamal, 2019)

2.4.3 Poor Site Management and Poor Supervision

The third highest ranked factor causing cost over runs in construction industry of Pakistan is poor site management (RII 0.749). Construction projects highly depend upon the managements mind set, the compatible the higher authorities the more easily the project objectives can be achieved. Site management can directly influence the project objectives especially its cost as all departments are directly controlled by the management therefore it can have both adverse and positive effect on the construction projects.

Poor supervision (RII 0.804) was ranked as the most critical risk factor affecting adversely to the quality of construction in Pakistan. Supervision is very important part of the site staff and slight negligence can not only cause damage to the quality of work but also hampers other project objectives including project cost. Therefore, the quality of site supervision at any construction site if improved can lead to superior quality of work (Asad Kamal, 2019).

2.5 Augmented Reality for Health and Safety Improvement

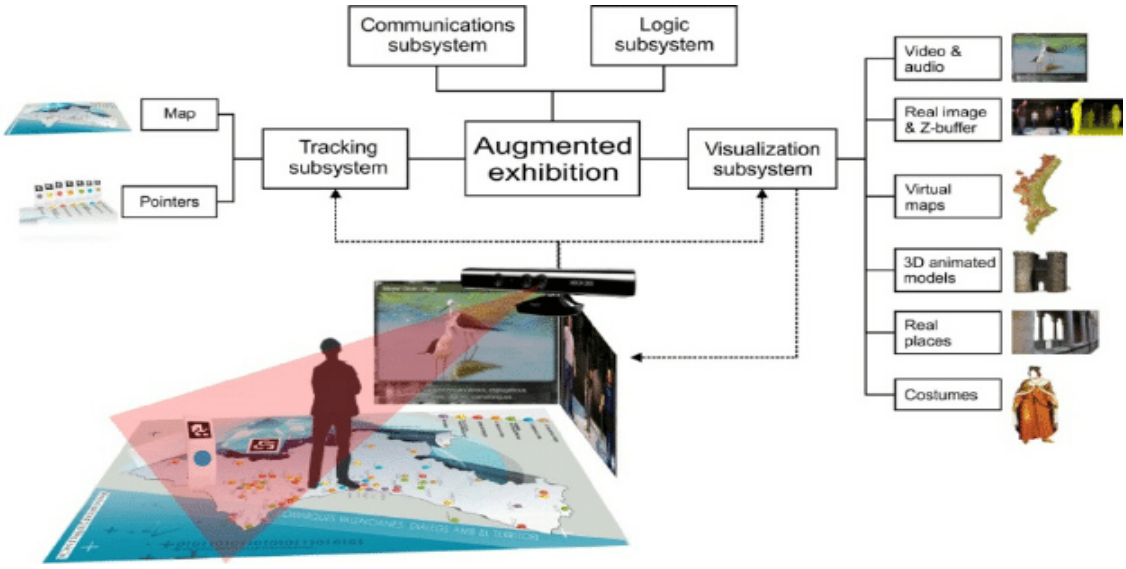
2.5.1 Working of Augmented Reality

Augmented Reality basically superimposes virtual objects on the real environment. The core functional abilities of Augmented Reality are

- Combine virtual and real graphics
- Proper tracking system
- Overlay virtual information over real information in real time

There are four components of Augmented Reality

- Camera
- Tracking Device
- Display Device
- Mobile computing process



Camera

The input of the real world is being given by the camera. The camera can either be mobile camera or some special camera for augmented reality. The camera detects any object through its lens and then the information is sent to be processed with virtual information.

Tracking Device

Tracking has been defined by Siltanen as the “heart ”of augmented reality systems: it calculates the position and orientation of the object (Siltanen, 2012). An accurate tracking, which locates the users and their movements in reference to their surroundings, is a crucial requirement for an augmented reality application. In augmented reality systems GPS (Global Positioning System) is used for tracking which is space base system to find location and time accurately. GPS sensors are used in wearable augmented reality systems. The GPS used in mobile phones are less accurate having an accuracy of about 10m. GPS sensors locate the position of device. These devices are also equipped with sensors that recognize the movement and orientation of device.

Display Device

Two ways for visualization are available. This super imposed model of real and virtual information can either be visualized through glasses in wearable augmented reality or through a handheld device such as smart phone or tablet. 3d visualization is also available now.

Mobile computing process

It is the most complex component of augmented reality system. Information of real world is taken from camera which has no coordinate and only the position of camera through GPS is known. The information coming from camera must be first give coordinates. The camera is equipped with sensors through which the pitch and the distance of objects is measured. For this purpose, computing is required. In wearable augmented reality laptops are used for this purpose and in mobile augmented reality processor of smart phones are used. After real and virtual information having the same coordinate system is processed it becomes very easy to overlay both virtual and real information to create one visualization. Both information is aligned and oriented by processing devices to create visualization. This processed information is sent to display device for users to visualize.

2.5.2 Augmented Reality in BIM

Augmented reality is an upcoming technology which is setting its ground in construction industry as well. It will replace the traditional construction practices which will result in improved productivity and work efficiency on construction sites. Due to advantages such as automated access to work progress on construction site and jobsite condition detection by the help of powerful computing devices will ultimately improve quality of work, safety of workers, improved profitability and sustainability (Rankohi and Waugh, 2013).

BIM modelling have exponentially improved the designing process of a structure. BIM modelling is used for 3D modelling of a structure indicating major components of a structure i.e. pipes, electrical wires, beams, columns etc. Information models are used to incorporate initial phases of project development. However most of the times, designs are displayed through 2D drawings or projection on portable displays. One of the main reason to use augmented reality is that it can incorporate information and situate it in time, place and context by combining computer generated information onto real world environment (Azuma et al. 2001), (Izkara et al. 2007).

Construction industry can benefit from the augmented reality in inaccuracy reduction, better marketing, review of project, saving man hours and cost reduction. Mentioned are the tasks in which augmented reality in collaboration with BIM can help: layout, excavation, positioning, and inspection, coordination, supervision, commenting and strategizing. Through this collaboration we can higher efficiency, sustainability and productivity in order to create safe and sound work environment (Zhou, Luo and Yang, 2017).

The major problem in collaboration of augmented reality and BIM is implementation and forming a bridge between the two to run the things smoothly without any error. If this bridge is formed than it will revolutionize the construction industry and give them competitive advantage from others who don't use augmented reality.

2.5.3 Augmented Reality For Safety Improvement

Almost thousands of workforce die annually during construction catastrophes. The main concerning issue are safety management programs and employee training are the issues which can be assisted by augmented reality technologies to provide the employees with an effective training and a safety management program can be implemented as well. Augmented reality technologies can be used significantly for training of construction workers to operate heavy machinery including cranes, excavators and assembling equipment. This technology can assist the project involved people to understand various project issues including complex designs and arrangements as well. (Chi et al, 2013), (Wang and Dunston, 2007).

Wang et al. (2013) developed a conceptual framework for integrating building information modeling with augmented reality for the safety management system in the construction industry. So augmented reality technologies are the new approach for the modern construction management, particularly in the training and safety management system. One of the increasingly important application areas of augmented reality is in training and education, where simulated scenarios can be used to illustrate concepts and provide exercises that allow the learner to train in a realistic environment. Compared to the real exercise, augmented reality could significantly reduce costs and hazards.

Augmented reality provides unlimited variability in training elements which gives greater flexibility with minor additional cost. An example of a safety advantage is the avoidance of any personnel injuries from materials accidentally falling while being raised by material handler to an elevated scaffold platform. Also, use of augmented reality can eliminate adverse effects associated with environmental concerns such as noise, dust, etc. These all advantages add up to increased operational performance, improved safety knowledge and practices and increased popularity of augmented reality in digital world and safe construction.

Following are also some of the uses of Augmented Reality which can be beneficial in the field

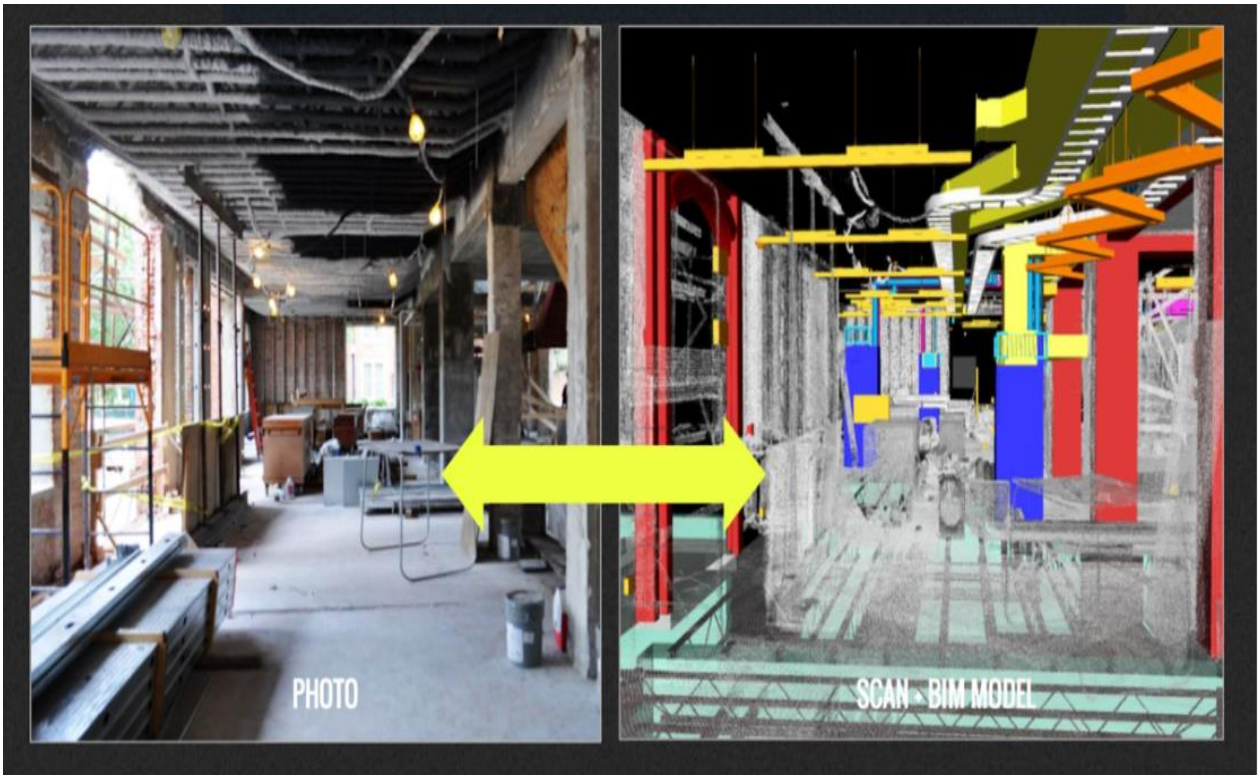
On site clash detection

Because of that people onsite have less knowledge what they would get beneath the road, that's why during the road construction and excavation, utility lines get damaged. Due to this reason the cost of product may increase resulting in cost overrun and time overrun. Using

augmented reality, such clashes can be easily avoided by just pointing the camera towards the ground and seeing all the pipelines and service lines running beneath it. It can be seen how deep they are located, and excavation can be planned. If augmented reality is used clashes can be identified early and design can also be changed according to that.

Identification of Hazards

One of the key concerns now a day in projects is safety. Severe injuries to workers are caused by many unknown hazards present on site. Such hazards can be detected using augmented reality. For example, there is an underground electric cable running underground and there is excavation going on near it. That electric cable is hazard to workers that we are unaware of it can cause electrocution. By application of augmented reality, cable as hazard can be easily identified and some measure can be taken eliminate this hazard. (Webster and Feiner, 1996)



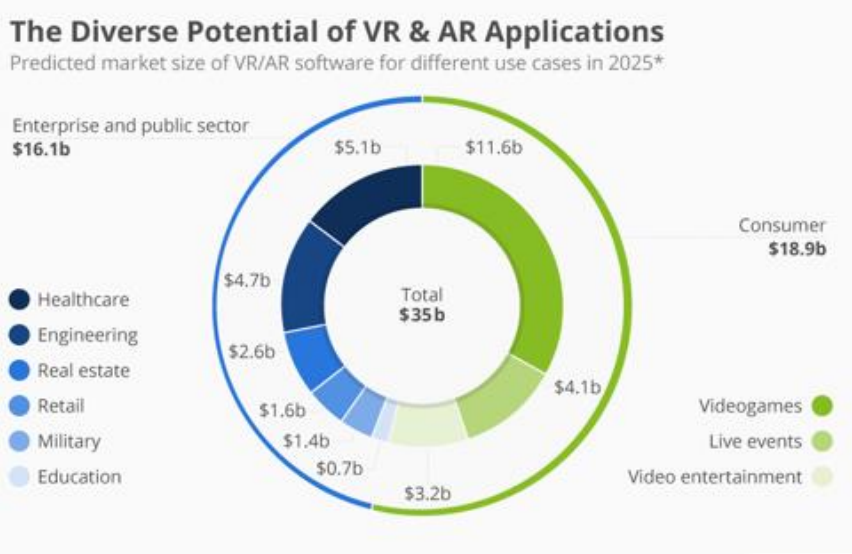
Early Identification of problems

Problems such as clashes, design problems, hazards etc. can be identified by augmented reality in the very early stage of project hence it will minimize the effect of these problems.

2.5.4 Economics of Augmented Reality

Globally construction sector employs 7% of worlds working age population. Every year 10 trillion dollars is spent on construction goods and services. For various reasons, poor productivity in construction is a costly and difficult challenge to address which results in poor economic growth of construction industry. Augmented reality (AR) technology can improve communication, reduce costs, and identify problems in advance.

Thought leaders and researchers have predicted that VR and AR technology applications in the construction industry could boost productivity, adding an estimated $1.6 trillion in value. If construction industry growth matches growth of global economy than global economy would grow by additional 2%.



2.5.5 Limitations of Augmented Reality

- Training required to operate augmented reality.
- Limited running time due to limited power of computing device
- Privacy and security of data
- Limited memory of smartphones and gadgets

2.6 Additional Applications of Augmented Reality

Augmented Reality is also very useful for quality improvement. It can detect the defects in the construction materials and thus improves the quality of the work. It also can help in schedule and project progress tracking and also reducing the time to complete a project.

Quality and Defect Management

Quality management and defect control are important parts of construction management. Many completed projects that are accepted by the client are defected or fail to meet the desired quality and thus arise disputes. Augmented reality plays a very important role in global construction to bring the automation in the quality and defect management system. Some defects that are probably not noticed in the inspection process are detected by the augmented reality technologies and save time to do so and thus help in construction management process.

Park et al (2013) noted that if core control time points and measures for works were realized by the managers and checked proactively through the defect element ontology, then the worker's performance can be automatically checked at the appropriate time with BIM and AR applied inspection equipment without visiting the workplace.

The study (Kwon et al. 2014) concluded through the use of augmented reality technologies the current manual-based defect management can be enhanced thus reduce site managers' workloads and prevent construction work defects proactively by utilizing BIM and augmented reality technologies. An effective defect less facilities management system is developed for the construction project in a modern automated way that facilitates users at a more satisfactory level than any time before (Koch et al. 2014). Augmented reality is also mentioned as a very helpful quality and defects management technology for on-site construction project (Kim et al., 2013).

Scheduling and Project Progress Tracking

Augmented reality has enhanced the scheduling aspect of the construction project significantly; it is able to show an as-planned vs. an as built form to allow visualization of progress. Wang et al. (2014a) showed in their study that as compared to any other existing tools, augmented reality could be used as a scheduling tool to understand and to make someone understand without any doubts. Hui et al. (2017) showed in their research that for the safety task scheduling in a construction project, augmented reality could also be effectively used.

Meža et al. (2015) stated in their study that for monitoring and tracking the construction project, as compared to any other 3D models or Gantt chart, augmented reality on mobile or tablet PC is the best option. Wang et al. (Park et al. 2013) noted that augmented reality can be used for construction project progress tracking as a way to compare the schedule to the actual progress of the project. Augmented reality technologies can be used for a visual comparison between the planned facilities versus as-built facilities. Gol parvaret al. (2009), Omar Nehdi (2016), Zhou et al. (2008) and Turkan et al. (2012) also showed that in construction progress tracking and scheduling, augmented reality is going to be one of the most used functions in advanced construction project management.

Time and Cost Management

Time and cost are the major issues of the construction process, without a doubt. All construction project management is to reduce the completion time and save the construction costs. To increase the effectiveness of construction management, technological changing take place in different form with the changing in time. AR based applications are used in construction management for controlling and monitoring the time and cost issues. Because of

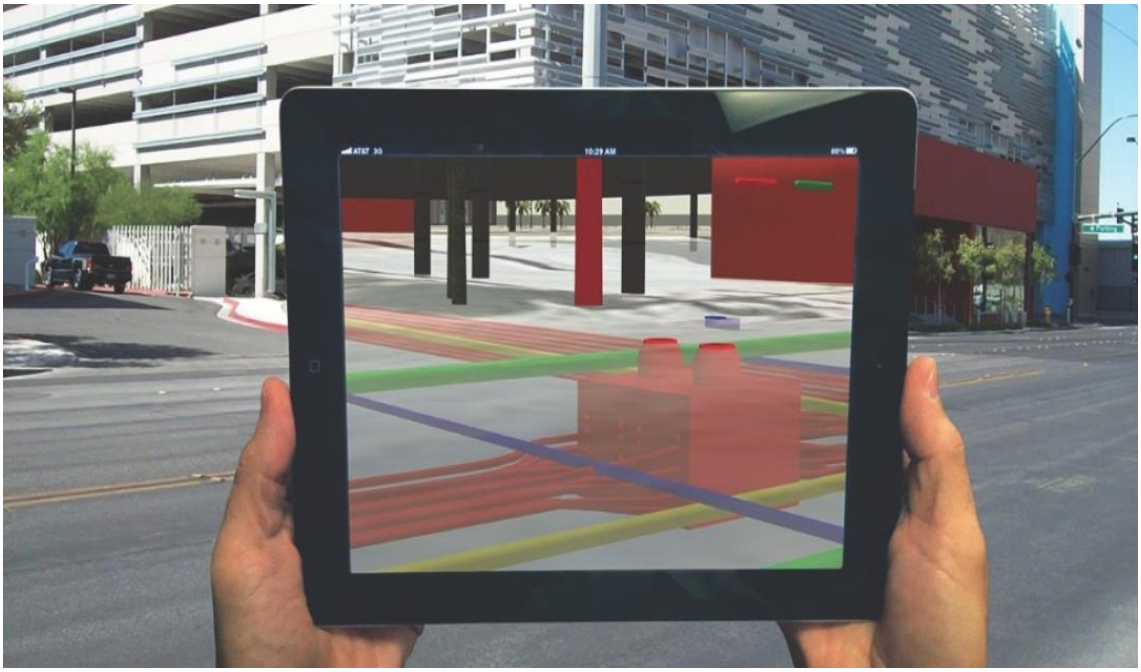
misinterpretation of plans or drawings or the information is transferred imprecisely from the plan to the real object about 9 to 13% time and 14 to 19% money are wasted (Kumaran et al., 2007).

The augmented reality technologies resolve issues including lack of manpower inside the management and cost efficiencies within the construction project (Behzadi, 2016). Augmented Reality Technologies are also used for data acquisition of the construction site which saves time, reduces the labor hours (Fard et al., 2009). The augmented reality technologies save time and cost of the construction project by reducing the defects and rework of the construction project through use of augmented reality mobile computing technologies (Kim et al. 2013).

Augmented reality will improve construction process in following ways:

Eliminating Guess Work

Any missing information has to be assumed in traditional 2D approach as information is limited or guess work is applied such guess work and assumption can be avoided through augmented reality because 3D model contains a lot more information as compared to 2D drawings.



Less Disputes among Stakeholders

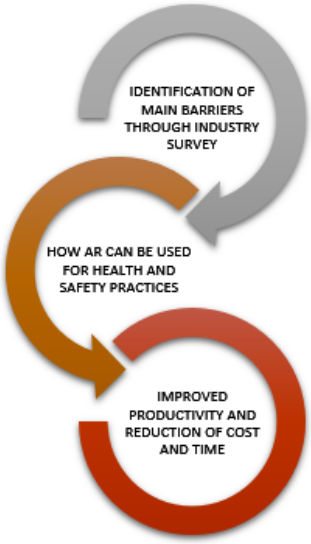
As a lot of problems in the design, utilities etc. are identified by augmented reality early in the construction process so it reduces the cost overruns and thus the disputes among the stakeholders are also less. The project can thus be executed in a smoother way.

Better Collaboration

Completion of project in time and in spending plan relies upon the joint effort and correspondence between stake holders. The correspondence and joint effort between client, consultant and designer can be improved by augmented reality. A flash snaps or video can be made of any ambiguity in design of structure and sent to the client for additional data or explanation. Here and there individuals working in field don't get change orders in time and they are dealing with old drawings this correspondence hole can be dispensed with by utilizing augmented reality.

CHAPTER 3

RESEARCH METHODOLOGY



3.1 Project Scope

With the advancement of technology, the team decided to work on revolutionizing the construction sector. In this regard, research was narrowed down to Augmented Reality in the construction sector of Pakistan and the challenges which were to be faced by someone who wishes to introduce and implement Augmented Reality in the construction sector of Pakistan.

3.2 Timeline

A timeline was set by keeping in view the nature and complexity of the project. The schedule was strictly followed so as to ensure timely progress and smooth work flow of the project.

3.3 Literature Review

In the initial stages of the project, published research papers of renowned scholars and thesis of NICE alumni were studied thoroughly. The aim was to go through all the work done on implementing technology in construction sector and the challenges faced to adapt these advanced methods. Afterwards, research was narrowed down to a regional level and particularly, Pakistan.

3.4 Development of Survey Questionnaire

A questionnaire was developed to analyze the main barriers faced by the contractors and consultants in the adaptation and implementation of a new technology in the country. Questionnaire was made on google forms and the information was collected. The questions asked were finalized after thorough research work so that no factor is left behind. An awareness page was also incorporated in the form to get an overview of Augmented Reality and how it can help in the construction sector improve efficiency, productivity, health and safety. The link to google form is https://forms.gle/VUCA3w1tGisGx8QU7 .

Survey Questionnaire for Implementation of Augmented Reality in Construction Industry of Pakistan

In the questions below, AR means augmented reality technology.

*Required

Awareness Page

1. Organization Name *

_____

2. Organization Type *

Mark only one oval.

- ◯ Government
- ◯ Semi Government
- ◯ Private

3. Designation *

_____

4. Qualification *

Mark only one oval.

- ◯ Diploma
- ◯ Bachelors
- ◯ Masters
- ◯ PhD

5. Professional Experience *

Mark only one oval.

- ◯ 0-1 years
- ◯ 2-5 years
- ◯ 6-10 years
- ◯ Above 10 years

6. Do you think augmented reality will help improve health and safety issues in the construction sector of Pakistan like safety from electrocutions and fall protection etc. *

Tick all that apply.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

7. Are you willing to use AR technology for the safety of employees? *

Tick all that apply.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

8. Are you willing to invest in AR technology?Investment includes training of employees, development of model on BIM 360 software and AR headsets capable of using smartphones. *

Tick all that apply.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

9. Are you contended with the current traditional practices? Traditional practices refer to 2D drawings which cannot be fed into AR systems. *

Tick all that apply.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

10. Are you familiar with the smart technology?Smart technology means the smart phones, tablets etc which can serve as the hardware to experience AR technology. *

Tick all that apply.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

11. Are you reluctant towards using AR Technology? Using AR technology means using augmented reality gadgets to visualize augmented environment on construction sites and familiarizing oneself to this technology. *

Tick all that apply.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

12. Will you be willing to change the practice of two dimensional drawings and shift to three dimensional drawings? Traditionally, two dimensional drawings are made on Auto-cad for projects. Augmented reality would require making of three dimensional drawings so that they could be put in BIM 360 software for making augmented environment. *

Tick all that apply.

- [ ] Strongly Disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly Agree

13. Will you be willing to get expertise in augmented reality? *

Tick all that apply.

- [ ] Strongly Disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly Agree

14. Would cost affect your decision regarding implementation of augmented reality? Cost includes training of employees, development of model on BIM 360 software and AR headsets capable of using smartphones. *

Tick all that apply.

- [ ] Strongly Disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly Agree

15. Would complexity of augmented reality affect your decision regarding implementation of augmented reality? Complexity of using smart gadgets and new three dimensional software. *

Tick all that apply.

- [ ] Strongly Disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly Agree

16. Would lack of expert users affect your decision regarding implementation of augmented reality? *

Tick all that apply.

- [ ] Strongly Disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly Agree

17. Would public unawareness affect your decision regarding implementation of augmented reality? For instance, unawareness of labor and other employees towards using technology. *

Tick all that apply.

- [ ] Strongly Disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly Agree

18. Would lack of augmented reality models and lack of augmented reality (AR) gadgets affect your decision regarding implementation of AR? *

Tick all that apply.

- [ ] Strongly Disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly Agree

19. Would this affect your decision that Augmented reality has not been previously used in the construction sector of Pakistan? *

Tick all that apply.

- [ ] Strongly Disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly Agree

20. According to you will AR surpass traditional practices?Traditional practices refer to two dimensional drawings which cannot be fed into AR systems and traditional safety practices. *

Tick all that apply.

- [ ] Strongly Disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Strongly Agree

3.5 Reaching Out to Contractors and Consultants

After the development of the questionnaire, next task was to collect data through different consultants and the contractors. The plan was to collect information about the different contractors and consultant in Islamabad and its nearby areas. After this it was planned to go personally to them and if they have no information regarding the technology of the Augmented Reality, then brief them about the Augmented Reality. In this way it was planned that the questionnaires would be filled.

The above mentioned plan could not be implemented because of the worldwide pandemic, Covid-19, which affected the whole world and there was a situation of lockdown. Due to the lockdown it was not possible to go to the contractors and consultants personally. Therefore, it was then decided to email the questionnaire to contractors and consultants. The email of different contractors and consultants were obtained from the website of PEC.

The response to the emails was not as good as hoped. About 2500 emails were sent to different consultants and contractors. In response to the emails sent, 112 responses were collected. Through these responses, the frequency analysis was done on the data collected and furthermore the results and conclusion was obtained.

3.6 Frequency Analysis

Frequency analysis is a descriptive statistical method that shows the number of occurrences of each response chosen by the respondents. Frequency analysis can be used to analyze different factors in a questionnaire separately. Frequency analysis gives us the frequency of different answers given by the respondents. It can also be used to find the mean, median and mode of the data. By using this data results and conclusions can be made.

The software that was used for the frequency analysis was SPSS (Statistical Package for the Social Sciences) which is a software for statistical analysis. First different variables i.e. factors were defined in the software. After that data was entered in the software and frequency analysis was done for the factor. The mean, mode and standard deviation of the data were also calculated. The results are given below:

Statistics

		Will AR Help improve Health and Safety Issues	Willing to use AR for Safety	Willing to invest in AR	Are you satisfied with 2D Drawings	Are you Familiar with Smart Technology
N	Valid	112	112	112	112	112
	Missing	0	0	0	0	0
Mean		3.9464	3.8929	3.6875	3.3571	4.1429
Mode		4.00	4.00	4.00	4.00	4.00
Std. Deviation		.84725	.72729	.97751	1.00321	.78105

Statistics

		Are you reluctant towards AR	Are you willing to shift from 2D Drawings to 3D Drawings	Are you willing to get expertise in AR	Will cost affect your decision regarding AR	Will complexity affect your decision regarding AR
N	Valid	112	112	112	112	112
	Missing	0	0	0	0	0
Mean		2.8571	4.0089	4.0536	3.7054	3.4732
Mode		2.00	4.00	4.00	4.00	4.00
Std. Deviation		1.12191	.85420	.82571	.85570	.92959

Statistics

		Will lack of expert users affect your decision regarding AR	Will Public unawareness affect your decision regarding AR	Will less AR models and AR gadgets affect your decision regarding AR	Will no previous use of AR in Pakistan affect your decision	Will AR surpass traditional practices
N	Valid	112	112	112	112	112
	Missing	0	0	0	0	0
Mean		3.6250	3.6696	3.6339	3.0625	3.5714
Mode		4.00	4.00	4.00	2.00	4.00
Std. Deviation		.91164	.94334	.96791	1.16465	1.05450

The results of the frequency analysis is also given:

Willing to use AR for Safety

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	2	1.8	1.8	1.8
	Disagree	1	.9	.9	2.7
	Neutral	21	18.8	18.8	21.4
	Agree	71	63.4	63.4	84.8
	Strongly Agree	17	15.2	15.2	100.0

When asked about willingness to use Augmented Reality for Safety 71 out of 112 respondents agreed that they are willing to use Augmented Reality for safety.

Willing to invest in AR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	4.5	4.5	4.5
	Disagree	8	7.1	7.1	11.6
	Neutral	22	19.6	19.6	31.3
	Agree	59	52.7	52.7	83.9
	Strongly Agree	18	16.1	16.1	100.0
	Total	112	100.0	100.0	
Total		112	100.0	100.0	

When asked about willingness to invest in Augmented Reality 59 out of 112 respondents agreed that they are willing invest in Augmented Reality.

Are you willing to get expertise in AR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	2.7	2.7	2.7
	Disagree	2	1.8	1.8	4.5
	Neutral	11	9.8	9.8	14.3
	Agree	66	58.9	58.9	73.2
	Strongly Agree	30	26.8	26.8	100.0
	Total	112	100.0	100.0	

When asked about willingness to get expertise in Augmented Reality 66 out of 112 respondents agreed that they are willing to get expertise in Augmented Reality.

Will cost affect your decision regarding AR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	2	1.8	1.8	1.8
	Disagree	8	7.1	7.1	8.9
	Neutral	26	23.2	23.2	32.1
	Agree	61	54.5	54.5	86.6
	Strongly Agree	15	13.4	13.4	100.0
	Total	112	100.0	100.0	

When asked will cost affect their decision regarding Augmented Reality 61 out of 112 respondents agreed that cost will affect their decision regarding Augmented Reality.

Will complexity affect your decision regarding AR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	2.7	2.7	2.7
	Disagree	13	11.6	11.6	14.3
	Neutral	36	32.1	32.1	46.4
	Agree	48	42.9	42.9	89.3
	Strongly Agree	12	10.7	10.7	100.0
	Total	112	100.0	100.0	

When asked will complexity affect their decision regarding Augmented Reality 48 out of 112 respondents agreed that complexity will affect their decision regarding Augmented Reality.

Will lack of expert users affect your decision regarding AR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	2.7	2.7	2.7
	Disagree	11	9.8	9.8	12.5
	Neutral	24	21.4	21.4	33.9
	Agree	61	54.5	54.5	88.4
	Strongly Agree	13	11.6	11.6	100.0
	Total	112	100.0	100.0	

When asked will lack of expert users affect their decision regarding Augmented Reality 61 out of 112 respondents agreed that lack of expert users will affect their decision regarding Augmented Reality.

Will less AR models and AR gadgets affect your decision regarding AR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	2.7	2.7	2.7
	Disagree	13	11.6	11.6	14.3
	Neutral	23	20.5	20.5	34.8
	Agree	56	50.0	50.0	84.8
	Strongly Agree	17	15.2	15.2	100.0
	Total	112	100.0	100.0	

When asked will less AR models and AR gadgets affect their decision regarding Augmented Reality 56 out of 112 respondents agreed that less AR models and AR gadgets will affect their decision regarding Augmented Reality.

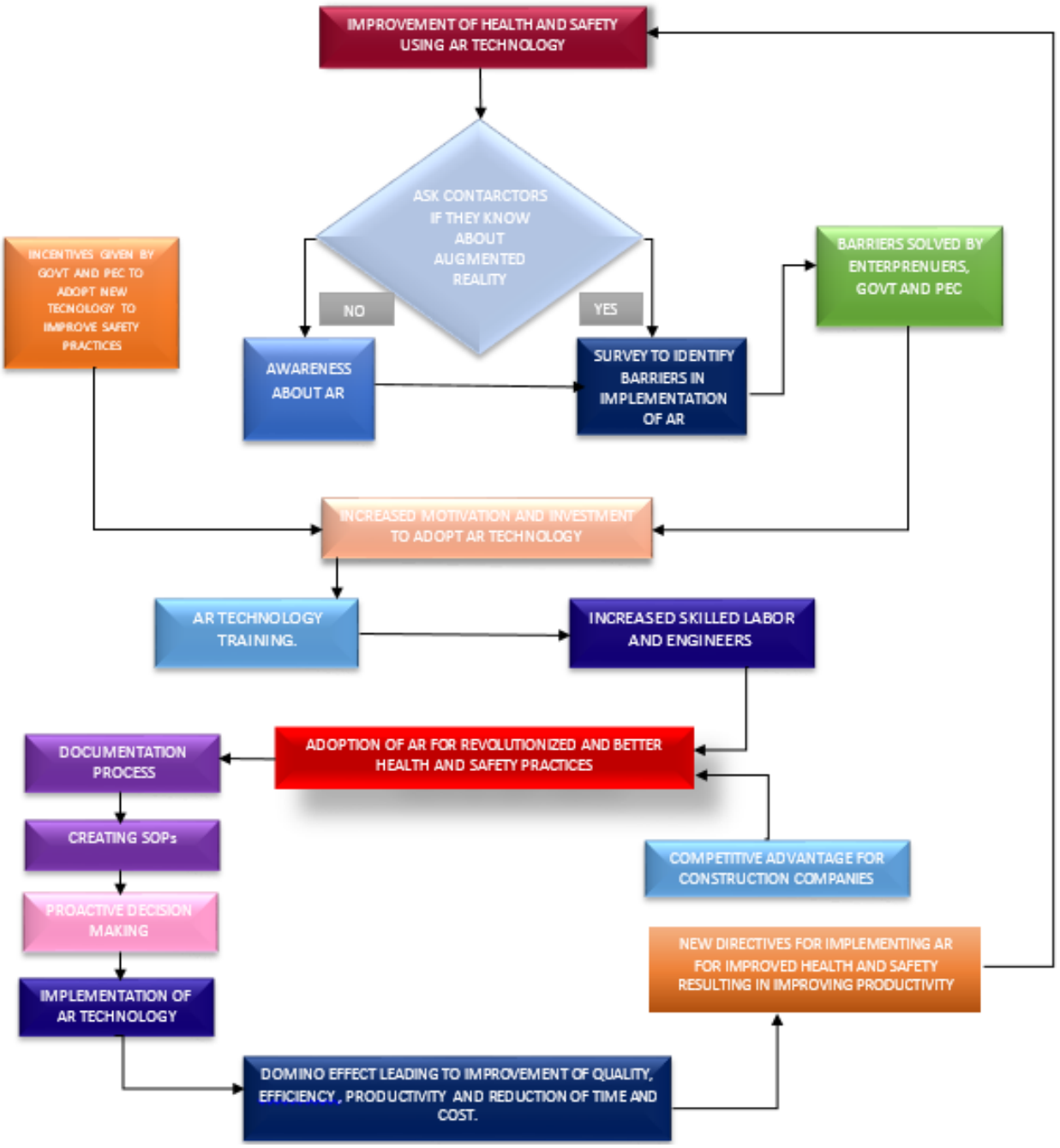
Will Public unawareness affect your decision regarding AR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	2	1.8	1.8	1.8
	Disagree	14	12.5	12.5	14.3
	Neutral	20	17.9	17.9	32.1
	Agree	59	52.7	52.7	84.8
	Strongly Agree	17	15.2	15.2	100.0
	Total	112	100.0	100.0	

When asked will public unawareness affect their decision regarding Augmented Reality 59 out of 112 respondents agreed that public unawareness will affect their decision regarding Augmented Reality.

3.7 Conceptual Framework

This cyclic framework is developed for technology adoption for improved health and safety, quality improvement, improved productivity and work efficiency improvement in construction industry of Pakistan. The first step in adoption of any innovative technology such as augmented reality starts with public awareness. After becoming aware of pros and cons of innovation different stakeholders become willing to accept the existence of technology and adopt it for their benefit. Proper training and education of AR technology are required to create and increase the quantity of skilled labors. This will require an initial investment to make it practically applicable on construction site. As a result, AR technology will not only improve health and safety but also improve productivity and work efficiency which results in cost and time reduction.


IMPROVEMENT OF HEALTH AND SAFETY USING AR TECHNOLOGY
ASK CONTARCTORS IF THEY KNOW ABOUT AUGMENTED REALITY
NO
YES
INCENTIVES GIVEN BY GOVT AND PEC TO ADOPT NEW TECNOLOGY TO IMPROVE SAFETY PRACTICES
AWARENESS ABOUT AR
SURVEY TO IDENTIFY BARRIERS IN IMPLEMENTATION OF AR
BARRIERS SOLVED BY ENTERPRENUERS, GOVT AND PEC
INCREASED MOTIVATION AND INVESTMENT TO ADOPT AR TECHNOLOGY
AR TECHNOLOGY TRAINING.
INCREASED SKILLED LABOR AND ENGINEERS
DOCUMENTATION PROCESS
ADOPTION OF AR FOR REVOLUTIONIZED AND BETTER HEALTH AND SAFETY PRACTICES
CREATING SOPs
COMPETITIVE ADVANTAGE FOR CONSTRUCTION COMPANIES
PROACTIVE DECISION MAKING
NEW DIRECTIVES FOR IMPLEMENTING AR FOR IMPROVED HEALTH AND SAFETY RESULTING IN IMPROVING PRODUCTIVITY
IMPLEMENTATION OF AR TECHNOLOGY
DOMINO EFFECT LEADING TO IMPROVEMENT OF QUALITY, EFFICIENCY , PRODUCTIVITY AND REDUCTION OF TIME AND COST.

3.8 Results and Conclusion

After the frequency analysis was performed, results were deduced and presented as pie charts in the next section.

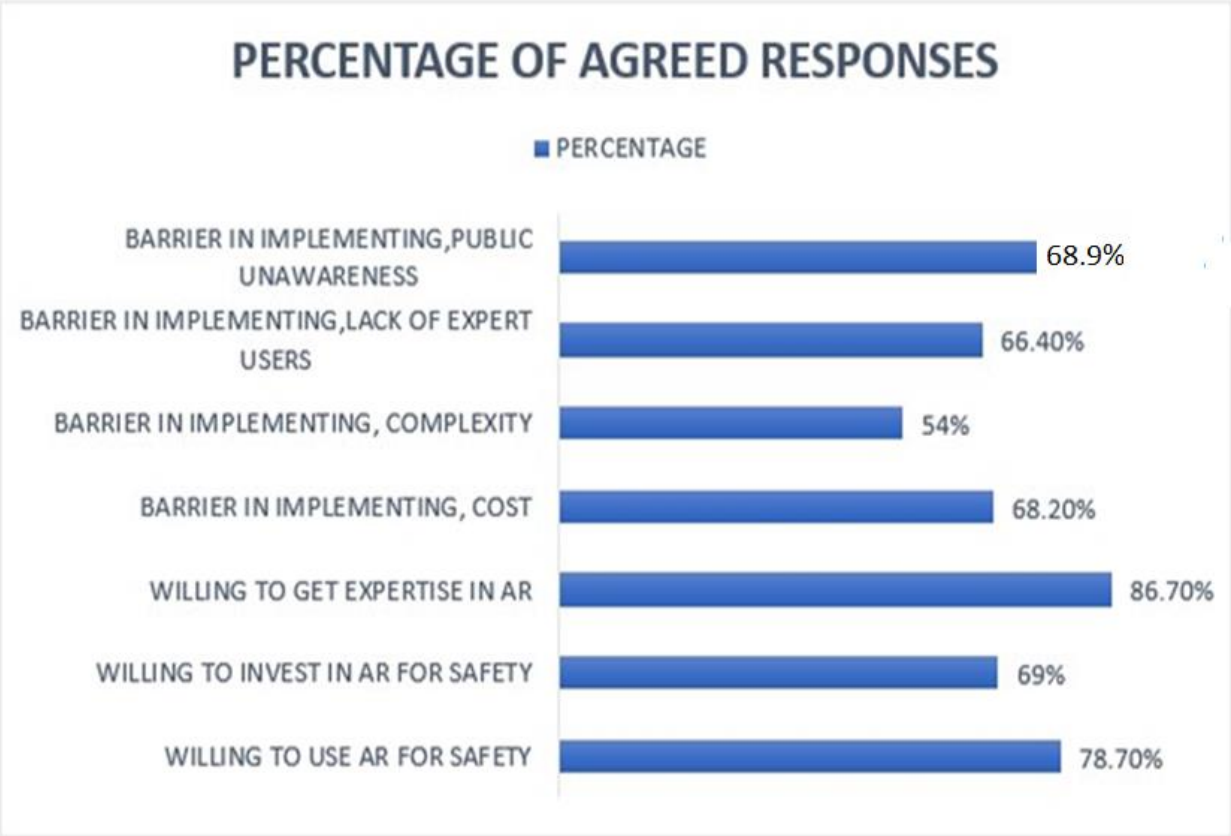
CHAPTER 4

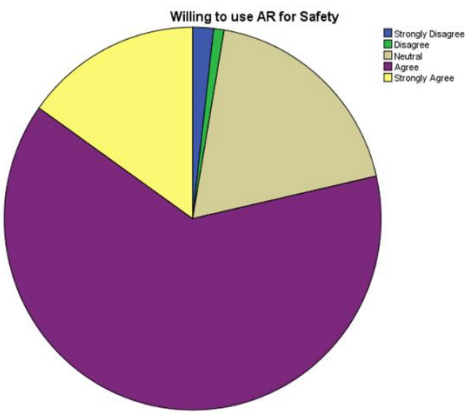
RESULTS AND DISCUSSION

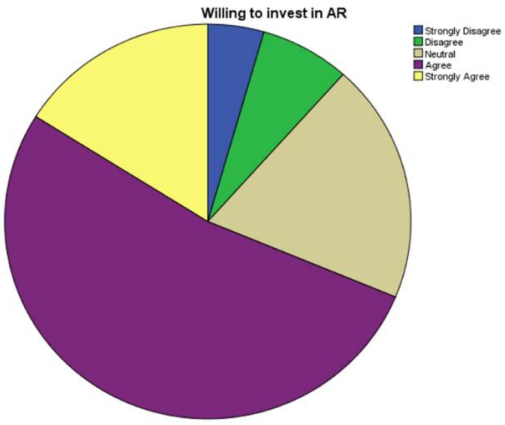
4.1 Results

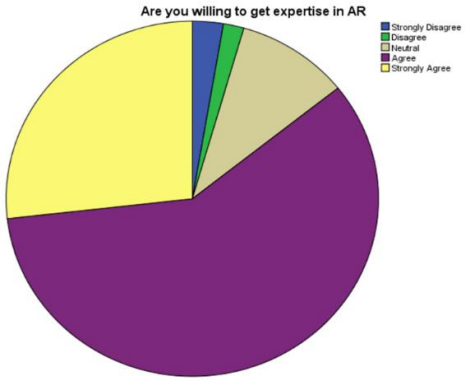
The questionnaire was online through google form. The questionnaire consisted of 15 questions which highlighted major barriers regarding implementation of augmented reality. Out of 112 responses 60 percent respondents were having sound professional experience. Following are the major outcomes extracted from responses of expertise:

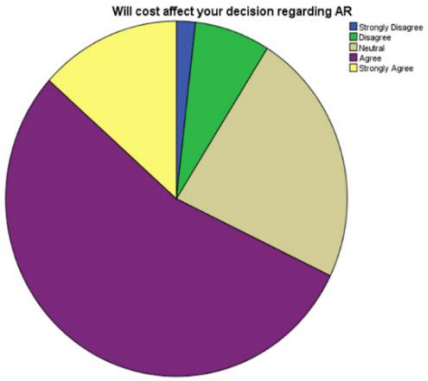
- Almost **75%** respondents (including agree and strongly agree) were willing to use augmented reality for the safety of employees and minimize accidents occurring on construction site
- Around **70 %** respondents agreed to invest in AR technology to boost up their construction practices and increase their work efficiency. Investment includes training of employees, development of model on BIM 360 software and AR headsets capable of using smartphones.
- **54%** expertise including engineers agreed to the fact that complexity of AR technology would affect their decision regarding practical implementation.
- **68.2%** organization were agreeing to the point that cost of training programs and gadgets in order to implement augmented reality will affect their decision
- Around **66.4%** respondents agree that they have lack of expertise and need proper training in order to implement AR technology
- Around **68.9 %** people agree that labor and other working staff who are unaware of AR technology creates a barrier and affect their decision regarding implementation
- About **40 %** organization expertise agrees that AR isn't used previously and they have doubts regarding implementation on construction site
- Regardless of the major barriers faced by construction industry regarding implementation of AR technology **87%** respondents from well reputed organizations were willing to get expertise in AR technology.

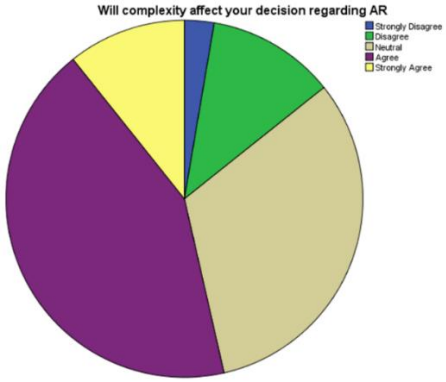

PERCENTAGE OF AGREED RESPONSES
PERCENTAGE
BARRIER IN IMPLEMENTING,PUBLIC UNAWARENESS
68.9%
BARRIER IN IMPLEMENTING,LACK OF EXPERT USERS
66.40%
BARRIER IN IMPLEMENTING, COMPLEXITY
54%
BARRIER IN IMPLEMENTING, COST
68.20%
WILLING TO GET EXPERTISE IN AR
86.70%
WILLING TO INVEST IN AR FOR SAFETY
69%
WILLING TO USE AR FOR SAFETY
78.70%

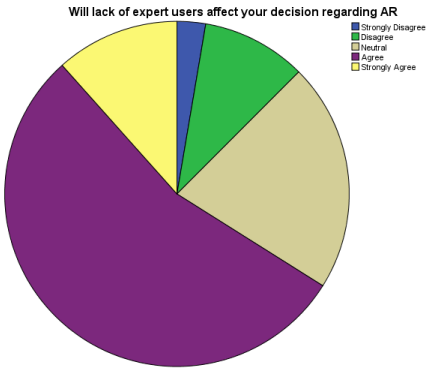

Willing to use AR for Safety
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree

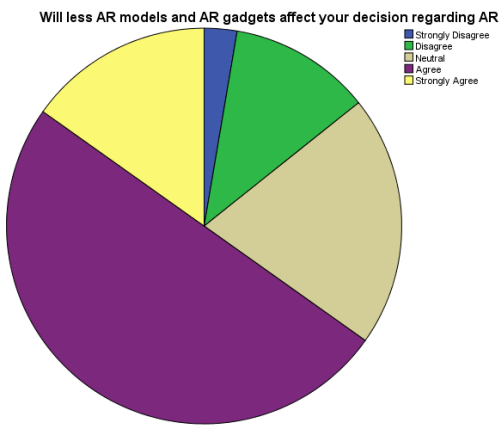

Willing to invest in AR
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree

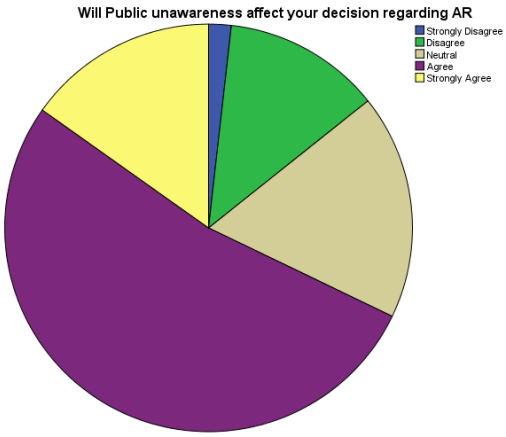

Are you willing to get expertise in AR
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree


Will cost affect your decision regarding AR
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree


Will complexity affect your decision regarding AR
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree


Will lack of expert users affect your decision regarding AR
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree


Will less AR models and AR gadgets affect your decision regarding AR
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree


Will Public unawareness affect your decision regarding AR
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree

4.2 Practical Implementation

Before introducing any new technology, a survey is made that whether it would be acceptable for the market or not. If not, what are the possible reasons. Our research identifies those barriers. When these barriers are addressed, for example, if concerned personnel are made aware then the acceptance rate will increase and it will ultimately result in a new trend of using technology for health and safety. It will revolutionize the construction sector enabling it to meet world class safety measures, productivity, efficiency and quality standards. Pakistan's construction sector would be able to get international certifications and form joint ventures with international clients as for example in CPEC. These barriers can be addressed either, by a government or a construction company and after that Augmented Reality technology can be implemented in the construction sector of Pakistan.

The construction sector and concerned authorities are recommended to address these barriers either by giving incentives to contractors or by mass awareness. Entrepreneurs can be encouraged to provide low cost, simplified and easy to operate Augmented Reality- AR Gadgets. Government can implement strict policies for the construction industry to adhere to international safety laws. Such measures can help new technologies to emerge and sustain in the market.

4.3 Limitations

- This research was limited to a theoretical study due to unavailability of Augmented Reality gadgets.
- The sample size was limited due to lack of responses from contractors and consultants over emails.
- On ground survey could not be performed due to COVID-19, a global pandemic.
- The limited number of technology adaption experts in the country that could help improve the framework.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The construction sector of Pakistan has been facing problems of quality management, workers safety, cost overruns and project delays because of its continuous reliance on traditional construction practices. The construction sector needs to be digitalized with a proactive approach to improve productivity, efficiency, health of workers and reduce the cost and time overruns. Our research was able to identify some of the barriers inhibiting the adoption and implementation of modern technology such as Augmented Reality for providing the ability to improve construction practices which would result not only in better productivity, health and efficiency of the workers but also help in reducing the cost and time of the construction projects.

The top barriers in the adoption of Augmented Reality in the construction industry of Pakistan, in decreasing order of significance were cost, public unawareness, lack of expert users and complexity. If we are able to address these issues then construction sector of Pakistan can be revolutionized resulting in better safety of workers, reduced time and costs, increased efficiency and productivity. The future research on this topic would be able to use the framework developed during this particular research and modify it according to needs of the time to practically implement Augmented Reality on actual construction sites across the country.

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