DYNAMICS OF MECHATRONICS ENGINEERING – A FUTURE VISION

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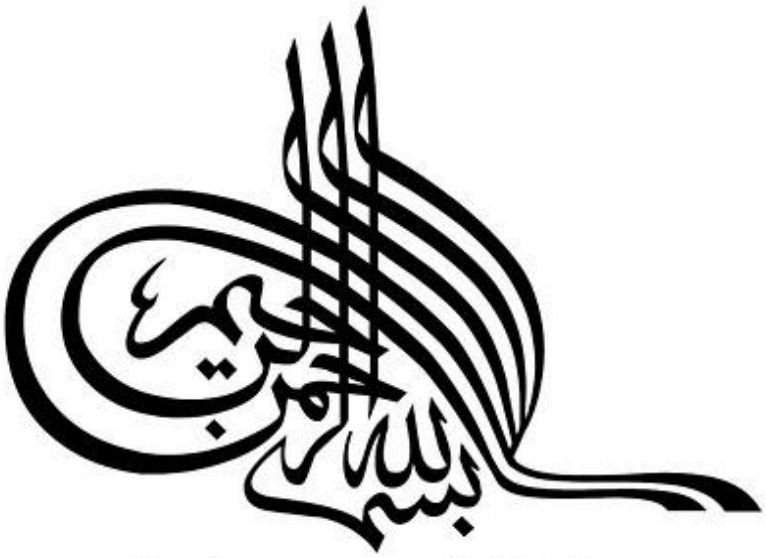

In the name of Allah,
the Most Beneficent,
the Most Merciful

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ABSTRACT

Mechatronics is relatively a new field in Pakistan and there is a lot of misconception about it. Being a new engineering discipline in Pakistan, Mechatronics has to face many risks for its successful establishment and growth. Every discipline owes its evolution and progress to the stakeholders, government, universities and experts. The research work is related to the general view of Mechatronics engineering education, the evolution of Mechatronics engineering in Pakistan and the status of Mechatronics in the industries as well as society of Pakistan. A survey based approach and the help of Cronbach Alpha for assessing reliability of the collected data are being used in the research.

There is an urging need of Mechatronics in industry to meet the changing demands. Emphasis is laid on highly demanding career prospects in Mechatronics. Mechatronics is a design philosophy that encourages engineers to concurrently integrate conventional core industries and modern processing-developing industries. This work also discusses and analyzes the development studies on current and future state of mechatronics, development of Mechatronics Curriculum and the future development trend of Mechatronics Engineering in Pakistan.

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CHAPTER 1

INTRODUCTION

1.0 Introduction - Philosophy of Engineering Disciplines

1.0.1 What is a Discipline?

A discipline is a way to view an occurrence or happening. Each discipline has a knowledge base that is distinct from that of other disciplines and that provides a foundation for practice. The purpose of a discipline is the development and pursuit of knowledge. This knowledge base is enhanced through research and provides new direction for practice. A discipline may be defined as an ordered study based upon defined models and procedure. Disciplines may be divided into sub-areas which have a unity of subject matter, a theoretical component, some significant abstractions, important design problems and implementation issues. A discipline is a body of knowledge that is expressed in practice and continually changed and expanded through research.

Disciplines get recognition due to the researchers and practitioners. As a result of evolution of research and understanding, a scientific base get gradually established. The first requirement for a discipline is a focus of study.

Many other characteristics of a discipline are discussed in the literature. Secondly, it is essential that a discipline have a viewpoint or paradigm. Establishment of a view point is essential for promotion of a specific discipline because the problems of normal science are so much challenging that the measurements undertaken without a view point seldom lead to any conclusions at all.

Thirdly, the disciplines are dependent upon other disciplines called reference disciplines. Disciplines get established upon the useful works of other disciplines. But the distinction and uniqueness from other disciplines is essential for recognition.

The fourth requirement is the principles and practices associated with a discipline should be distinct and well defined. The fifth characteristic is that a discipline should also be identifiable with a research community that sustains its own literature. The sixth requirement is the need of professional societies and journals for that discipline.

The above discussion shows that a *discipline* has six basic requirements or characteristics. These are explained as below:

1.0.2 A Focus of Study

A focus of study is a fundamental question and the needs of society are the cause of its emergence. The goals and objectives of the discipline help to answer the question. Engineering as a discipline emerged from the need to enrich human life and for the promotion of social progress. It is the unique basic question being addressed by the discipline that determines the focus of study. This fundamental question leads to the development of a knowledge base, principles and practices to deal with the analysis, designing and implementation of that engineering discipline.

1.0.3 A World View

A discipline must be able to define the way in which it views the world. It must have a unique perspective. This paradigm helps in determination of the framework necessary for the development of the discipline through practice and research. The paradigm of a discipline needs to have complexity and should be substantial enough to get divided into sub-disciplines or subareas. Each sub-discipline is in turn concerned with and specialized on a particular kind of process, product and industry.

1.0.4 Reference Disciplines

A reference discipline is a knowledge base that helps in establishing an emerging or new discipline. For the development of a new discipline, researchers must have to discover the contributions and works of the supporting disciplines. History has shown that the emergence of

discipline is due to the need of solving new problems that are not currently addressed by already existing disciplines.

New disciplines establish on the knowledge, methods and theories of existing disciplines for solving the new problems. Identifying and understanding the contributions of reference disciplines provide a support for a new discipline. With the help of reference disciplines, a logical connection with the new discipline can be established. Researchers can then follow these connections and then develop a measure of acceptance for the discipline. Existing disciplines may question and raise objection on the grounding theories of a new discipline and may also dismiss its importance and establishment if such linkage does not exist.

1.0.5 Principles and Practices

Principles and practices build the base of a discipline. Principles are the operating philosophy by which problems are approached and solved. Practices are the methodologies, procedures and theories that are used for the application of the knowledge base of the discipline. In an engineering discipline, scientific research and logical analysis develop the body of abstract knowledge. The activities that take place in these processes differentiate specific engineering disciplines from each other.

Principles and practices should be arranged logically for facilitating decision-making, critical thinking and problem solving tasks. The main elements of engineering practice are:

Theory –It involves four steps: 1) definition 2) theorem 3) proof 4) Interpretation of the results. The theory is essential because it contributes a base of principles from which discipline is advanced and established. Theory gives focus to develop the principles and practices.

Abstraction - Abstraction, called modeling, consists of four steps :1) Formation of a hypothesis, 2) Construction of a model and prediction making 3) Design of an experiment and collection of data, 4) Analyzing the results. Abstraction provides a way for engineers for representing the focus of study in a way to be tested.

Design - The design process have four steps: 1) Preparation, 2) Incubation, 3) Illumination, 4) Resolution. Preparation is defining the task. Incubation is the period of immersion in irrelevent tasks which occurs in searching for alternatives. Illumination step involves the sudden spark of insight of a solution and the resolution is the implementation of the solution. Design is an iterative generation of alternatives that meet and satisfy the identified needs.

Implementation - Implementation is an essential part of the engineering process. The cause of many good designs is the poor implementation. When the design is implemented, it can then be analyzed for further improvements.

Principles and practices are the integral part of a discipline. They incorporate paradigm as well as the methodologies and procedures that are necessary to advance the discipline.

1.0.6 An active research or theory development agenda

Development of an active research or theory agenda is necessary to establishing the concepts that are unique and distinct. Both theory and practice enhance any discipline and the lines of research build a network between practitioners and researchers. Practitioner's task is to uncover new problems and then communicate those problems to the researchers. Then the researcher's task is to work for the development of solutions by means of already existing research agendas or by new lines of research and then communicate that to the practitioners. This is a repetitive process that facilitates in the enhancement of both theory and practice. Lines of research represent a logical division of a discipline. These lines have a synergistic effect that collectively support a discipline as a whole.

1.0.7 Deployment of education and Promotion of Professionalism

For the recognition of a discipline, the deployment of education and promotion of professionalism are very important. Deployment of education includes professional journals, societies, conferences and curricula in the universities. Development and maintenance of

deployment will help in the recognition of a new discipline. The professional journals develop new knowledge base and help in identification of future lines of research. Professional conferences provide a platform for discussion of current thoughts and to help in publishing the new and emerging ideas and professional societies helps in encouraging the involvement at the grass roots level. Societies and conferences promote the skills of already existing researchers and practitioners by providing exposure to the new and emerging ideas in the field. Curricula in universities are a way to generate new researchers and practitioners and to help in sustaining the profession in future years.

1.1 Implementation of the Philosophy and technicalities involved

Any concept or philosophy is useless until and unless it is implementable practically. The work presented here is the implementation of the above discussed philosophy of discipline. The concepts and philosophy discussed above are implemented for the Engineering Discipline "Mechatronics".

Generally the following technicalities are involved for the implementation of any discipline:

- Industry Acceptance level
- Society Acceptance level
- Need of Curriculum
- Need of Research regarding that discipline

In the next chapters, all of these technicalities will be discussed and explained in detail.

In Chapter 2, the history and evolution of Mechatronics will be discussed in detail. Chapter 3 contains the reasons and justification for selection of Mechatronics engineering. It also discusses in detail what a mechatronics engineer can do and provides guidelines to the students for the selection of appropriate career in Mechatronics.

Chapter 4 comprises of a general view of Mechatronics in Asia and detailed analysis of Mechatronics Engineering education in Pakistan. In Chapter 5, the development of Mechatronics Engineering education is discussed. In Chapter 6, the status of Mechatronics in industries of Pakistan is discussed using a survey based approach for knowing the acceptance level of Mechatronics in the industries of Pakistan. Chapter 7 comprises of the survey results showing acceptance of and awareness about Mechatronics in the society of Pakistan. Chapter 8 discusses the new emerging directions of research in Mechatronics and the strategy to modify the curriculum of Mechatronics to make it better and well suited for betterment of the society. Chapter 9 discusses the conclusion of the research work followed by the future development trend of mechatronics engineering in Pakistan and its mathematical modeling.

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CHAPTER 2

MECHATRONICS – HISTORY AND EVOLUTION

2.0 Mechatronics - History

The word 'engineering' originated when man started inventing devices like the wheel and pulley, using his skills. The word engineer originated from the word ‘engine’, which comes from the Latin word ingenium. Ingenium means "innate quality specifically of thinking power". The word engineer is therefore defined as a person who makes effective and practical inventions.

Today the definition of an engineer is a person who has got scientific and technical knowledge and is making use of this knowledge to design, analyze and build functional works. Engineering is a wide discipline with many sub-disciplines dedicated to various fields of study with respect to specific technologies.

2.1 Revolutionary Phases

The history of engineering can be roughly divided into three overlapping revolutionary phases. These are:

2.1.1 Pre-scientific revolution

Before the revolution of science, the word engineer has definition: "a constructor of military engines". In the start, engineering was categorized as: Civil Engineering and Military Engineering. Military Engineering was related to construction of walls to strengthen an army, city or nation against attack and involved the manufacturing of military engines. Civil Engineering was related to non-military construction, like construction of bridges and houses. This meaning of engineering is now obsolete because of the reason that engineering has expanded to involve variety of disciplines now [1].

2.1.2 Industrial revolution

After scientific revolution, modern engineering’s first phase emerged. This phase evolved when machines started to replace manpower in production sector. The traditional artists got converted into professionals. The French led civil engineering by emphasizing on mathematics and worked for the development of engineering education in universities. The British initiated mechanical engineering and autonomous professional societies [2]. With the passage of time, practical

thought process transformed into scientific realization in addition to the power of understanding, as engineers worked for the development of mathematical analysis and controlled experiments. Technical training got shifted from learning a trade to university education. Information got spread more rapidly in organized meetings and journal publications as professional societies evolved.

After the advent of electricity and mass production, the industrial revolution got driven by many branches of engineering. Chemical and electrical engineering emerged and worked together with chemistry and physics and played essential roles in the evolution of chemical, electrical, and telecommunication industries [3]. Marine engineers tamed the great danger of ocean exploration. Aeronautic engineers transformed the dream of flight into a travel freedom with ease [4]. Control engineers catalyzed the pace of automation. Industrial engineers worked for designing and managing mass production and distribution systems. University engineering curricula got well established and graduate schools emerged. Workshops transformed into the laboratories, industrial research started and individual inventions were organized into systematic innovations.

2.1.3 Information revolution

After the expansion of graduate education, the evolution of engineering research started. Engineering got catalyzed by evolution of new technologies. Microelectronics, telecommunications and computer engineering joined force to initiate the information revolution. For the development of these new technologies, engineers reshaped themselves by reforming educational programs and expanding research. Doing engineering research in depth gave rise to new technologies and gave power to the knowledge of systems, the sciences of engineering and theories in information, computer, control, and communications. The coordination and merger of traditional disciplines in the development of new technology became the trend of the future.

The field of engineering has conventionally been categorized as:

- Civil Engineering
- Aerospace Engineering
- Electrical Engineering
- Chemical Engineering

- Mechanical Engineering.

Since, the humans has been progressing and developing in terms of technology, new fields of engineering have been emerged. Although all these fields may be defined in different manners, still there is generally some overlap. The overlapping fields are:

- Computer Engineering
- Molecular Engineering
- Software Engineering
- Nanotechnology
- Mechatronics

The merger of most of the fields occurs in case of Mechatronics. A mechatronics engineer is one who can understand all technologies and integrate them to produce a useful system. The conventional disciplines have nothing in common so they can no longer work together.

Mechatronics engineering is based on elements of mechanical engineering, electrical and electronic engineering and computer science, but has its own uniqueness and is a distinct discipline in its own right.

2.2 Evolution of Mechatronics

Mechatronics evolved due to cross breeding and merger of various technologies and disciplines, not only merger, it has novelity in it.

Basically mechatronics is an industrial driven program because the term mechatronics was first coined by Tetsura Mori of Yaskawa Electric Corp. back in 1969.

Because of needs of the society and the products that were needed by society, Mechatronics evolved. Due to evolution of industrial products having mechanical design, involvement of electronics and computer based control. A pure mechanical, electronic or computer engineer is

unable to deal with all this. As a mechatronics engineer is capable of handling this situation, so mechatronics evolved to design such products.

Yaskawa, the inventor company of the term Mechatronics, describes its evolution as: [5,6]

Most of the people had no knowledge about it when the word 'mechatronics' was evolved. With the passage of time and technology development, mechatronics has become a well-known in the field of engineering in the world.

2.3 What is Mechatronics?

Mechatronics is an idea to work in a smart manner and to get the more work done without much expenses in as less time as possible. This term can be defined in various ways, but it is designed to be used as a merger of mechanics and the synergistic use of precision engineering, control theory, computer science, sensor and actuator technology, all these are used for designing useful products.

But mechatronics is something far more than this definition. It also involves mechanics, electronics, control and molecular engineering and computing. All of these technologies blend to produce economical , simple and reliable systems. Mechatronics can also be defined as the whole of basics and methods in a consolidate framework for producing machines and products.

One more definition of mechatronics is related to the synergistic integration of mechanical engineering, intelligent computer control and electronics for design and manufacture of industrial products and processes. As a whole, Mechatronics has been linked with various topics including, motion control, manufacturing, modeling and design, intelligent control, robotics ,system integration, automotive systems, vibration and noise control ,actuators and sensors and micro devices.

2.4 History of Mechatronics

Mechatronics began in 1969 in Japan when Tetsura Mori, of Yaskawa Electric Corp., coined the term. Mechatronics was considered initially as electromechanical systems, control and automation engineering. As is clearly to be seen, the term mechatronics is a combination of words, which is not new for Yaskawa; a company that has been combining words and blending concepts since the 1950s. One of the first terms they used was "minertia," which was used for a servomotor line that used minimum inertia for developing super-fast starting and stopping ability. After that they created the term, "mochintrol" , used for motor, machine and control , which speed up electrical actuators capable of freely controlling mechanical arms and fingers.

Yaskawa won the rights to the term mechatronics in 1973 after applying for a registered trademark for mechatronics in 1970. The foundation was made for the study of mechatronics, it did not become successful to reach to its full level. The engineers at Yaskawa, did not agreed for widespread advertisement.

The term started to become popular in the mid of 1980s. Yaskawa made decision that they will not renew the trademark and will give up the rights to the term to continue the research and advancement of the technology in the industry.

The focus of mechatronics was on servo technology during 1970s. This work was related to control methods like automatic door openers and auto-focus cameras. Mechatronics focused on information technology in 1980s, in which microprocessors were embedded into mechanical systems for improvement of performance, for example, antilock braking and electric seats. In 1990s, finally mechatronics focused on communication technology for connection of products into large networks that included the production of air bags and other similar technologies.

2.5 Mechatronics Today

The world became familiar with the term mechatronics as the needs of society started to expand. As the global market started to shrink and reliable and cost-effective products were needed, these became the two factors that have contributed to its development. For designing and manufacturing new products , the need is to develop new technologies, for companies to overcome the challenges and competition. The ultimate needs for any company are competitive product properties and shortened product cycles. So, Mechatronics helps to react quickly to change.

As mechatronics is all about the fusion of mechanics and electronics, it involves software and information technology too. Mechatronics merges new technologies to already working technologies and merges them for solving problems, creating products and innovating new ideas of doing things differently. Mechatronics integrates different technologies for solving problems in efficient manner. In old days, engineers tried to use their own fields of study for solving a problem, but the trend has been changed now. The thought processes are used for various views to make their research better by using more effective tools.

2.6 Future of Mechatronics

As more and more views and ideas will be developed for improvement of the way we live and do things, the need of mechatronics has been increased. Innovations and technologies will have to be improved and developed with the fastly changing environment as the needs and wants of the world changes. In the future, the focus of mechatronics will be on affordability , safety and reliability.

Mechatronics will also contribute majorly in the development of robotics to help in increasing productivity, efficiency , accountability and control. Robots not only master tedious and hazardous tasks, it also do that tasks in minimum cost and errors. Companies using robotics will have the facility of keeping work in their own plants rather than exporting it other countries.

Mechatronics also plays a great role in the field of medicine, in the world of computers and components of industry-based manufacturing of products. Rather building a computer to operate a machine, mechatronics will assist in making the computer a component of the machine that makes a product.

The design process should not be changed by mechatronics, instead of this it provides the engineer with greater knowledge so that ideas and concepts can be developed in an efficient manner; for improving the communications with other engineering disciplines. The satisfaction of client and market are the ultimate purpose in mechatronics. Once the needs of a client are understood in right manner, product specifications can then b expressed and developed keeping in view those needs. After that the design process starts.

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CHAPTER 3

WHY MECHATRONICS?

3.0 Why Mechatronics?

A simple yet important example explaining the need of mechatronics is as follows:

A civil engineer faced a problem. After the pre-2000 Olympics construction boom, his company bought a partially-complete water works to produce a steady cash flow. The work related to construction and mechanical pumping equipment was completed and perfectly installed. The water works needed a control and monitoring system for the guarantee of 24 hour, 7 day maintenance of water quality. The company hired an electrical engineer, a mechanical engineer and a software expert to accomplish the tasks but he faced so much delay, anguish and disappointed by the work that he decided to fire them from job after 6 months. For the faced technical problems no engineer was ready to take the blame rather all of them blamed others. The best suggestion for solution to this problem was to recruit a mechatronics engineer: someone who could understand all the technologies and is able to integrate them to produce a working system. The traditional disciplines have gone so far from each other that they can no longer work together easily.

Mechatronics engineering is focused on elements of mechanical engineering, electrical and electronic engineering and computer science, but is also a distinct discipline in its own right.

The word ‘mechatronics’ evolved in Japan in the 1980s as a core engineering discipline related to robots and automation. Many mechatronics engineering students have the urge to make robots. In learning to do so, they develop special skills necessary for many industries.

For efficient and reliable operation all machines are dependent on electronic and computer control systems and many mechatronics engineers are working on it. Automatic systems monitor process plants for errors and faults, and helps in keeping the plant in working condition, but we take it for granted. All modern aircraft, cars and appliances depends on mechatronics engineering. Mechatronics engineers work for building and designing these products and need is to get expertise in computing, mechanical engineering knowledge, electronics and the quality to combine them to make such systems which can have the safety and reliability levels we take for granted normally.

Mechatronics engineers also have contributed in project engineering where their knowledge provides them an edge and advantage over mechanical or electrical engineers. Mechatronics engineers can work with both electrical and mechanical systems in a team and work for solving problems that cross the boundaries of disciplines. The command, the mechatronics engineer have on different disciplines make them enable to be very versatile in problem solving process.

Mechatronics engineers also develop strong team skills by learning. At many universities, during student team projects, students develop team work skills which help them in professional life.

Many companies have the difficult of breaking from their traditional discipline boundaries,. Electrical, chemical and process, instrumentation, civil engineering, mechanical engineering, all these disciplines are the typical "vertical" organizational supports for all engineering organizations. But at the same time, companies have been putting pressure upon universities to produce engineers that have the ability to work on cross-discipline boundaries, to avoid the "silo mentality". Mechatronics engineering is both a discipline in its own right, closely linked with control and instrumentation, but also the graduates have the ability to work on the cross-discipline boundaries.

Some 'traditional' engineers still argue on the fact that a mechatronics engineer do not have his own identity that makes him distinct, they argue that a mechatronics engineer get its existence one third from that of a mechanical engineer, same from an electrical engineer and one third programmer and they argue that a mechatronics is not any of them complete. But in reality the scenario is very different. Our own research predicts that almost all the technical knowledge and approximately all working roles in engineering have to be learned and all the technical skills have to be developed in one after completion of an engineering qualification degree at university. Mechatronics engineers start with many different but extremely useful foundation backgrounds and have been well received and welcomed in almost every industry across the world. In fact, it is important to remember that the most mechatronics engineering courses evolved because of the industry pressure for producing more adaptable and multi-disciplinary engineers [1].

3.1 Guiding Mechatronics students and Mechatronics Engineers for selection of career

The word ‘mechatronics’ is usually not clearly mentioned in descriptions of jobs, but reading the fine print can provide help and knowledge. Industries and academic institutions are of the view that mechatronic jobs are in great demand, and they are in demand but very rarely the term "mechatronics" appear in the job titles advertised in newspapers. So, the question rises that how can one find a job after doing Mechatronics engineering, when the job title rarely exists?

- The very first thing a mechatronics engineer needs to do is to know what types of jobs are mechatronics in nature. From experience, many mechatronic jobs are advertised under the title of systems engineer, controls engineer, project engineer, mechanical design engineer, mechanical modeling and simulation engineer, electro-mechanical engineer and automation engineer.
- The second thing is to have knowledge of the industries that utilize mechatronics. The major industries are manufacturing, automotive and medical. The best and the useful thing about mechatronics is that any industry that involves use of technology, whether it is electrical, mechanical and software, there is likelihood of a mechatronics job.
- The third and important thing is reading closely. If the job description is closely read then it will be observed that the phrases: “must have knowledge of mechatronics” and “experience in mechatronics is preferred” are wriiten there but they are not clear in the text of the advertisement. Whenever one sees electro-mechanical engineering written in the job advertisement, it is quite sure that the company requires a person with mechatronics engineering background, so the need is to make sure on reading closely these types of job advertisements.
- The fourth thing is to look for certain software in the job advertisements. If one finds a job whose requirement is to have skills in LabVIEW, MATLAB, Simulink, SolidWorks or some type of programming language like C++, it is likely that this job is mechatronic in nature. Almost all mechatronics engineering job positions require knowledge of such softwares.

- The fifth and the final thing is that it is helpful to know that mechatronics can be an area of expertise for the people working in the technical field and a job for those people who are engineers. We can say that a mechatronics technician and a mechatronics engineer both need to acquire a lot of the common skills and programs. The difference is however in the level of education and experience of both.

A technician's task is to make sure all components of a mechatronics system such as electrical, mechanical and embedded software are working correctly and should also know how to fix them when they malfunction. Many of these jobs exists in industries and involves robotics.

A mechatronics engineer who is practicing and designing large scale products needs to acquire the same skills but they must have a BS, MS or Ph.D. degree in mechatronics engineering. They have to spend a considerable amount of time in the field too. [2]

3.2 What a Mechatronics Engineer do?

A Mechatronics Engineer, a super human, is a result of the collision of an Electrical Engineer, a Mechanical Engineer and a Computer Expert. The job of a Mechatronics Engineer is a fused pack of concepts of electrical, mechanical, and computer engineering, all rolled together to produce complex machines for multiple functions.

A Mechatronics Engineer have to work with a team of other specialists who compliment his own specialty, it may be electrical wiring or can be computer programming. On the average workday, a mechatronics engineer has to spend time to examining circuit boards or testing computer code in order to check how it works. A Mechatronics engineer and his team work for designing, creating, and testing projects that includes from microscopic circuit boards to huge robotic assembly lines. [3] A mechatronics engineer on his job do the following tasks:

- A mechatronics engineer has to do a lot of paper work too.
- He has to write and document each and every aspect of the project so that other people can easily study what he has found and done in the project.

- He has to sketch out various mechanical parts that are used in the projects like the parts that make a conveyor belt work and run.
- Furthermore, he has to type up and make an instruction manual for guidance of the users explaining how to use it.

Finally, the result is a work of science and art that advances technology into unknown and thrilling territory.

A mechatronics engineer works for the development of innovative systems by fusing and combining the elements of electrical, mechanical and computer engineering. In the field, the professionals work for designing a wide range of industrial machinery and consumer products, ranging from variety of cars to televisions to robotic assembly lines. In addition to all this, a mechatronics engineer uses his or her skills for the creation of safer and more efficient medical equipment. Regardless of the nature of the work they do, a mechatronics engineer must be enough creative, well-determined and must be able to understand intuitively the relationships between mechanisms, electronics, and computers.

For planning a new project, a mechatronics engineer has to acquire consultancy from experts belonging to different disciplines. He or she may have to interact with marketing managers to see if there is any demand for a new design, he has to consult with factory workers to determine if they could get benefit from the changes to their equipment. The engineer can therefore start brainstorming, drawing schematics and then creates computer models with drafting software.

After finalizing the plans, a mechatronics engineer leads a team of technicians to build a prototype. Many engineers have to participate personally to test and inspect a machine or product once it has been constructed. They work to identify expected faults, potential setbacks or related problems before they rise in order to make the adjustments properly. Engineers who are quite confident in their products may even write technical instruction or user manuals and apply for patents on their designs. Then the successful systems can be produced and distributed afterwards.[4]

Mechatronics engineers have worked for and contributed towards many modern advancements in medical equipment. Engineers have worked for the improvement of monitoring machines, CT

scanners and MRI. In addition to having conventional engineering knowledge, many mechatronics engineers working in the medical industry have practical or academic experience in the biological sciences.

In recent years, the demand for new engineers has drastically increased the number of mechatronics programs offered worldwide. A graduate can start his career by looking for entry-level opportunities at local manufacturing plants and product development centers. New engineers typically have to spend some years in supervised junior positions to gain experience before advancing to official mechatronics engineer jobs.

A Mechatronic Engineer performs a daring deed of a combining mechanics and electronics for designing, constructing and maintaining improved products and processes. It may include designing of a smarter and more efficient washing machine or doing some innovation as making a automated robotic assembly line. A Mechatronic Engineers have the ability to work in a comfortable and competent manner with electrical and mechanical technology in a wide range of disciplines. A mechatronics engineer can work as a team with electrical or mechanical engineers as well as on their own.

3.3 Where can a Mechatronics Engineer work?

Domestically and internationally, the Mechatronic Engineers are in great demand. Most engineering graduates upon completion of the course either have employment arranged or are employed within few weeks after their study completes. Many graduates work overseas while some continue on to higher (postgraduate) degrees [5]. Some areas of employment for Mechatronics Engineers are as follows:

- Design (of consumer products to industrial products)
- Manufacturing
- Management
- Hi-tech research and development
- Defense
- Consulting
- Public Utilities

The personal attributes and qualities of a Mechatronic Engineer are as follows:

- Strong will and desire to exercise and practice creativity in designing and visualization, and to see creative ideas transforming into a reality
- Strong social awareness and great concern for improving the quality of life
- Curiosity about how things work function and thinking and working how to improve the things and their function.

Some of the other tasks that a Mechatronics Engineer can do are:

- Using automated and intelligent computer-control systems, Mechatronics engineers integrate electronics and mechanical systems to produce new devices. For Example artificial hearts, anti-lock braking systems etc.
- Mechatronics engineers are usually performing tasks related to the development and design of advanced Mechatronic technologies and their applications in real world.
- Mechatronics Engineers design, test and manufacture all the control system in automotive and aerospace equipments.
- The Mechatronics Engineer design digital tachometers & speedometers [6].
- Mechatronics Engineer design and operate computer-machine controls, like CNC
- Mechatronics engineers work for assembling industrial robots, programmable machine tools or automated production facilities and install the software required to control them.
- They work to commission the systems, use their skills to operate them and plan for operating cycles.
- They work for upkeep, maintaining and controlling the quality of products.
- Mechatronics engineers build electrical, mechanical, pneumatic and hydraulic assemblies and components and install or connect these to the systems.

3.4 The Future of A Mechatronics Engineer

Due to the multidisciplinary nature of Mechatronics Engineering and its emerging trends, Mechatronics engineers are expected to be in high demand in future.

Mechatronics Engineers can find the job opportunities in any of the following mentioned categories:

- Design of the Industrial & Commercial Robots
- Product Development
- Manufacturing of Robots
- Research & Development Engineer
- Software Engineer in IT industry
- Instrumentation Engineer in Manufacturing Industry
- Power Engineer in Power Plants & Electrical Substation
- Maintenance & Repair Engineer in maintenance

A person who has the urge to become a Mechatronics engineer must :

- Enjoy working in a team.
- Be good at maths.
- Enjoy working with technical and electronic devices.
- Have good spatial abilities.

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CHAPTER 4

MECHATRONICS IN ASIA

4.0 Mechatronics in Asia

Being a synergistic combination of core technologies, mechatronics is rapidly becoming an important part of modern products and processes and has balanced to become an important and key technology to employ for gaining a competitive edge and advantage in the modern manufacturing world where products and processes are becomingly great integrated in functions. The development of mechatronics will therefore be of great importance for the continued competitiveness of a manufacturing high economy, typical of many countries in Asia [1].

Various developments of mechatronics in Asia from three perspectives will be under discussion. These are as follows:

- Education
- Research
- Application of technology.

The overview of development of mechatronics is as follows:

4.0.1 Mechatronics in Japan

The term "mechatronics" was coined by a Japanese engineer from Yasukawa Electric Company in 1969 to reflect the merger of mechanical and electrical engineering disciplines. Before the start of 1980s, mechatronics was known just as a mechanism that is working on electricity. In the middle of 1980s, mechatronics emerged as a field of engineering that is the border between mechanics and electronics. In present world, the term covers a huge segment of technologies, many of which have become popular in their own right. Each technology has the foundation of the fusion of mechanics and electronics but now also may include more than that, especially software and information technology.

For instance, many robots in early days came to existence from progress and development of mechatronics. As robotic systems grew smarter, software development, as well as the mechanical and electrical systems, became foundation to mechatronics.

Mechatronics acquired popularity lawfully in academic circles in 1996 after the publication of the first referred journal: *IEEE/ASME Transactions on Mechatronics*. The authors struggled to

define mechatronics in the initial issue. After admitting that many definitions have been circulated, they decided to select the following for articles to be selected in *Transactions*: "The synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products" [2]. The authors suggested eleven topics that should fulfill the criteria and should fall under the general categories of mechatronics:

- modeling and design
- system integration
- vibration and noise control
- actuators and sensors
- robotics
- intelligent control
- manufacturing
- motion control
- automotive systems,
- micro devices and optoelectronic systems and other applications.

The field of mechatronics faces many dilemmas and unpleasant situations, in spite of the rate interest growth in mechatronics. For instance, despite of the rising interest in mechatronics, many younger people in Japan's engineering community are unaware of mechatronics and even have never heard of this technology. Also, a survey and study of all fields and areas that lie under mechatronics as defined in that starting issue of *Transactions* would be very broad, and would contain topics that have very less things in common.

Because of the strong and effective lead that the Japanese had in development and commercialization and research in robotics in the 1980s, the original Japanese Technology Evaluation Program (JTECH) declared mechatronics as a part of the original four areas that have to be evaluated. In March 1985, the study got completed. During the previous 12 years, WTEC (JTECH's successor organization) has completed many studies in fields closely linked to mechatronics. These are: Rapid Prototyping (1997); Optoelectronics (1996); Electronic Manufacturing and Packaging (1995); Human-Computer Interaction (1996); Micro-electromechanical Systems (1994); Knowledge-Based Systems (1993); Advanced Manufacturing

Technology for Polymer Composite Structures (1994) and Material Handling Technologies (1993).

On the basis of this experimental information, the author concluded that a repeated ITRI study of all of "mechatronics" would be too wide, but some selected topics that fall under the category of mechatronics could be chosen and shortlisted for full-scale studies. Areas of research may include university/government/industry cooperation, social/cultural changing in manufacturing and the impact of information technology on mechatronics. [3]

4.0.2 Mechatronics in Australia and New Zealand

Mechatronics is considered as youngest engineering discipline. It combines mechanical, electrical, electronics and computer engineering but the essential and the most important role of the discipline is to integrate the machines and systems that make use of these elements.

The National Panel on Mechatronics (NPMech) had their first meeting in December 2006. The main agendas that were discussed were related to industry standards a mechatronics engineers had to work with very often, and graduate development problems for mechatronics engineers. The panel decided that this was a challenging and risky issue for companies which often have fairly distinct and separate discipline groups like mechanical, electrical and instrumentation. The need was to provide opportunity to graduates to have enough exposure in all of these groups to reinforce the cross-discipline capabilities that has been created for education.

Mechatronics engineering is available in degree courses at 23 universities in Australia and New Zealand. Mechatronics engineering comprises of 10% of Australian engineering graduates.

The courses vary reasonably. Although the courses are accredited by Engineers Australia (for Australia) and Institution of Professional Engineers New Zealand (for New Zealand).[4]

4.0.3 Mechatronics in Turkey

The term “mechatronics” got introduction in Turkey in 1993, but the advancements and developments regarding this field had a slow pace. In Turkey, Mechatronics education entered into expansion phase in late 1990s. Now in Turkey, though it is very late as compared to others, but there is mechatronics education that starts from high school to graduate level. Due to lack of technical personnel and infrastructure and other weaknesses, very less students theoretically got domination over the set curricula. The major obstacles of mechatronics education in Turkey were the insufficient coordination among state, industry and university. Despite of all this, there is an ever increasing demand for skilled and qualified persons in mechatronics field. Thus, it can be anticipated that a new perspective and boost will occur in vocational and technical education system of Turkey with the development of mechatronics education classes in all high schools, training schools, training centers, graduate and postgraduate schools levels.[5]

The mechatronics education started in 2001in Turkey, with two vocational high schools and quota of 55 students. The number was raised to 43 programs, 1917 evening education, 805 primary education, totally quota is 2272, in 2010 [6].

4.0.4 Mechatronics in India

The importance of mechatronics is increasing day by day with the increase in needs and demands of society. Mechatronics is contributing a lot and taking part in research and development, and handles Robotics and IT, space technology, space exploration. As it is a fusion of various disciplines, its applications are wide. There is also an ever increasing demand from other countries for mechatronics engineers. In India, there is a lot of scope and options for the graduate of mechatronics for selecting jobs in information technology based companies as the rate of development and the increased implementation of new research and development projects. Mechatronics is also a very important part of the progress in this field. The progress and development of the field is will be ever increasing because of the demands of the society and as a result the demand of mechatronics engineers will also be increased.[7]

in India, More than 20 engineering institutions are offering B.E Mechatronics engineering and B.Tech Mechatronics and the number is increasing day by day.

4.0.5 Mechatronics in Pakistan

A totally new and nascent field of engineering for Pakistan, the "Mechatronics" was started in Pakistan by the NUST College of E&ME in 1998 and took the initiative. [8]. At that time, the society was totally unaware of mechatronics and no one knew about this field. People only have a general idea that it is a blend of Mechanical and Electronics. UET Lahore initiated its Undergraduate program in 2002 and later on in 2003 Air University came forward and became the third institute to start an undergraduate Mechatronics Engineering Program in Pakistan. But today some more Universities in Pakistan including UET Taxila (Chakwal Campus), Wah Engineering College and UET Peshawar are offering BE Mechatronics programs. Universities offering mechatronics engineering in Pakistan are listed in the Table 1as follows:

Program Name and the year of first intake of students	Institution Name
B.E. Mechatronics (From Intake of Batch 1998)	College of Electrical and Mechanical Engineering, NUST, Rawalpindi
B.Sc. Mechatronics & Control Engineering (from intake of Batch 2001)	University of Engineering and Technology, Lahore (Main Campus)
Bachelor of Mechatronics Engineering (From Intake of Batch Fall-2003)	Air University, Islamabad
B.Sc. Mechatronics & Control Engineering (From Intake of Batch 2004)	University of Engineering and Technology, Lahore (Faisalabad Campus)
B.Sc. Mechatronics Engineering (From Intake of Batch 2005)	Wah Engineering College, Wah Cantt (affiliated with University of Engineering and Technology, Taxila).
B.Sc. Mechatronics Engineering (From Intake of Batch Fall-2005)	University of Engineering and Technology, Taxila (Chakwal Campus)
B.Sc. Mechatronics Engineering (Intake Batch 2007)	NWFP University of Engineering & Technology, Peshawar (Main Campus)
BE Mechatronics Engineeing (Intake 2011)	SZABIST Karachi

Table 1. List of Universities offering Mechatronics in Pakistan

Brief history of Mechatronics in above mentioned engineering institutions is as follows:

4.1 History of Mechatronics in CEME, NUST, Rawalpindi

In today's world, all the research carried out, production processes and production lines working in the industry are electromechanical in nature. It is unavoidable for the people working on those process and production lines to have all the knowledge of all the concerned systems. Currently, the employees get training while doing on the job training but it is not so helpful for them because they lack the required theoretical knowledge. The College after realizing this difference between industrial requirements and the contents of curriculum gave rise to Mechatronics Engineering from January 1999 at the undergraduate level. Mechatronics is related to a flexible multi-technological approach for integrating Mechanical Engineering, Electronics, Computer Engineering, Software and Information Sciences. To make these disciplines strong enough the need is to design, build and maintain intelligent products with special emphasis on industrial systems. Mechatronics Engineering presents a solid foundation in dynamics, mechanical design, sensors, instrumentation and control. [9] These technologies are then used in application of intelligent machines.

MS leading to PhD program in Mechatronics engineering started in the College in 2005. The Masters' program is focused towards intelligent Autonomous Systems and Robotics. The Masters in Mechatronics Engineering Program is designed especially for busy students that do jobs and all classes are scheduled in the evenings for the convenience of the students. The students are urged and encouraged to actively contribute and take part in real-world projects during their studies.

4.2 History of Mechatronics in UET, Lahore

In UET, Lahore , the Department of Mechatronics & Control Engineering (MCE), was established in December 2005. In main campus, the undergraduate and postgraduate programs were established in 2001 and 1999 respectively and are being run successfully. There is an enrollment of 250 students in present undergraduate level. In Faisalabad campus, department of mechatronics was established in 2004.

The Bachelors Programme in Mechatronics is specifically designed to cater the needs of technology-based-industries. It will provide knowledge in the fundamentals in-depth, designing analyzing and operation of mechatronics systems. The objective of the programme is to enable the student to work effectively. [10] . The record of student enrollement in BSc, MSc and Phd programs from 2006 to 2010 is shown in Table 2 as follows:

No. of Enrolled Students	**Level**	**Year**
2	Ph.D	2010
30	MSc./M.phil	2009
44	MSc./M.phil	2010
13	MSc./M.phil	2011
58	BSc.	2011
57	BSc.	2010
64	BSc.	2009
54	BSc.	2008
54	BSc.	2007
61	BSc.	2006

Table 2. Record of Student Intake in Mechatronics in UET Lahore

4.3 History of Mechatronics in Air University, Islamabad

In Air University, Islamabad, the Mechatronics Engineering Department, was established in 2003. Three batches with Bachelor's degrees have been graduated from the university and there is an academic staff of 20 with 03 senior Ph.D. faculty members. The laboratories of CNC machines, control and automation, robotics and industrial automation, mechanics of materials, thermo-fluids, , heat transfer and a general mechanical workshop are available. Some of the other university facilities available to the department are well set computer labs, library and laboratories of digital electronics and microprocessors.

The First Convocation of Air University was held in September 2007 and the number of students graduating with B.E and M.S degrees was 55 and 2 respectively. The Second Convocation was held in February 2010 and the degrees were awarded to the second and third batches.

In Pakistan, Mechatronics is best suitable for the industry because it presents the correct blend of mechanical, electronics, and computer programming that makes an engineer able to grasp and fight with the important things. At a graduate level, the objective of the department is to focus on instrumentation, sensors and control systems. The M.S programme provides a student enough time after completing the compulsory course work, to carry on research that is acceptable internationally. An M.S. thesis in mechatronics builds on the undergraduate base, is focused at producing work of a quality that leads to PhD research and is enough to reach at the standards of international conferences. [11]

4.4 History of Mechatronics in Wah Engineering College

Wah Engineering College, a constituent college of the University of Wah, was established in 2004 and has started department of mechatronics in 2005. The department of mechatronics is affiliated with UET, Taxila.

4.5 History of Mechatronics in UET, Taxila (Chakwal Campus)

In UET, Taxila Chakwal campus in 2005, the department of mechatronics was established. The educational objective for the undergraduate program in the Department of Mechatronics Engineering is to create and develop versatile multi-technological approach by integrating mechanical engineering, computer engineering, electronics and information sciences. Mechatronics engineers handles the national needs and requirements of industries in the field of automated manufacturing equipments, robotics, automobiles, treatment plants, security systems medical apparatus etc. [12]

4.6 History of Mechatronics in SZABIST Karachi

From 2011, SZABIST is being offering a four year (eight semesters) BE (Mechatronics Engineering). The BE program is a morning program and consists of Internship and the passing of the exams. The time limit to complete the BE degree is seven years (maximum). A summary of the degrees being offered in mechatronics by the above mentioned universities of Pakistan are shown in the Table 3:

Name of the institutions offering Mechatronics	BS	MS	PhD
College of Electrical and Mechanical Engineering, NUST, Rawalpindi	Yes	Yes	Yes
University of Engineering and Technology, Lahore (Main Campus)	Yes	Yes	Yes
Air University, Islamabad	Yes	Yes	X
University of Engineering and Technology, Lahore (Faisalabad Campus)	Yes	X	X
Wah Engineering College, Wah Cantt (affiliated with University of Engineering and Technology, Taxila).	Yes	X	X
University of Engineering and Technology, Taxila (Chakwal Campus)	Yes	X	X
NWFP University of Engineering & Technology, Peshawar (Main Campus)	Yes	Yes	X
SZABIST Karachi	Yes	X	X

Table 3. List of Universities offering BS, MS and PhD in Mechatronics in Pakistan

From the above data, we see that only two institutions in Pakistan are offering PhD degree in Mechatronics. This means that the research in the field of mechatronics is negligible as compared to other countries. The reason is the lack of teaching and research facilities in Pakistan. Also, out of 8institutions, only 4 are offering MS degree in Mechatronics.

The intake of students per year in BS, MS and PhD in the respective universities is summarized in the following table:

Name of the institutions offering Mechatronics	BS	MS	PhD
College of Electrical and Mechanical Engineering, NUST, Rawalpindi	75	35	1 – 2
University of Engineering and Technology, Lahore (Main Campus)	60	40	2 – 3
Air University, Islamabad	50	5-6	X
University of Engineering and Technology, Lahore (Faisalabad Campus)	20	X	X
Wah Engineering College, Wah Cantt (affiliated with University of Engineering and Technology, Taxila).	*	X	X
University of Engineering and Technology, Taxila (Chakwal Campus)	50	X	X
NWFP University of Engineering & Technology, Peshawar (Main Campus)	30	*	X
SZABIST Karachi	*	X	X

* data not available

Table 4. Record of Students Intake in BS, MS and PhD in Mechatronics in Universities of Pakistan

From the data enclosed in the above table, it can be seen that very little work is being done in research field of mechatronics. The induction of PhD students in mechatronics is negligible in comparison with other engineering areas.

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CHAPTER 5

COMPARISON OF DEVELOPMENT OF COMPUTER ENGINEERING AND MECHATRONICS

5.0 Comparison of Development of Computer Engineering and Mechatronics

5.0.1 Introduction to Computer Engineering

Computers are gradually becoming an essential aspect everywhere. Because of speedy growth of IT, computer industry has rapidly grew as one of the fastest developing part of our economy. As a consequence, there is a great demand for Computer engineering professionals for the development of fast hardware parts, communication systems and software. Computer Engineering involves design and testing of computer components. It studies elements from both electrical engineering and computer science angles, and joining the principle and techniques of these two to make and develop computer and computer-based systems. Computer engineers are the professionals who work with computer hardware and software.

Computer engineers work as part of a team who apply their knowledge of mathematics and science for designing and developing computer and its components. The people who deal with the computer components and equipment are known as computer hardware engineers and those who work with the computer programs and do software related work are called computer software engineers.

Computer software or software is a combination of computer programs, procedures and documentation that help in performing the major tasks on a computer system. Software engineers must develop strong programming skills because they have to deal with the designing and development of various kinds of software, including computer games, business applications, word processing, operating systems and network distribution and compiling devices that work to transform the programs to language that machine can understand for executing on a computer system.

The work of hardware engineers is related to research, design, testing, to manufacture and install the computer hardware for example, circuit boards, computer chips, computer systems and other related equipments. Their work is very much similar to the work of electronic engineers but their work is bounded to computers and computer-based equipments. Computer engineers have the

choice of opting hardware or software positions or fusing them together. In case of projects, both these engineers normally work together in a team. These computer engineers are the people who work for designing software and hardware computer-related systems for embedded micro controllers, to design VLSI chips, mixed signal circuit boards, analog sensors and operating systems.[1]

5.1 Computer Engineering and Mechatronics in Pakistan

Although Computer Engineering and Mechatronics both started in Pakistan in parallel in late 90's but the development of computer engineering is far more than that of mechatronics. No doubt, Computer engineering holds its own importance but a mechatronics engineer can also perform the tasks of a computer engineer. Unfortunately, in Pakistan, if we compare the number of institutions offering Computer Engineering, with that of Mechatronics Engineering, we have to face disappointment because only 8 institutions in Pakistan are currently offering Mechatronics Engineering. Out of these 8, one institution is in Islamabad, 5 are in Punjab and only one in Khyber Pakhtunkhuwa and one in Sindh. In Baluchistan not even a single university is offering Mechatronics. While on the other hand, about 27 engineering universities are offering Computer Engineering in different cities of Pakistan including more than 10 universities of Sindh and Baluchistan. The list of the universities offering Computer Engineering is given in the Appendix A.

So the need is to create awareness about mechatronics in society and emphasize on the importance of mechatronics among the students as well as industry. So, that the industries pressurize educational institutions to start more mechatronics programs. In this way, more and more students will get degrees in mechatronics and work in industries to meet the demands of society.

As shown in Figure1, it is clear that Mechatronics Engineering should be promoted in Sindh and Baluchistan zone as there is only one university offering Mechatronics in Sindh and no university in Balochistan.

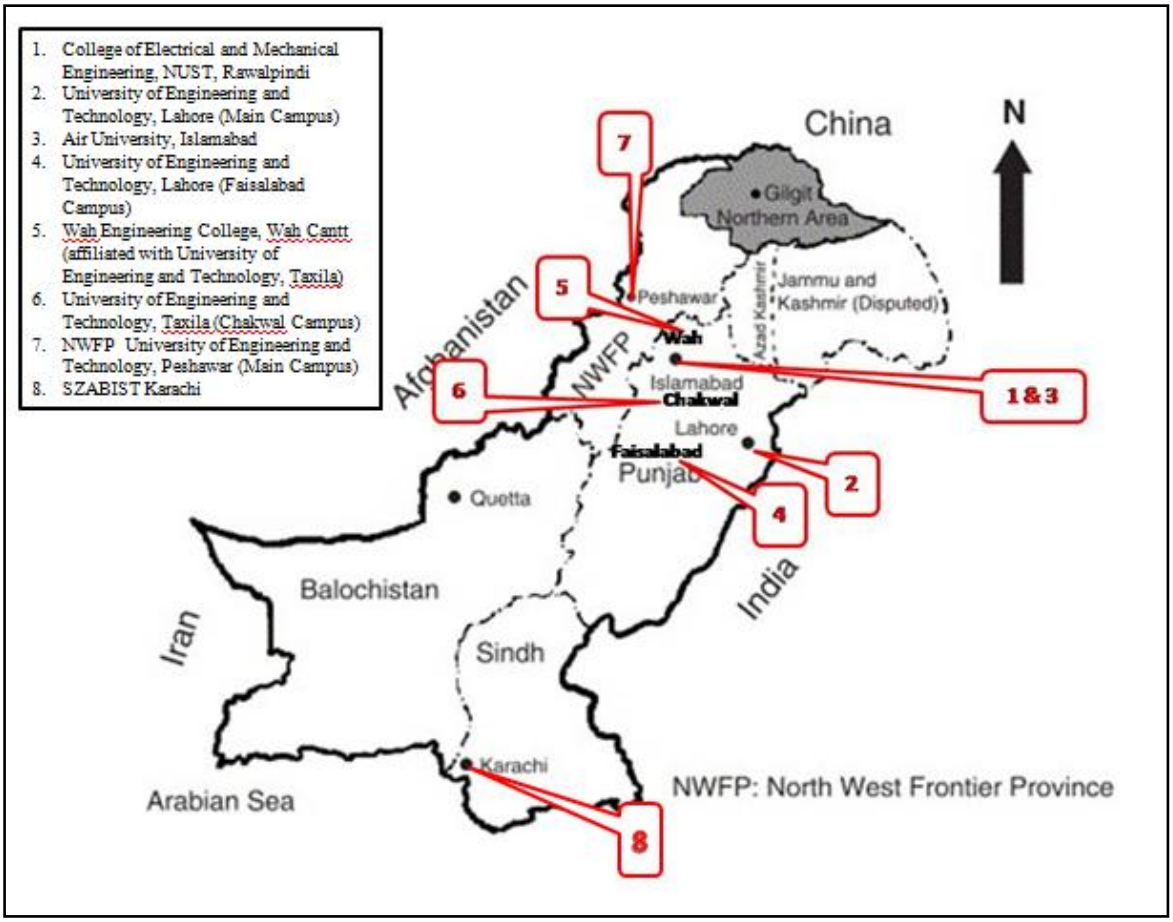

Figure 1. Location of universities offering mechatronics in Pakistan [2]

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CHAPTER 6

MECHATRONICS AS A CAREER IN PAKISTAN

6.0 Mechatronics As A Career

With the advancement of technology, the products and systems are changing rapidly into mechatronic, so, it has become essential for engineers and technicians to be "multi-craft" or "Multi-skill". Multi-skill engineers and technicians know all or most of the different systems linked with mechatronics. They are able to perform traditional and conventional responsibilities and tasks. Unfortunately, most of the fresh technicians have done graduation from programs that give training of only one or two of the areas that fall under the category of mechatronics. Generally, the technicians become proficient in mechatronic systems by on-the-job training and learn by experience. However, companies, in general, wants and see significantly those people who have formal mechatronic training.

6.1 Mechatronics Industry Survey

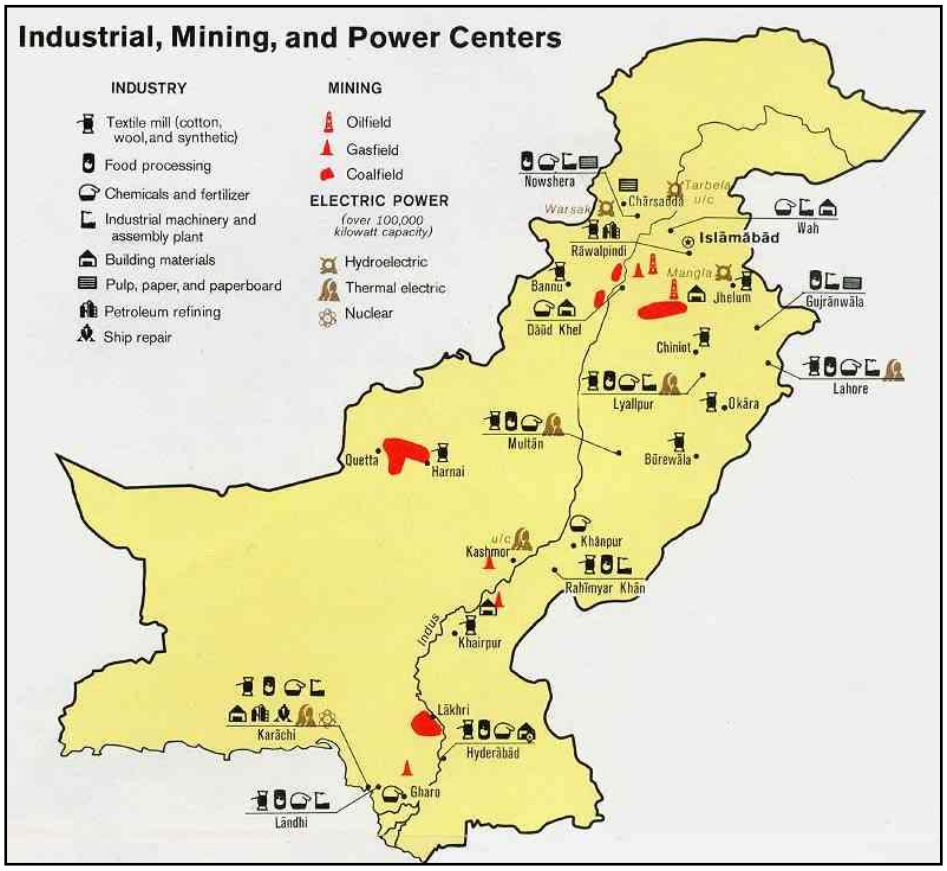

Figure 2. Industrial Map of Pakistan [1]

Figure 2 depicts the industrial map of Pakistan. It can be seen that industrial sector can be roughly divided into three categories:

1. Industry
2. Mining
3. Power centers

A Survey containing questionnare related to Mechatronics was carried out to have an overview of the status of mechatronics and mechatronics engineers in all the three above mentioned sectors in Pakistan. The questionnare was sent to many industries, mining and power centers of Pakistan. In accordance with the response and the data we received after the survey, the results are compiled and discussed in the next section. The survey questionnare is given in the Appendix B. The list of companies that participated and helped in survey is given in Appendix C.

6.2 Survey Results

Most of the companies that actively participated in the conduction of the survey belong to private sector.

These participants belong to the following industries:

- Oil and Gas
- Clothing
- Food Processing
- Plastic products
- Automotive

The services offered at the participating companies are:

- Training / Consulting
- Maintenance
- Design & Development
- Instrumentation
- Production
- Maintenance
- Sales

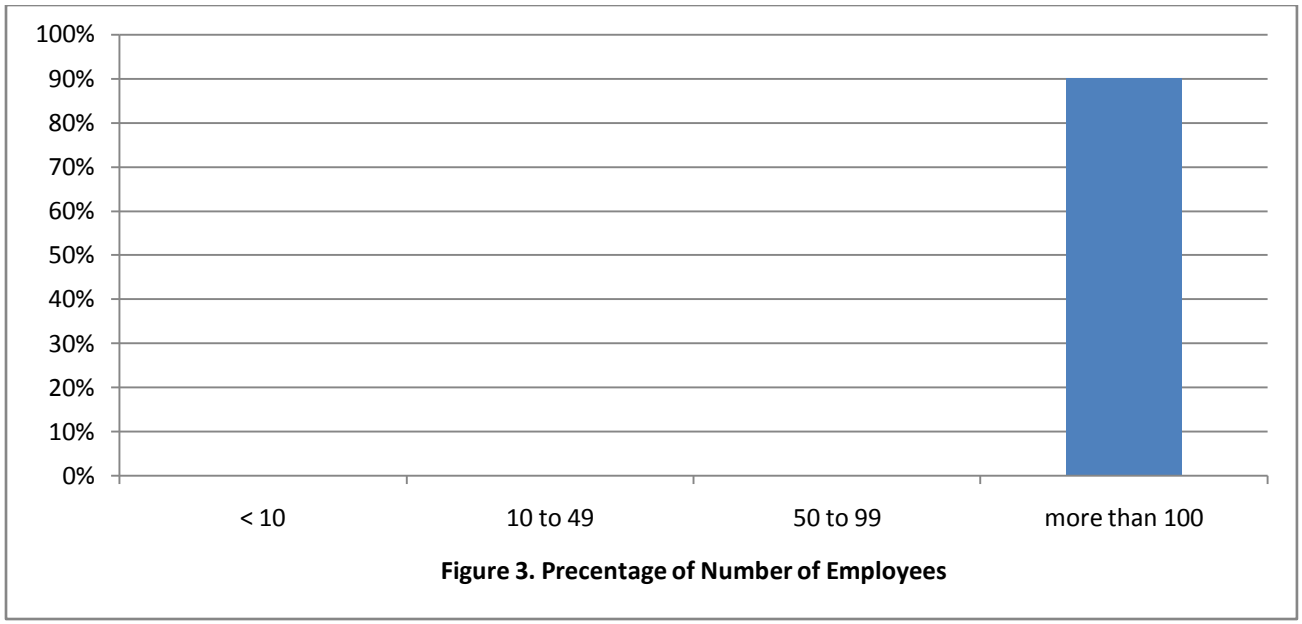

Figure 3. Precentage of Number of Employees

Figure 3 shows the percentage of number of employees in the participating companies. All the companies that participated in the survey have more than 100 employees in their company.

Number of Engineers at each company is shown in the Figure 4 as follows:

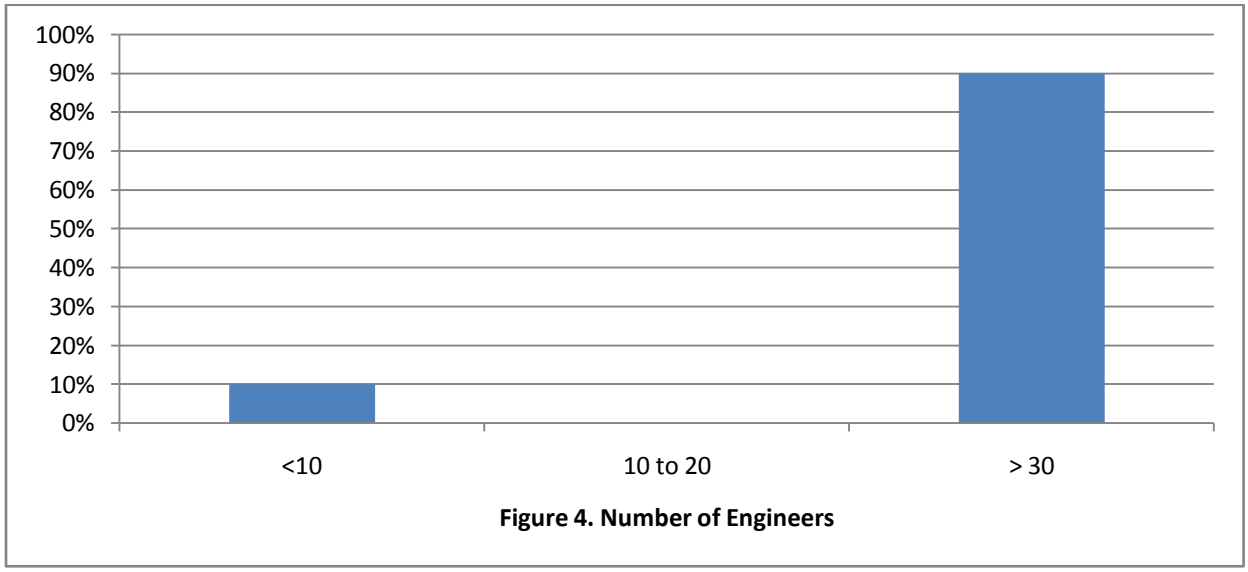

Figure 4. Number of Engineers

90% of the companies that participated in the survey have more than 30 engineers working in that company. Only 10 % of the participants have less than 10 engineers in their company. This means still there are some companies in Pakistan where there is lack of engineers and these companies are finding some difficulty to hire engineers.

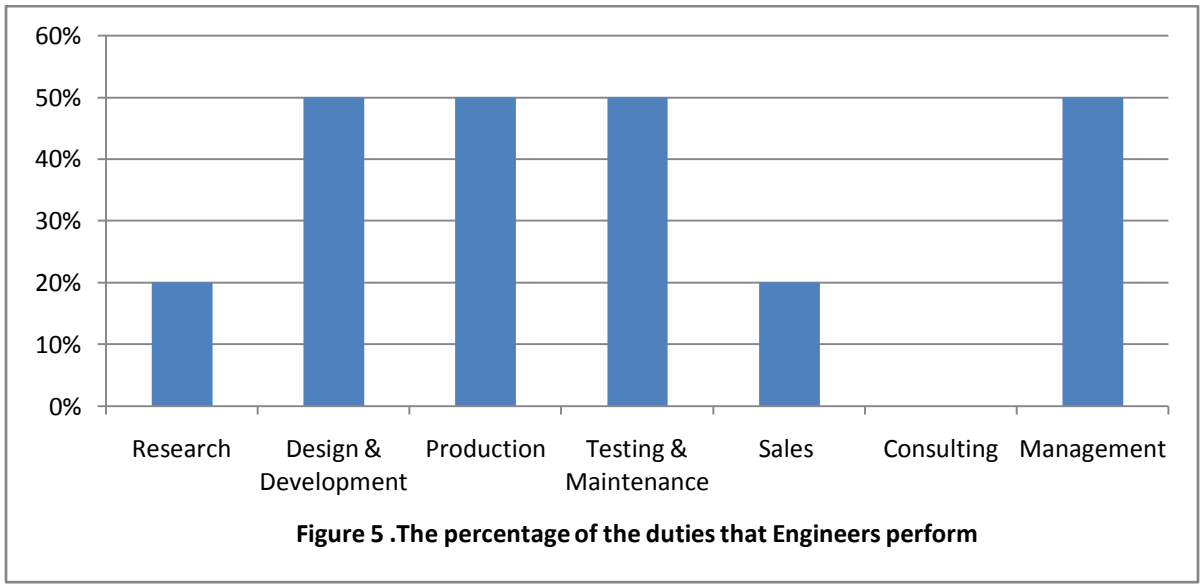

Figure 5 .The percentage of the duties that Engineers perform

Figure 5 shows the percentage of importance of the duties that engineers perform while working in companies. This result will help fresh engineers to get awareness so that they can expertise in these areas and tasks which engineers perform in industries.

From Figure 5, we see that Design & Development, Production, Testing & Maintenance and Management tasks are equally important in almost all the industries. Research is negligibly carried out in Pakistan industries.

In the survey, industries were asked whether they do Research & Development or not. The results are shown in Figure 6.

The need is to motivate the industries to work for the progress of R &D department so that our country excels from other countries in this area.

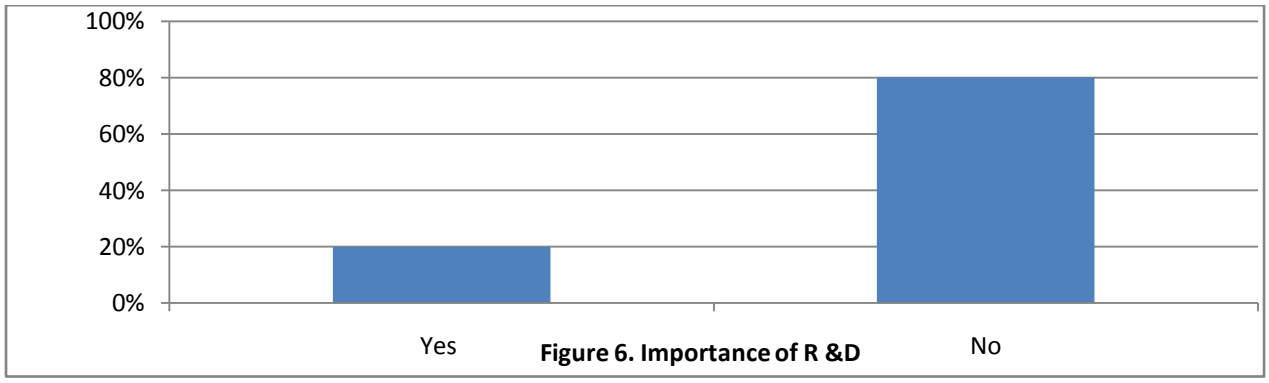

Figure 6. Importance of R &D

Only 20% of the companies have R & D department which is very less and needs to be increased.

Interest of companies in common projects or research with universities is shown in Figure 7.

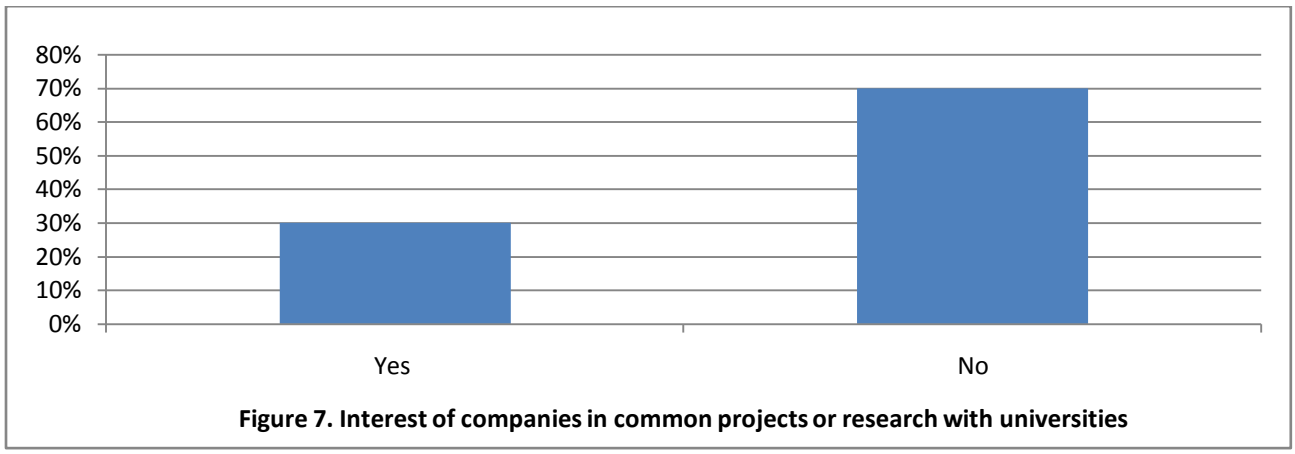

Figure 7. Interest of companies in common projects or research with universities

Only 30 % of the companies are interested to do projects and research by involving universities and students. This means universities and students are not provided the opportunity to use their knowledge and skills practically. The need is to convince the industries and to create awareness among them to provide opportunities to the universities and provide them with adequate financial support for doing research projects to promote research and development in the country. They should realize their responsibility to support the universities that provide them

qualified engineers. The companies that respond positively in this regard say that they involve universities in Energy Management and Automation projects.

Interest of engineers at companies in obtaining masters degree is shown in the Figure 8.

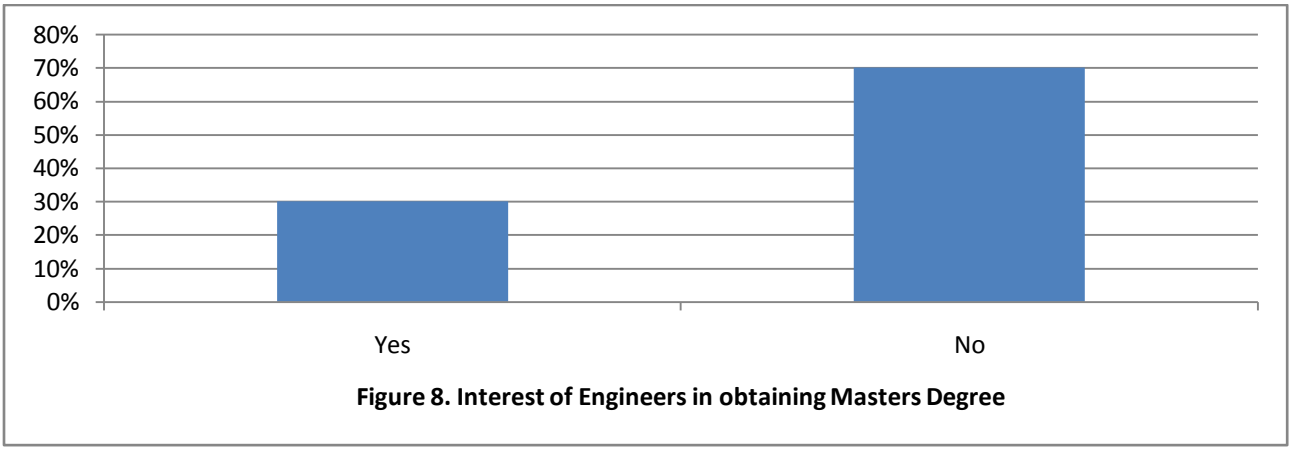

Figure 8. Interest of Engineers in obtaining Masters Degree

Figure 8 shows only 30% engineers are interested in studying further and obtaining Masters Degree. The reasons for not studying further and lack of interest in doing Masters are not particular but might be the jobs are too hectic that it is not feasible for engineers to study with job or might be they are too satisfied with their jobs and salaries that they are not getting interest in obtaining Masters Degree.

Difficulty level for companies in finding qualified engineers is shown in the Figure 9.

90% of the participating industries said they do not have any difficulty in finding qualified engineers for their companies. This means that our universities are doing their duties properly and are producing efficient and qualified engineers but still employment opportunities are very less for engineers.

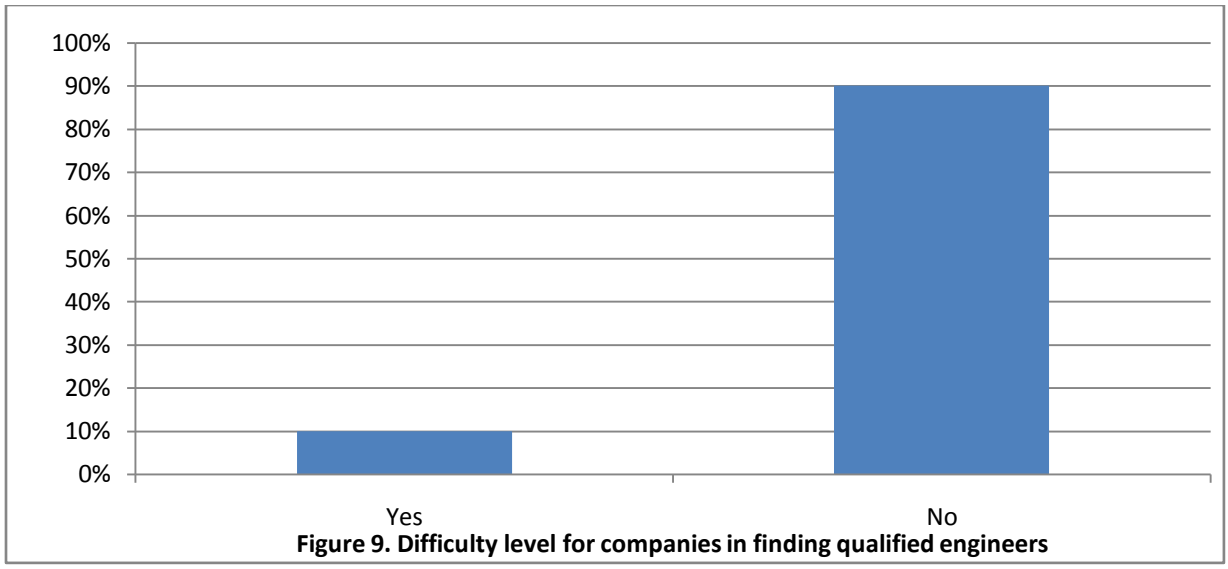

Figure 9. Difficulty level for companies in finding qualified engineers

We asked the participating companies about the importance of the following 16 areas in their company. These areas are:

1. Mechanical Design
2. Hydraulics and Thermo-fluids
3. Electronic Design and Testing
4. Electrical Power and Drives
5. Control
6. Modeling and Simulation
7. Robotics
8. Industrial Automation
9. PLC+SCADA
10. Embedded Systems
11. Computer Aid Manufacturing (CAM)
12. System Interface and Integration
13. Software Programming and Packages
14. Production and Project Management
15. Quality Control
16. HVAC systems

The survey result is shown in Figure 10. The percentage of each area in the figure depicts its importance in the industry. The results of figure 10 will help and work as guideline for the fresh engineers to expertise themselves in the areas that are of more importance in industry.

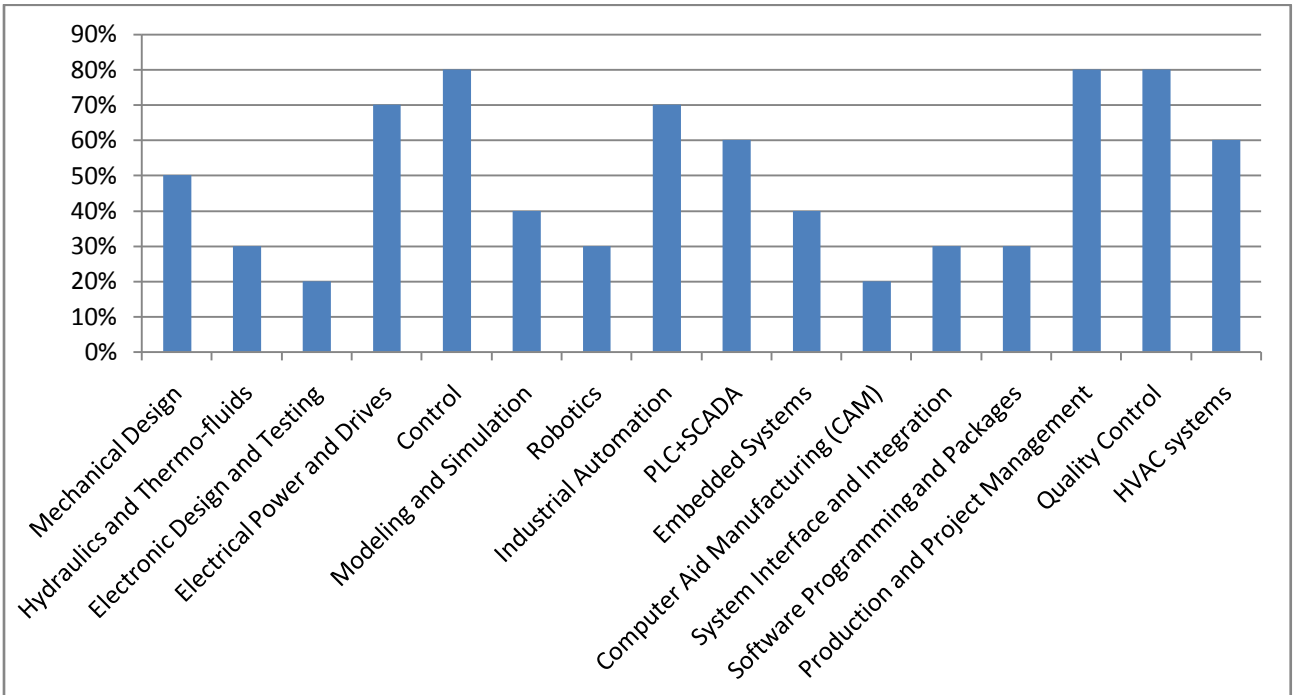

Figure 10. The importance of 16 areas in the company

If we closely observe the most important areas of the Figure 10, it can be seen that the most important areas in industry are related to Mechatronics Engineering. So, consciously or unconsciously, industries are moving towards Mechatronics technology but still there is not enough awareness about Mechatronics.

Knowledge of companies about Mechatronics Engineering is depicted in figure 11 as follows:

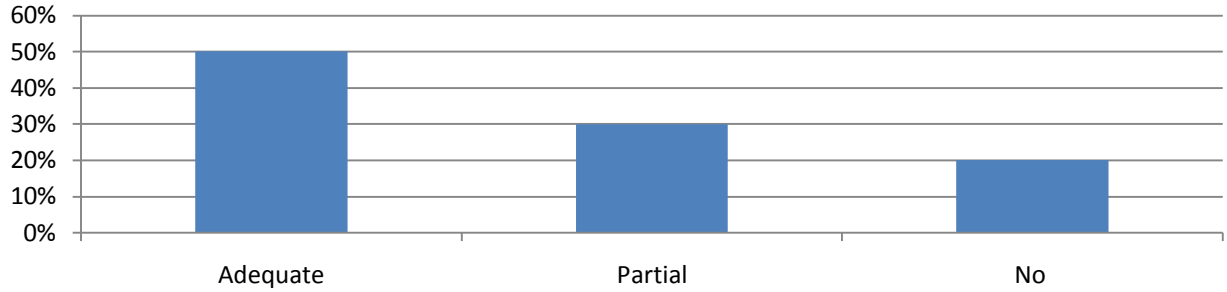

Figure 11. Knowledge of companies about Mechatronics Engineering

Only 50% of the participating companies had adequate knowledge of Mechatronics Engineering, 30% said that they partially know about it and they have knowledge about either electronics or mechanical part of it, 20% of companies do not even heard about Mechatronics Engineering or did not like to discuss anything about it.

The need is to create awareness among the industries about mechatronics. Although the industries are making use of the technology areas related to Mechatronics but still they don't know what mechatronics really is.

Participating companies were asked about the advertisement of job vacancies having title 'Mechatronics Engineer'. The results are shown in Figure 12.

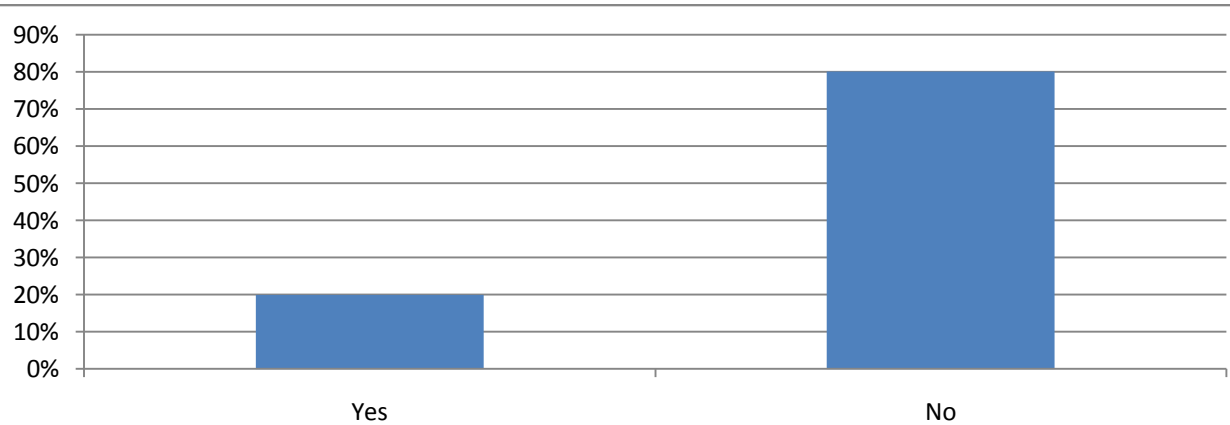

Figure 12. Advertisement of job vacancies having title ' Mechatronics Engineer'

The results show that only 20% of the companies said that they advertise jobs by the title of Mechatronics Engineer rest of the 80% said that there is not any job vacancy in their company for a Mechatronics engineer. Rather they advertise jobs as 'Automation Engineer or Electrical Engineer' and sometimes consider Mechatronics Engineers for this job. But they do not have job vacancy purely for Mechatronics Engineer. Some companies even said there is nothing special in hiring Mechatronics Engineers by restricting the job vacancy by the title of Mechatronics Engineer.

The number of Mechatronics Engineers in the participating companies is shown in Figure 13 as follows:

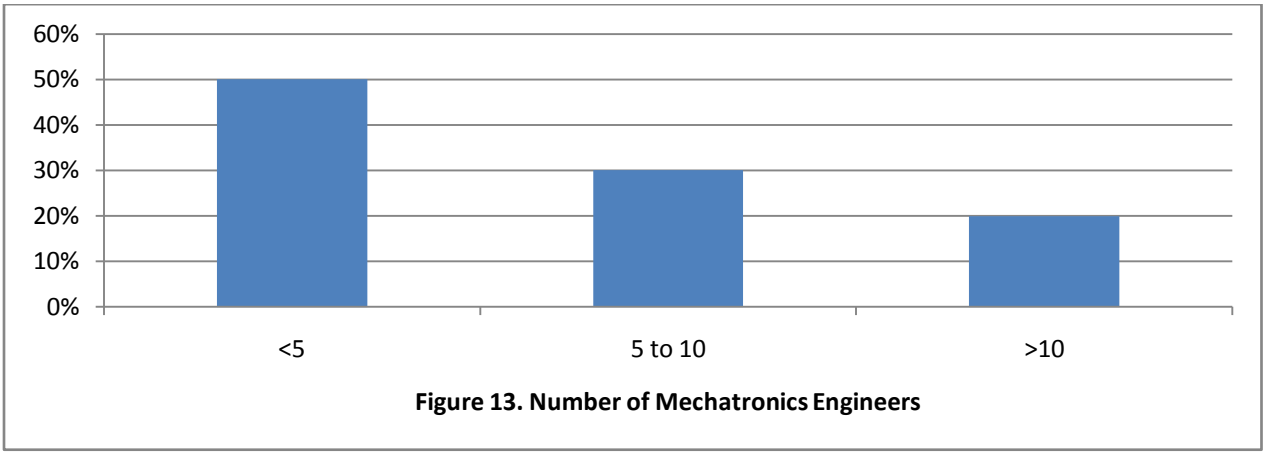

Figure 13. Number of Mechatronics Engineers

From the survey result we see that Mechatronics Engineers are not hired in the industries in appreciable number. The industries involving automotive, clothing and plastic products have very less number of Mechatronics Engineers. Only 10% of the companies have more than 10 Mechatronics engineers as their employees. Rest of the 90% has less than 10 Mechatronics Engineers and these are treated as Automation Engineer rather Mechatronics Engineer.

In the survey, the industries were asked about the reasons of hiring Mechatronics Engineers in their companies. We got a mixed response in this regard. Some of the companies said they are brilliant and are capable of multi-tasking, they can perform the tasks of Mechanical as well as Electrical tasks. Some said they are hired just because they are Engineers like any other Engineer; there is not any special reason to hire them. Some of the companies said because of the

automation skill, Mechatronics Engineers are hired. Some said Mechatronics Engineers can work as an Electrical engineer too, so they are hired for the post of Electrical Engineer. Some said they are not much important for their company and the company can do work without them.

Companies were asked whether they hire female Mechatronics Engineers or not. This was done to know if industries accept female Mechatronics Engineers. The results are shown in Figure 14.

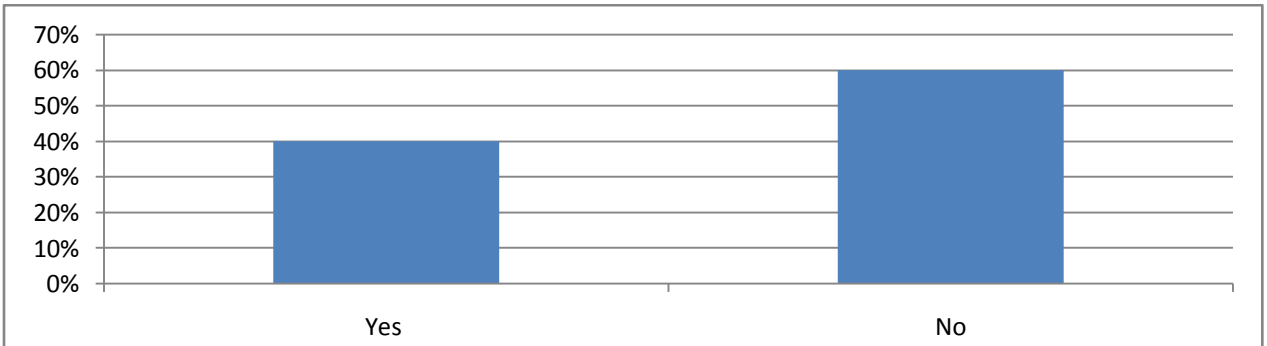

Figure 14. Hiring of Female Mechatronics Engineers

The survey results show that 60% of the industries do not hire female Mechatronics Engineer in their companies. This is really a drawback of our country where females are competing with males in every field of life and are even excelling them but they are not provided enough opportunities to work in the industrial environment. In every Engineering institution which offer Mechatronics engineering, almost 40% of each batch comprise of female students and they are more competent but many of the industries do not accept females engineers .

In the survey, companies were asked how they would compare performance of Mechatronics Engineer with that of Electrical and Mechanical Engineers in the company. The results are shown in Figure 15.

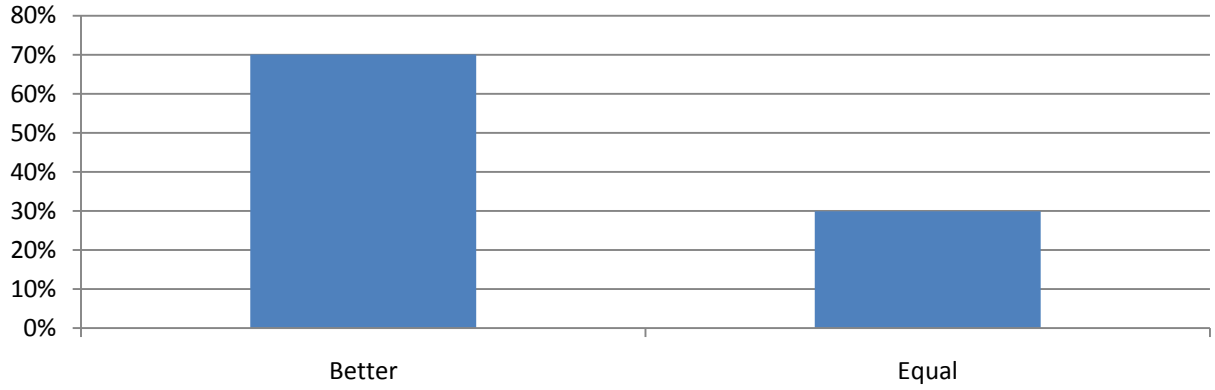

Figure 15. Preformance Comparison of Mechatronics Engineers with Electrical and Mechanical Engineers

70% of the companies realize that Mechatronics are better in performance than other engineers because of their automation skills and better grasp over both Electrical and Mechanical part. The rest of 30% were of the view that Mechatronics Engineers are same in performance as Electrical and Mechanical Engineer. Some even said mechatronics Engineer are not required essentially in their company.

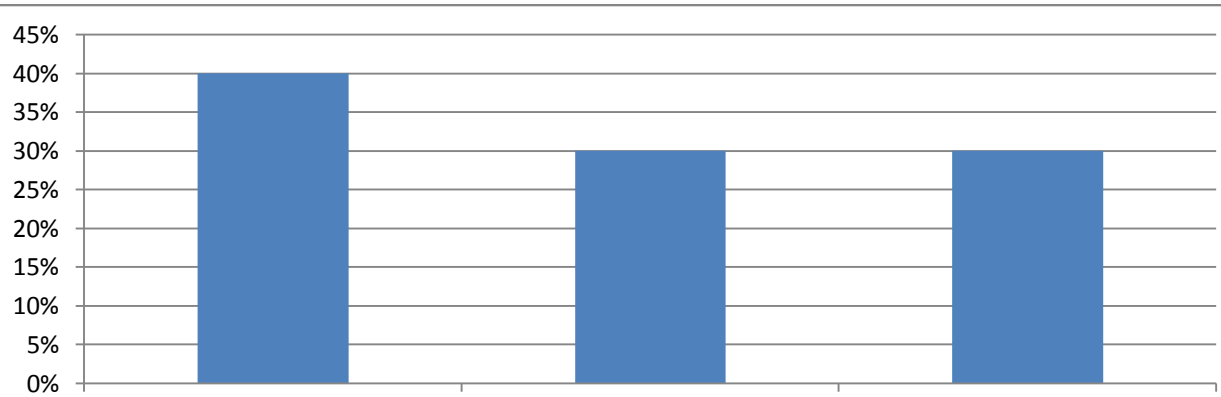

Figure 16. Willingness to Recruit more Mechatronics Engineer in Future

Figure 16 shows the result of willingness of companies to recruit more Mechatronics Engineers in future. The results depict a mixed response. 40 % of the industries showed willingness to recruit more Mechatronics Engineers because of their better performance. 30% said they do not need Mechatronics Engineers in their companies while 30% of the companies were not sure of recruiting more Mechatronics Engineers in future.

Figure 17 shows the graphical results of the question: "Do the technicians at the company have Mechatronics training or background?"

The results show that 90% the companies do not have technicians that have mechatronics background 90% of them said their technicians and engineers require Mechatronics training to make them capable in the industrial working environment. This result is shown in Figure 18.

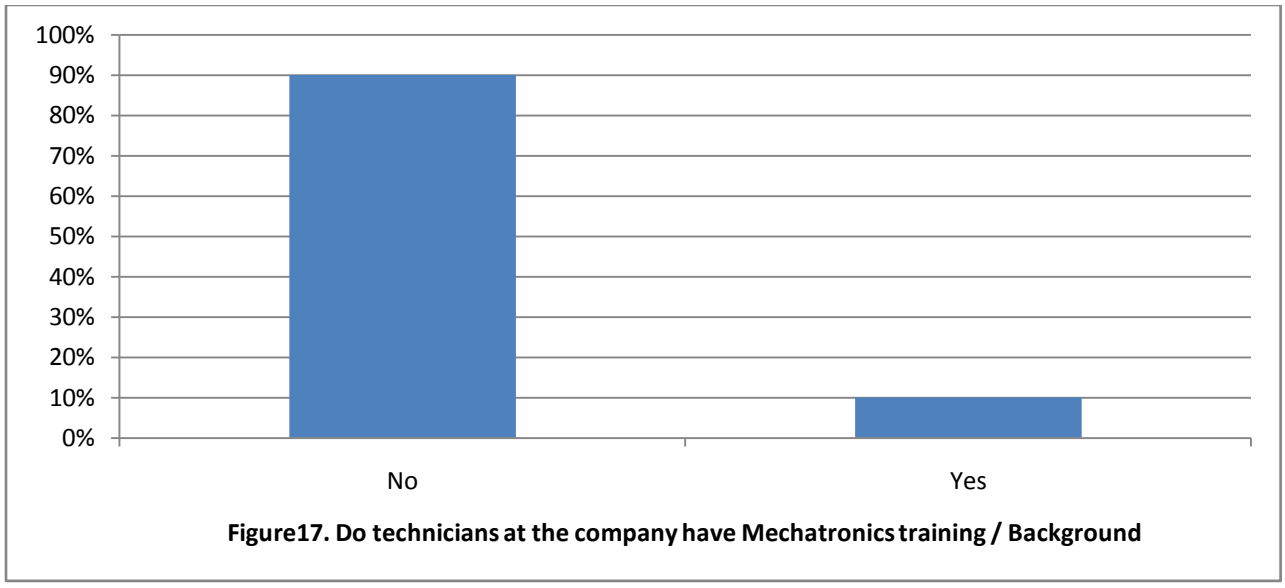

Figure17. Do technicians at the company have Mechatronics training / Background

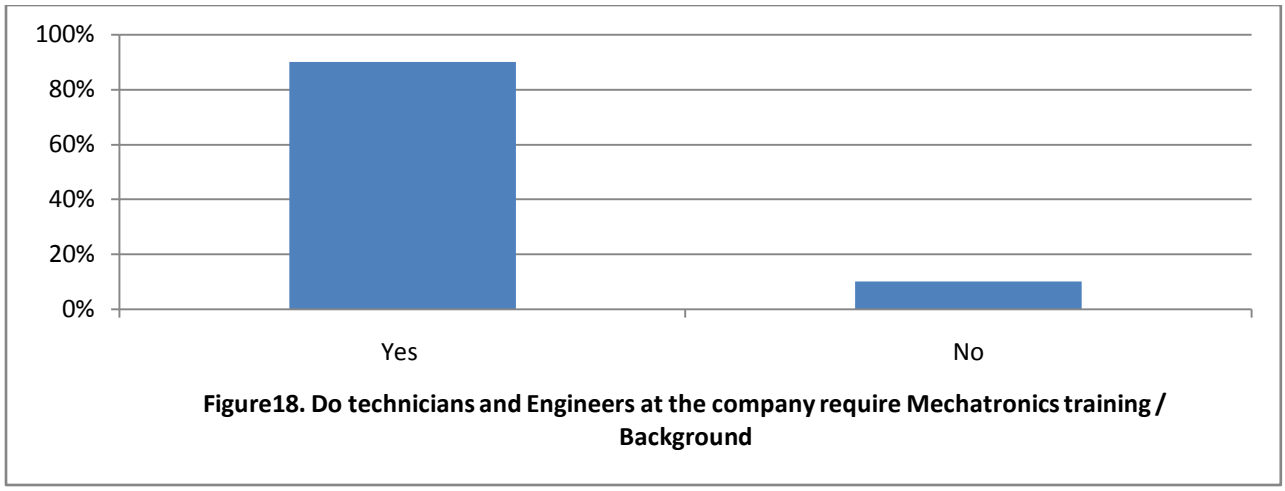

Figure18. Do technicians and Engineers at the company require Mechatronics training / Background

The participating companies themselves realized that their technicians and engineers need to develop mechatronics and automation skill to perform better yet most of them are reluctant to hire Mechatronics Engineers and advertise jobs by the title of Mechatronics Engineer. Rather they prefer to hire Electrical or Mechanical Engineers and afterwards train them with mechatronics skills.

So, awareness must be created in industries to hire more and more Mechatronics Engineers as they are more capable of performing the tasks that are of importance in industries.

6.3 Summary of the Survey

The results of the survey are being summarized as follows:

- R & D department of the industries need to be developed and improved.
- Very less Mechatronics engineers are being hired in the industries.
- No job title of 'Mechatronics Engineer' exists.
- Mechatronics Engineers are hired for job titles of 'Automation Engineer' or 'Electrical Engineer'.
- By doing survey we came to know people in industry with Electrical, Electronics or Mechanical background do not have complete knowledge of Mechatronics.

- Most of the industries are not willing to hire female Mechatronics Engineers.
- Most of the industries said that Mechatronics Engineers are better in performance than Electrical and Mechanical Engineers.
- Technicians at the industries do not have former training of Mechatronics
- Technicians and Engineers have to get Mechatronics training to work in the industrial environment.

6.4 Reliability Analysis of Mechatronics Industry Survey

In SPSS, Cronbach Alpha is an important concept in the evaluation of assessments and questionnaires. It is mandatory that assessors and researchers should estimate this quantity to add an extent of validity and accuracy to the interpretation of their data. Alpha was developed to provide a measure of the internal consistency of a test or scale; it is expressed as a number between 0 and 1. Internal consistency describes the extent to which all the items in a test measure the same concept or construct and hence it is connected to the inter-relatedness of the items within the test. Internal consistency should be determined before a test can be employed for research or examination purposes to ensure validity. In addition, reliability estimates show the amount of measurement error in a test. Put simply, this interpretation of reliability is the correlation of test with itself. As the estimate of reliability increases, the fraction of a test score that is attributable to error will decrease. If the items in a test are correlated to each other, the value of alpha is increased. to increase alpha, more related items testing the same concept should be added to the test [2].

There are different reports about the acceptable values of alpha, ranging from 0.70 to 0.95. If a low alpha is due to poor correlation between items then some should be revised or discarded. The easiest method to find them is to compute the correlation of each test item with the total score test; items with low correlations (approaching zero) are deleted. If alpha is too high it may suggest that some items are redundant as they are testing the same question but in a different guise. A maximum alpha value of 0.90 has been recommended. High quality tests are important to evaluate the reliability of data supplied in an examination or a research study. Alpha is a

commonly employed index of test reliability. A high value of alpha (> 0.90) may suggest redundancies and show that the test length should be shortened.

Reliability analysis of the data related to mechatronics industry survey compiled in form of graphs is now done using SPSS by computing Cronbach alpha value. The snapshots of the variable view, data view and the resulting outputs computed in SPSS are shown as follows:

A. Variable View

file1.sav [DataSet1] - SPSS Data Editor

File Edit View Data Transform Analyze Graphs Utilities Add-ons Window Help

	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure
1	Q1	Numeric	8	2		{1.00, less t...	None	8	Right	Scale
2	Q2	Numeric	8	2		{1.00, resea...	None	8	Right	Scale
3	Q3	Numeric	8	2		{1.00, yes}...	None	8	Right	Scale
4	Q4	Numeric	8	2		{1.00, mech...	None	8	Right	Scale
5	Q5	Numeric	8	2		{1.00, adeq...	None	8	Right	Scale
6	Q6	Numeric	8	2		{1.00, yes}...	None	8	Right	Scale
7	Q7	Numeric	8	2		{1.00, less t...	None	8	Right	Scale
8	Q8	Numeric	8	2		{1.00, Yes}...	None	8	Right	Scale
9	Q9	Numeric	8	2		{1.00, better...	None	8	Right	Scale
10	Q10	Numeric	8	2		{1.00, better...	None	8	Right	Scale
11	Q11	Numeric	8	2		{1.00, better...	None	8	Right	Scale
12	Q12	Numeric	8	2		{1.00, yes}...	None	8	Right	Scale
13	Q13	Numeric	8	2		{1.00, Yes}...	None	8	Right	Scale
14	Q14	Numeric	8	2		{1.00, Yes}...	None	8	Right	Scale
15										

B. Data View

file1.sav [DataSet1] - SPSS Data Editor

File Edit View Data Transform Analyze Graphs Utilities Add-ons Window Help

1 : Q1 | 1

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
1	1.00	1.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	3.00	5.00	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	1.00
3	3.00	2.00	1.00	5.00	1.00	2.00	1.00	2.00	1.00	1.00	1.00	1.00	2.00	1.00
4	3.00	2.00	2.00	4.00	1.00	2.00	1.00	2.00	1.00	1.00	1.00	1.00	2.00	1.00
5	3.00	3.00	2.00	4.00	1.00	2.00	1.00	2.00	1.00	2.00	1.00	2.00	2.00	1.00
6	3.00	3.00	2.00	1.00	2.00	2.00	3.00	2.00	1.00	2.00	1.00	2.00	2.00	1.00
7	3.00	4.00	2.00	8.00	2.00	2.00	3.00	2.00	1.00	2.00	1.00	2.00	2.00	1.00
8	3.00	4.00	2.00	8.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	3.00	2.00	1.00
9	3.00	6.00	2.00	9.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	3.00	2.00	1.00
10	3.00	6.00	2.00	9.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00
11														

C. Output and Result Summary

```
RELIABILITY
  /VARIABLES=Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE
  /SUMMARY=TOTAL.
```

Reliability

[DataSet0]

Scale: ALL

Case Processing Summary

		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

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

Reliability Statistics

Cronbach's Alpha	N of Items
.849	14

Inter-Item Correlation Matrix

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
Q1	1.000	.533	.509	.107	.299	.667	.299	.667	.218	.408	.167	.361	1.000	.111
Q2	.533	1.000	.376	.650	.772	.185	.378	.185	.698	.553	.739	.711	.533	.492
Q3	.509	.376	1.000	.211	.587	.764	.587	.764	.429	.802	.327	.709	.509	.218
Q4	.107	.650	.211	1.000	.640	.161	.175	.161	.756	.345	.645	.621	.107	.430
Q5	.299	.772	.587	.640	1.000	.448	.672	.448	.810	.732	.832	.879	.299	.555
Q6	.667	.185	.764	.161	.448	1.000	.448	1.000	.327	.612	.250	.542	.667	.167
Q7	.299	.378	.587	.175	.672	.448	1.000	.448	.251	.732	.192	.570	.299	.128
Q8	.667	.185	.764	.161	.448	1.000	.448	1.000	.327	.612	.250	.542	.667	.167
Q9	.218	.698	.429	.756	.810	.327	.251	.327	1.000	.535	.764	.867	.218	.509
Q10	.408	.553	.802	.345	.732	.612	.732	.612	.535	1.000	.408	.885	.408	.272
Q11	.167	.739	.327	.645	.832	.250	.192	.250	.764	.408	1.000	.662	.167	.667
Q12	.361	.711	.709	.621	.879	.542	.570	.542	.867	.885	.662	1.000	.361	.441
Q13	1.000	.533	.509	.107	.299	.667	.299	.667	.218	.408	.167	.361	1.000	.111
Q14	.111	.492	.218	.430	.555	.167	.128	.167	.509	.272	.667	.441	.111	1.000

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Q1	27.1000	60.100	.458	.	.842
Q2	26.3000	44.233	.782	.	.818
Q3	28.2000	60.178	.611	.	.840
Q4	24.1000	39.211	.578	.	.892
Q5	28.2000	53.511	.897	.	.818
Q6	28.1000	61.433	.511	.	.844
Q7	28.2000	58.178	.488	.	.840
Q8	28.1000	61.433	.511	.	.844
Q9	28.6000	58.711	.817	.	.834
Q10	28.3000	58.900	.735	.	.835
Q11	28.7000	60.011	.735	.	.838
Q12	28.0000	52.889	.890	.	.817
Q13	28.0000	62.444	.489	.	.846
Q14	28.8000	62.400	.498	.	.846

After doing statistical analysis, we have got Cronbach alpha value as 0.849. From this high value we conclude that the survey data is valid and accurate and the results are reliable.

References

[1] http://www.pakistanpaedia.com/maps/maps-of-pakistan.html

[2] Tavakol M, Mohagheghi MA, Dennick R. Making sense of Cronbach alpha, International Journal of Medical Education. 2011; 2:53-55

CHAPTER 7

MECHATRONICS IN SOCIETY OF PAKISTAN

7.0 Mechatronics in Society of Pakistan

A survey was carried out in society to know where Mechatronics stands in our society. To know how many people actually know what mechatronics is. The survey participants were some Engineering institutes teaching faculty members and the freshly inducted engineering students (other than mechatronics students) and their families. The survey questions are given in the Appendix D.

These survey participants were chosen intentionally to know whether they had knowledge of Mechatronics engineering or not. To know the reasons why they opted engineering field other than Mechatronics, did they opt other engineering field by choice in spite of having complete knowledge of Mechatronics or they did not know about Mechatronics.

Figure 18 shows the percentage of family occupation of the participants of survey.

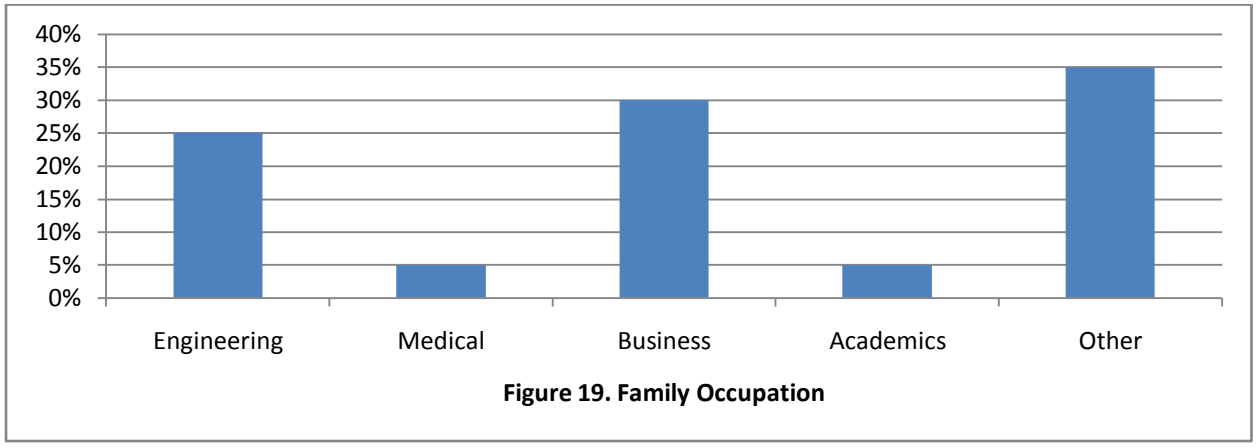

Figure 19. Family Occupation

25% of the participants had Engineering, 5% had Medical, 30% had business as their family occupation. 5% of the participants belonged to families having Academic background and 35% of the participants belonged to families having other occupation or more than one occupation.

In the survey, participants were asked to tell if they have any family member as Engineer. Figure 19 shows the results. 55% participants have Engineers in their family while 45% said thay they don't have a single family member as an Engineer.

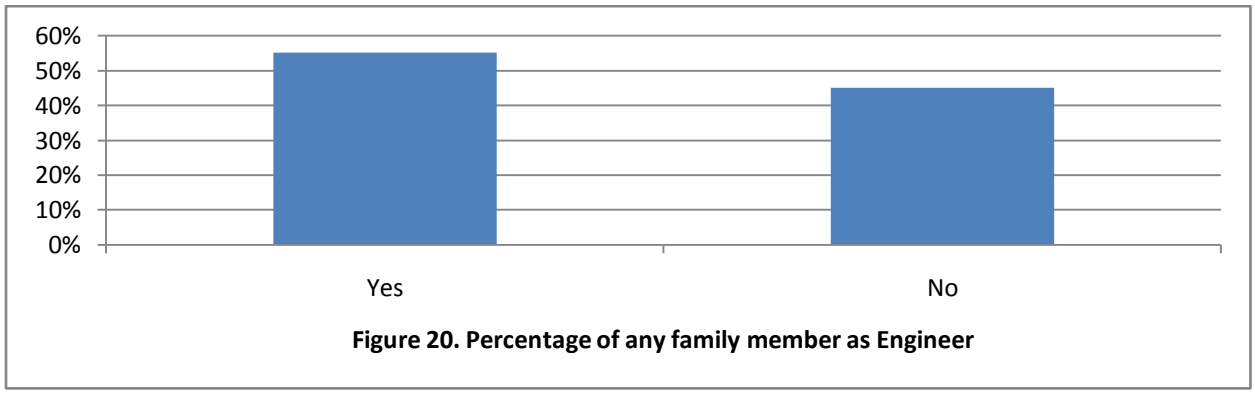

Figure 20. Percentage of any family member as Engineer

The survey comprised of a question to know whether the participants have ever heard about Mechatronics. The result is shown in Figure 20.

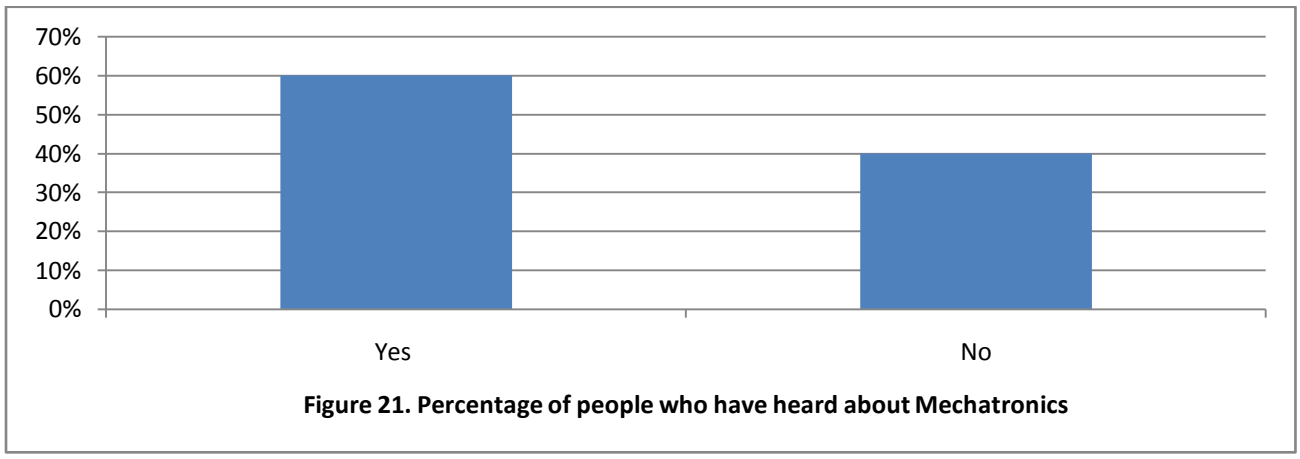

Figure 21. Percentage of people who have heard about Mechatronics

60% of the participants claimed that they have heard about Mechatronics Engineering while 40% replied that they have not even heard about Mechatronics Engineering. This means in our

society, still people are not aware of Mechatronics Engineering to such an extent that they have not ever heard about it.

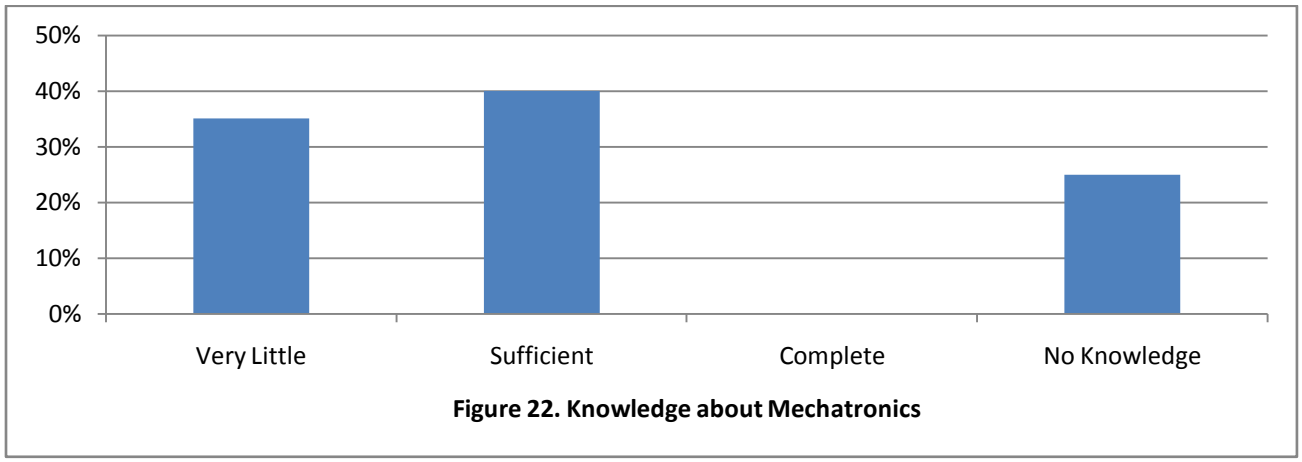

Figure 22. Knowledge about Mechatronics

In order to know the level of the knowledge that the participants had about Mechatronics, we asked about the level of their knowledge related to Mechatronics. The result is shown in Figure 21.

35% of the participants had very little about Mechatronics, 40% of them said they had sufficient knowledge, 25 % said they had no knowledge of Mechatronics. No one said that they had complete knowledge about Mechatronics.

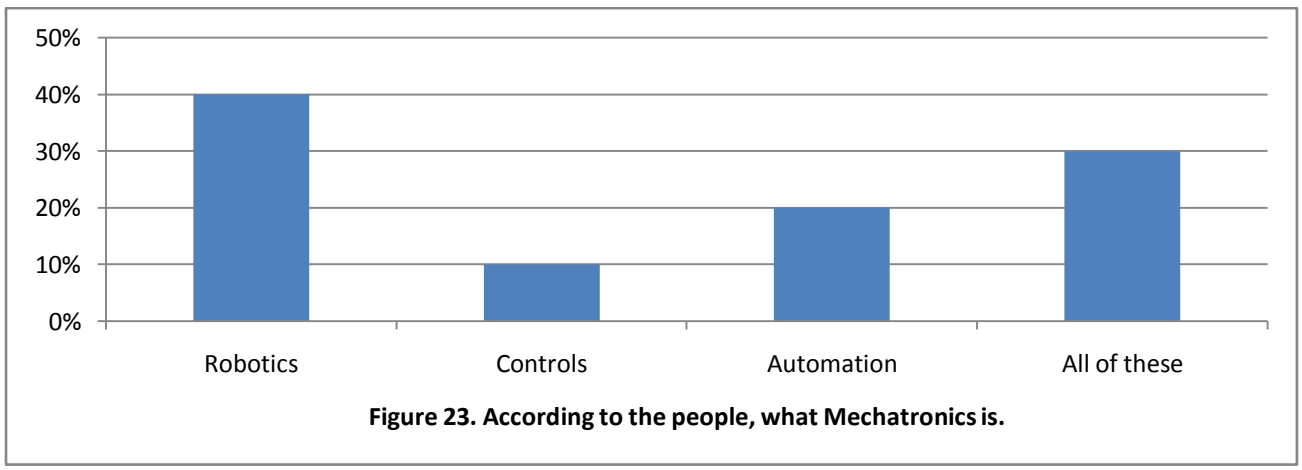

Figure 23. According to the people, what Mechatronics is.

Figure 22 shows the results of the question asked from the participants: According to their knowledge what mechatronics is.

40% of them were of the view that Mechatronics is related only to Robotics, 10% said is all they know about mechatronics is that it is related to controls. 20% claimed that Mechatronics is related to automation and 30% said Mechatronics is related to all of these three areas.

The participants were asked if they can tell how many universities in Pakistan are offering Mechatronics Engineering. The correct answer was 7. Only 35% of them knew the correct answer. 10% said the number is 15, 35% said it is 3 in number and 20% said that there are 5 universities in Pakistan that are offering Mechatronics Engineering. The result is shown in Figure 23 as follows :

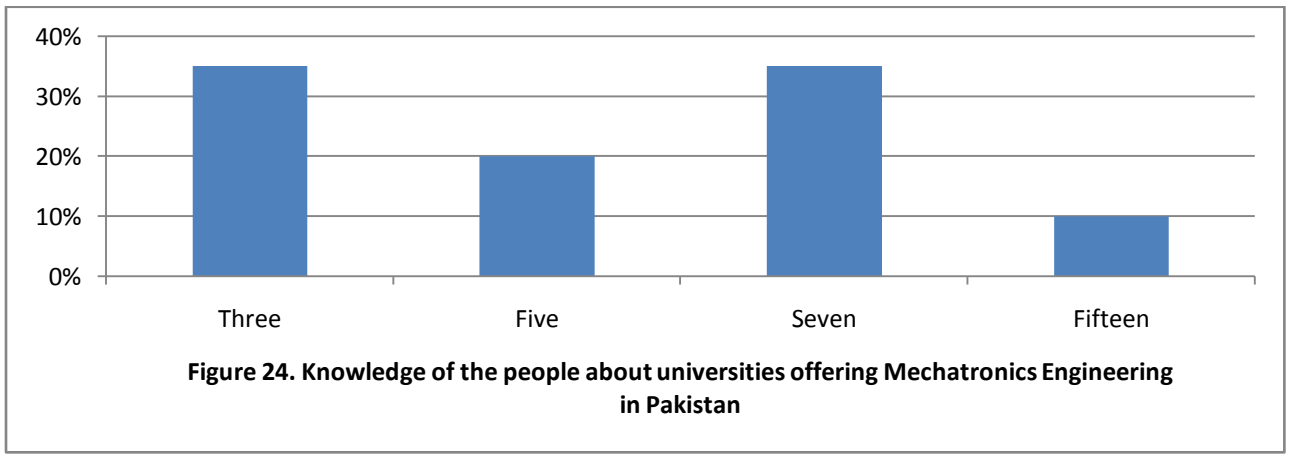

Figure 24. Knowledge of the people about universities offering Mechatronics Engineering in Pakistan

In the survey, the participants were asked to give any two names of the universities that are offering degree in Mechatronics Engineering. 80% of the participants were able to give two names while 20% did not know any name of the university in this regard.

Also, a question was asked from participants if they knew in which industries Mechatronics Engineers are in demand. Almost 80% of them were able to correctly answer the question and gave almost 2 names of the industries in which Mechatronics Engineers are in demand. 20% of the participants did not know the names of the industries where Mechatronics Engineers are in demand.

CHAPTER 8

MECHATRONICS: NEW DIRECTIONS AND ENGINEERING CURRICULUM DEVELOPMENT

8.0 Introduction

Modern engineering encloses a wide range of multidisciplinary areas. Therefore, there is a crucial need for the identification of new directions in engineering education and research for addressing, pursuing, and implementation of new meaningful research initiatives and open up new areas of thought to design the engineering curriculum. By integration of variety of disciplines, mechatronics provides multidisciplinary leadership and also it supports the existing gradual changes in industry and academia. The need is to do advanced research work in mechatronics and a reform of curriculum for undergraduate as well as graduate programs.

The current developments in research and severe and effective technological advancements in power electronics, electromechanical motion devices, solid-state devices, microelectronics, Micro- and Nano-electromechanical systems, packaging, computers, system intelligence, microprocessors, computer-aided-design tools, signal and optical processing, and simulation environments have brought new directions and challenges to the education and academia. As a consequence, many scientists are doing work and research in the area of mechatronics, and engineering institutions have to revise and reform their curriculum to offer the relevant and related courses in mechatronics.

Mechatronic systems are categorized as:

1. Conventional mechatronic systems
2. Microelectromechanical-micromechatronic systems (MEMS)
3. Nanoelectromechanical-nanomechatronic systems (NEMS)

Conventional mechatronic systems and MEMS have the same operating principles and base. Classical mechanics and electro-magnetics are applied to study conventional mechatronic systems and MEMS. Quantum theory and nano-electromechanics are applied for NEMS.

One of the evident weaknesses of the electrical, computer and mechanical engineering curriculum is the difficulty and problem to achieve sufficient knowledge, background, depth, and breadth in integration of electromechanical systems areas for solving complex and difficult

multidisciplinary engineering problems. Mechatronics provides introduction to the subject material, multi-disciplines and disciplines from combined perspectives through the electromechanical theory fundamentals and sequence of mechatronics courses within an electromechanical systems track or program. The course can be designed based upon the objectives, strength, and goals. For different engineering programs, the number of mechatronic courses and their coverage are different because mechatronic courses complement the basic curriculum.

However, the ultimate goal is the same:
To educate and prepare a new generation of students and engineers for solving a wide range of engineering problems.

Mechatronics is an essential part of modern engineering. The multidisciplinary mechatronic research and academic activities, unified with a variety of student learning processes and synergetic teaching methods, will help in producing a level of overall student completion that is more than the achievements which can be produced by reforming the conventional electrical, computer, and mechanical engineering curriculum. The multidisciplinary mechatronic model of thought serves very important role because it brings new depth to engineering areas, help in advancement of students' knowledge and background, and make students capable of solving problems that are helpful and needed to handle and cope with advanced electromechanical systems that are being controlled by microprocessors or DSPs, emphasizes and applies modern software environments. With the help of mechatronic curriculum, important objectives and goals can be achieved easily.

The ultimate goal is to identify the role of mechatronics curriculum, to examine the already existing courses, reform and enhance mechatronic curriculum for improvement of the structure and content of engineering programs, to recruit and motivate students, to increase teaching effectiveness.

8.1 Nano-, Micro-, and Mini-Scale Electromechanical Systems and Mechatronic Curriculum

Conventional, mini- and micro-level electromechanical systems are studied from a combined perspective because of the basic phenomena, operating features and dominant effects that are based upon classical electro-mechanics. Electric machines, sensors, power electronics, microcontrollers, and DSPs should be designed, emphasized, analyzed and optimized but the focus is centered on integrated issues.

The designer often faces failure in getting hold and understanding the global view because it requires the extensive experience, background, knowledge, and capabilities for attaining detailed assessment analysis with outcome prediction and overall performance evaluation. The component-based approach is quite valuable and is applicable in the initial design phase, it is very essential that the design and analysis of integrated electromechanical systems must be completed and accomplished with proper objectives, requirements, specifications and bounds imposed.

The main focus and objective of the mechatronic curriculum development is to work for satisfaction of academia, industry and government needs and demands and to help students in developing in-depth the basic concepts, analytic and experimental skills, design, optimization, control, and proper implementation of advanced integrated electromechanical systems. It is impossible to cover the complete spectrum of mechatronics issues in a single course. Therefore, the mechatronic curriculum must be developed assuming that students already have sufficient fundamentals in calculus, physics, circuits, electromechanical devices, sensors, and controls.

The engineering curriculum usually has integration of science, general education and engineering courses. The incorporation of multidisciplinary engineering science and engineering design courses is a representation of a major departure from the conventional curriculum. Even electrical engineering students have some weaknesses and deficiencies in advanced electro-magnetics, electric machinery, power electronics, ICs, microcontrollers, and DSPs because many of these courses are elective. Mechanical engineering students advancing electrical engineering

students in the fields of mechanics and thermodynamics, have deficiencies and limited access to electro-magnetics, electric machines, power electronics, microelectronics, and DSP courses.

In addition, there are weaknesses and deficiencies in computer science and engineering mathematics courses for both of the electrical and mechanical engineering students because these courses are oftenly required and taught to only computer engineering students. The need for engineering mathematics, electro-magnetics, power electronics, and electromechanical motion devices has not diminished and cannot be neglected, rather it is strengthened more. Also new advanced hardware has been developed using fabrication technologies for the fabrication of nano - and micro-scale sensors, actuators, ICs, and antennas.

Efficient software has been emerged. To overcome the problems and difficulties that are being encountered, the mechatronic courses which cover the multidisciplinary areas need to be developed and introduced to the engineering curriculum. Mechatronics has been enthusiastically explored and supported by undergraduate and graduate, academic and research oriented universities, high-tech industry and laboratories. However, there is a need to develop the long-term plan and strategy in mechatronic education and research and defining the role to implement, commercialize, and market the mechatronic and electro-mechanics program.

In order to acquire and expand the engineering core, there is the need to combine interdisciplinary areas and to relate and integrate the actuators, sensors, power electronics, ICs and DSPs for attaining the required performance. The engineering practice of high performance electromechanical systems should be taken as the combined strength of the engineering curriculum through mechatronics. The combined analysis of the actuators and sensors, power electronics, ICs, DSPs and advanced hardware and software have hardly been introduced into the engineering curriculum. Mechatronics, as the concept of sudden success in the design and analysis of conventional-, mini-, micro- and nano-scale electromechanical systems, was introduced for coping, integrating and solving a wide range of emerging problems.

8.2 Systems Synthesis, Mechatronics Software and Simulation

The complementary activities performed in the design of mechatronic systems are modeling, simulation and synthesis. Simulation initiates with the development of model, while synthesis with the specifications imposed on the behavior and analysis of the system performance. This is done by help of analysis using modeling, then simulation and experimental results. The designer studies, analyzes and evaluates the mechatronic system by using state, performance, control and other variables. As a flexible and high-performance modeling and design environment, MATLAB has become an efficient standard, cost-effective tool.

The MATLAB environment is used in order to increase the speed of analysis and design with assessment analysis that facilitate various gains in terms of productivity and creativity and integrate control and signal processing by using advanced microprocessors and accelerate features by generating real-time C code and get the results visualized and perform data acquisition and analysis.

The following commonly used toolboxes can be applied in MATLAB:
SIMULINK, Real-Time Workshop™, Control System, Signal Processing, Nonlinear Control Design, Symbolic Math, Optimization, Robust Control, System Identification, Neural Networks, Partial Differential Equations as well as other application-specific toolboxes.

In order to increase student's productivity and creativity MATLAB capabilities should be demonstrated by coping important practical examples by demonstrating the use of the advanced software in electromechanical system applications. The MATLAB provides an efficient and rich set of capabilities for solving a wide range of complex problems that are encountered in undergraduate and graduate mechatronic courses. A variety of mechatronic systems can be modeled, simulated, analyzed, and optimized using MATLAB. The examples of electromechanical systems that are integrated within mechatronic courses, will assist in the practice and help to educate students with the high degree of comprehensiveness.

8.3 Mechatronic Curriculum

The main focus and objective of the mechatronic curriculum is to educate a new generation of students and engineers and to assist industry and government for the development of high-performance electromechanical systems enhancing and combining the conventional engineering curriculum with an expanding electro-mechanics core.

The emphasis is laid on advancement and development of the overall mission of the engineering curriculum because it is possible to further define, reform and expand the objectives into three fundamental and basic areas through mechatronics. These areas are:

- Research
- Education
- Service

Using the mechatronic paradigm, academia will perform world-class high level fundamental and applied research by:

- Integration of electro-mechanics, electro-magnetics, power electronics and control
- Development of specialized and efficient computer-aided-design software
- Devising the advanced concepts, paradigms, and technologies
- Devising the advanced design, analyzing and optimizing, simulating and analytizing tools
- Supporting research and cooperative multidisciplinary education programs for undergraduate and graduate students
- Development of actuation, sensing and control hardware
- Supporting and assisting faculty in emerging new areas.

The design of Mechatronic curriculum comprises of the development of goals set and objectives defined. It also includes programs of study and curriculum guides, educational courses, laboratories, instructional materials, textbooks, experiments, manuals, material delivery techniques, visualization, demonstration approaches and other helping materials to attain a

variety of educational and research goals. Students can provide their contribution. Because there is an ever increase in the number of students who have good programming knowledge and skills and have theoretical background but have complete inability in solving simple engineering problems.

The basic goal of mechatronic courses is to work for the demonstration of the application of applied, theoretical, and experimental results in analyzing, designing and deployment of complex electromechanical systems that includes MEMS and NEMS. The main objectives are:

- To cover latest and emerging hardware and software.
- To introduce the theory and concept of electro-mechanics.
- To help students in developing strong problem-solving skills.
- To provide the required engineering practice to the students.

The intention of the courses included in mechatronics is to develop a thorough understanding of combined and integrated perspectives in analyzing, simulation, modeling, optimization, designing and implementing complicated electromechanical systems.

With the help of practical examples, students will be trained and prepared for using the results in the engineering practice, research and development. Advanced hardware and software of engineering importance must be covered in detail from multidisciplinary integrated perspectives.

The following undergraduate courses are included in the Electrical Engineering plan of study in most of the universities:

- Linear Circuit Analysis I and II,
- Electric and Magnetic Fields,
- Signals and Systems,
- Microprocessor Systems and Interface
- Semiconductor Devices
- Feedback Systems Analysis and Design

The following elective courses assist the mechatronics area:

- Electromechanical Motion Devices,
- Digital Signal Processing
- Computer Architecture

In addition to these Electrical and Computer Engineering courses, there is a critical requirement to teach the courses in mechatronics. The mechatronic curriculum should lay emphasis in augmenting traditional engineering topics and the latest trends, technologies and developments for integrating and stimulating new advancements in analyzing and designing advanced state-of-the-art mechatronic systems.

People argue that mechatronics curriculum has no uniqueness in it, rather it contain courses of Electrical, Mechanical and Computer Engineering. So, the need is to reform the Mechatronics curriculum to create its unique identification and place in academia. In order to achieve this goal, the following courses should be developed and offered in mechatronics curriculum:

- ***Mechatronic Systems***
- ***Smart Structures***
- ***Micro-mechatronics* (*Micro-electromechanical Systems*)**
- ***Nano-mechatronics* (*Nano-electromechanical Systems*)**

The chief goal of introducing these courses is to ensure a deep understanding of the field and integrate engineering, science and technology, and developing the modern picture of electro-mechanical engineering by using the fundamentals and basics of mechatronics. It is recognized and realized by industry, academia and government that the most important and urgent areas of modern engineering and mechatronics that need development are MEMS and NEMS. [2] Therefore, rapid and current developments should be focused in performing fundamental, applied and experimental research in these emerging fields of mechatronics.[1]

The four mentioned courses are developed to bridge the gap between engineering, science and technology by bonding multi-disciplinary developments, by focusing on state-of-the-art

hardware and focusing on high-performance software. These courses when developed will dramatically cause reduction in the time students require to acquire basic skills for high-technology employability. The main objective of this course is two-fold:

- To bring developments of modern electro-mechanics
- To integrate an interaction based and studio-based methodology of instruction and delivery

Keeping in view the importance of the above mentioned needs, following nine sub-courses should be developed and introduced related to the four mentioned courses in mechatronics curriculum and program. These are:

- ***Introduction to the electromechanical systems and mechatronics***
- ***Energy conversion***
- ***Dynamics of mechatronic system***
- ***Transducers and smart structures: actuators and sensors***
- ***Micro-mechatronics (Micro-electromechanical Systems)***
- ***Nano-mechatronics (Nano -electromechanical Systems)***
- ***Motion control of the electromechanical systems and smart structures***
- ***Microprocessors and DSPs in control and data acquisition of mechatronic systems***
- ***Mechatronic systems: case-studies, modeling, analysis, control, and laboratory experiments.***

8.4 Books in Mechatronics

The demand for books in mechatronics has exceeded very rapidly by academia and industry more than expectation [3]. Examples in analyzing and designing of linear electromechanical systems are easily available from control systems books. *Control Systems Theory With Engineering Applications* shown in Figure 18, contains a number of educational and illustrative examples in areas like modeling, simulation, and control of complex non-linear

electromechanical systems [4]. Particularly the analysis and control of nonlinear transducers, squirrel-cage induction motors, permanent-magnet DC and synchronous motors, power converters and servomechanisms are covered thoroughly.

Using the mechatronic paradigm, comprehensive treatment of nonlinear electromechanical systems is quite evident. Excellent books related to conventional electromechanical motion devices and many textbooks of mechatronics have been used in Electrical and Mechanical Engineering departments. There is a still room for more books and critical need for modern books in mechatronics that are comprehensive in their coverage and are global in their perspective for all engineering departments. Now the need is to target new areas using the developed engineering enterprise, new and emerging technologies, advanced hardware and state-of-the-art software. The book *Nano- and Micro-Electromechanical Systems: Fundamentals of Nano- and Micro-Engineering* can be used effectively for NEMS and MEMS. The book [5 – 9] was written by taking advantage of the modern engineering curriculum, shown in Figure 19. The basic theory of electro-mechanics, new technologies, fundamental engineering principles, system integration, modeling, analysis, simulation, control and spectrum of emerging engineering problems, were comprehensively covered in this book. In these books a variety of demonstrations and examples of electromechanical systems are covered.

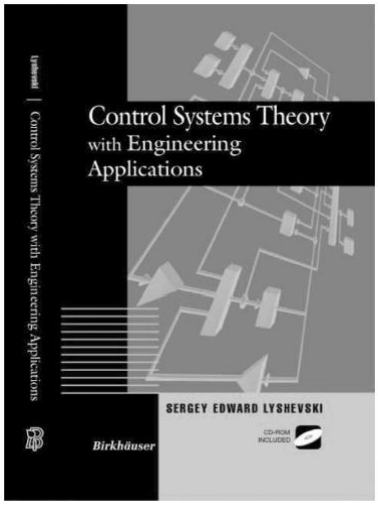

Figure 25. Control book with coverage in analysis and control of electromechanical systems. http://www.birkhauser.com/cgi-win/ISBN/0-8176-4203-X.

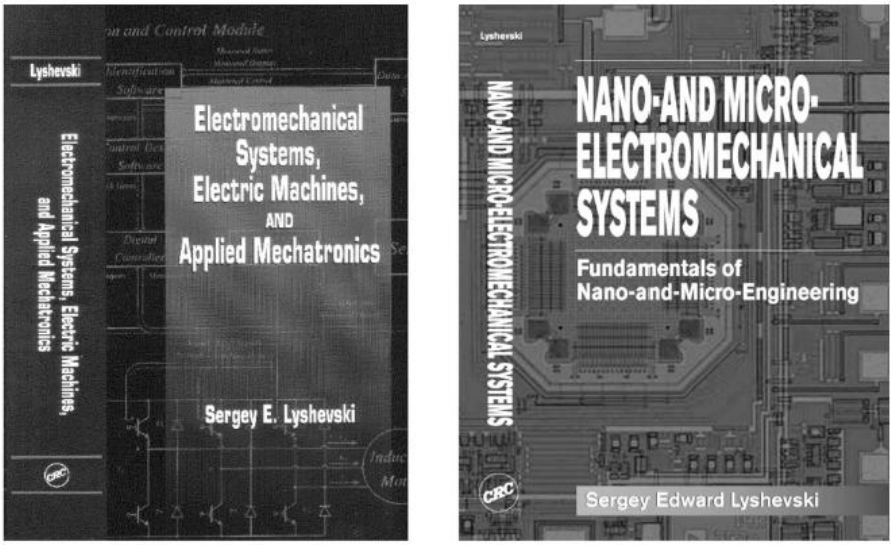

Figure 26. Books for Electro-Mechanical Systems , MEMS and NEMS

8.5 Mechatronics Curriculum Developments – The Strategy

The existing mechatronic curriculum needs much attention and leaves much to be desired. The following strategy can be modified and further expanded and should be pursued by academia to integrate and develop the mechatronic courses in the undergraduate and graduate curricula:

- Commercialize as well as market the mechatronic program.
- Work for the expansion of the mechatronic curriculum to conventional and mini-scale mechatronic systems as well as to MEMS and NEMS which are new, important and emerging areas in engineering worldwide
- The engineering curriculum needs revision. Particularly the Electromechanical Motion Devices, Electro-magnetics, Power Electronics, Microelectronics, Control and DSP courses should be offered as the core courses and as necessary pre-requisites for advanced courses in mechatronics
- Demanding, progressive, well-balanced mechatronic curriculum and mechatronic courses should be developed with laboratories

- Complex electromechanical systems and case studies should be covered in the undergraduate mechatronic courses and highly specialized topics of this area should be relocated to the graduate program
- Mechatronics should be extended to the undergraduate senior design projects
- Computer-aided-design tools and advanced high-performance simulation software should be integrated fully
- Comprehensive books, textbooks and handbooks in mechatronics should be written and published

The following courses should be offered and developed in the Mechatronics curriculum:

- ***Introduction to Mechatronics***
- ***Electromechanical Motion Devices***
- ***Control of Mechatronic Systems***
- ***Smart Structures***
- ***Electromechanical Systems***
- ***Micro-electromechanical Systems***
- ***Nano-electromechanical Systems***

8.6 Mechatronics Perspectives

The fundamental and technological advancements in electromechanical motion devices, solid-state devices, power electronics, ICs, MEMS and NEMS, computers, informatics, microprocessors and DSPs, materials and packaging , digital signal processing and optical processing, CAD tools and simulation software, have created competition and brought new challenges to academia, industry and government. As a consequence, many engineering institutions worldwide have to revise their engineering curricula in order to cope up with this new trend and have to offer the relevant courses such as Electro-mechanical Systems and Mechatronics.

Due to the absence of a long-term strategy the attempts to introduce mechatronics have been only partially successful. Most engineering curriculum provides only one elective course to introduce mechatronics briefly to electrical, computer, mechanical and aerospace engineering students. It is impossible to comprehensively cover the whole material and emphasize thoroughly the cross-disciplinary nature of mechatronics in one introductory course, due to the lack of time. As a consequence, this undergraduate or dual level course is insufficient and might not serve adequately the students' professional needs and goals and does not satisfy growing demands of academia, industrial and government.

References

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CHAPTER 9

FUTURE DEVELOPMENT TREND OF MECHATRONICS ENGINEERING IN PAKISTAN

9.0 Future Development Trend of Mechatronics Engineering in Pakistan

A survey was conducted in order to see the vision of the people of society about future development trend of Mechatronics Engineering in Pakistan. The people rated different parameters depending upon the effect of those parameters on the future development of Mechatronics in Pakistan. The survey form is available in the Appendix E and the survey results are being compiled in form of a bar chart as shown in the Figure 27. The participants of the survey were from Engineering faculty.

The bar chart of Figure 27 uses estimation approach. The data compiled is for the survey results taken in 2012 – 2013. Figure 27 shows the results that are valid only in case of Engineering Faculty. Similarly one can conduct a survey in different sectors of the society and make a model for each sector to observe the trend of development of Mechatronics. If this type of survey is conducted after every six months or a span of one year, we can observe a clear trend line for the development trend of Mechatronics and can make a mathematical model out of it easily. This is pictorially explained in figure 28.

The mathematical formula for the probability estimation of the parameters shown in Figure 27 is derived as :

$$\mathbf{Y(X) = P(SA^X)\, W_1 + P(A^X)\, W_2 + P(D^X)\, W_3 + P(SD^X)\, W_3}$$

Where

X = Parameters Affecting the development of Mechatronics

Y(X) = Estimation of Affect of X on Future Development of Mechatronics

SA= Strongly Agree, A= Agree, D= Disagree, SD= Dis-Agree

$P(SA^X)$, $P(A^X)$, $P(D^X)$, $P(SD^X)$ are the probabilities of SA, A, D, SD for a given parameter X

W_1, W_2, W_3, W_4 are the weightage given to Probabilities of SA, A, D, SD respectively.

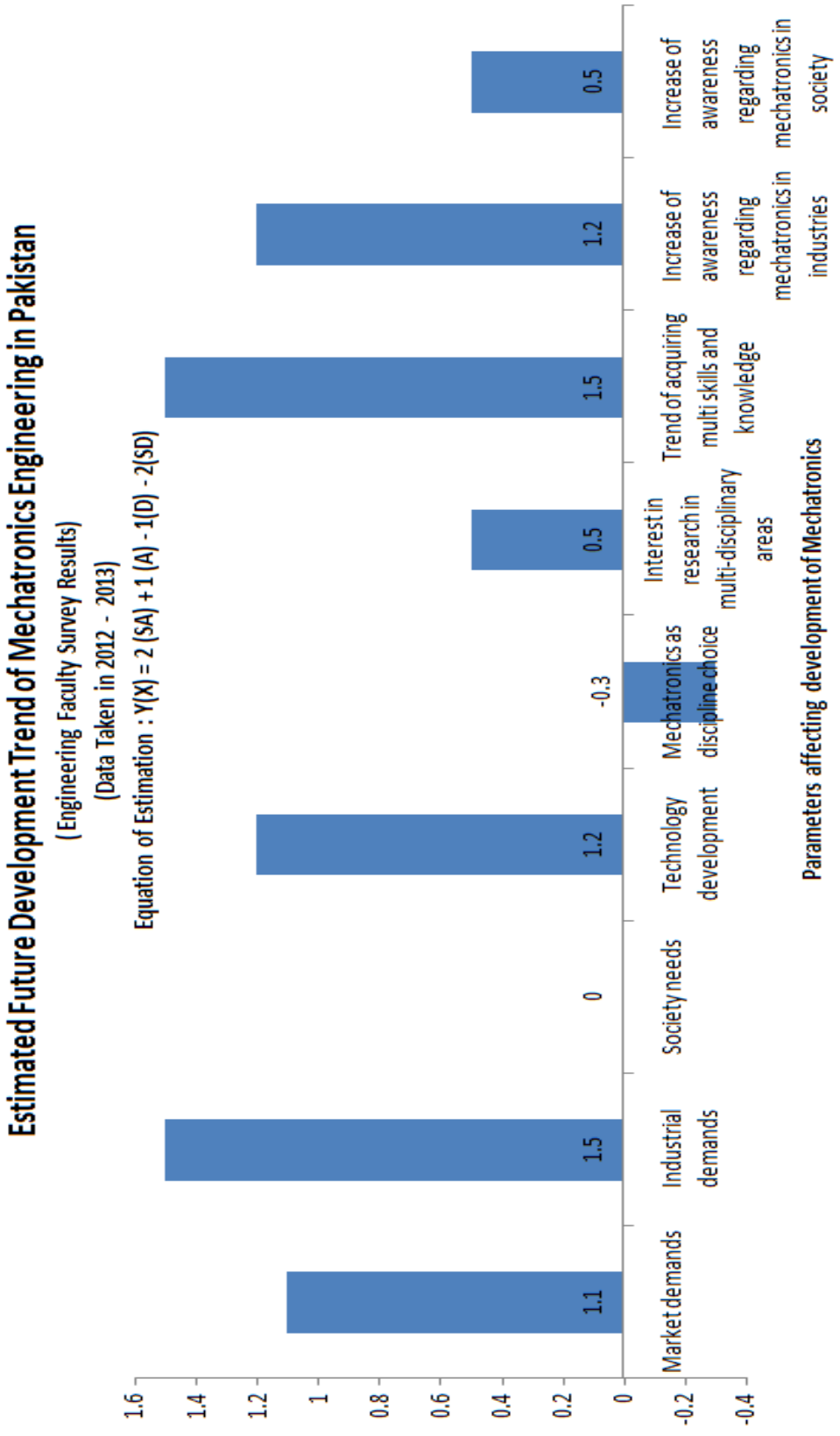

Figure 27. Future Development Trend of Mechatronics in Pakistan

For n number of parameters, the mathematical formula for probability estimation can be written in a matrix form.

$$\begin{pmatrix} Y(X_1) \\ Y(X_2) \\ . \\ . \\ Y(X_n) \end{pmatrix} = \begin{pmatrix} P(SA^{X1}) & P(A^{X1}) & P(D^{X1}) & P(SD^{X1}) \\ P(SA^{X2}) & P(A^{X2}) & P(D^{X2}) & P(SD^{X2}) \\ . & . & . & . \\ . & . & . & . \\ P(SA^{Xn}) & P(A^{Xn}) & P(D^{Xn}) & P(SD^{Xn}) \end{pmatrix} \begin{pmatrix} W_1 \\ W_2 \\ . \\ . \\ W_n \end{pmatrix}$$

Using the average values of the probabilities of the parameters, one can get the estimation of overall trend of Y with respect to time for all parameters collectively using the following estimation formula :

$$Y(t) = Avg(P(SA^X))W_1 + Avg(P(A^X))\ W_2 + Avg(P(D^X))\ W_3 + Avg(P(SD^X))\ W_3$$

Where Avg = Average

If we have the data of previous years, then by using it and conducting surveys in future we can make a mathematical model for future development trend of Mechatronics Engineering in Pakistan. Figure 28 shows the example of such model.

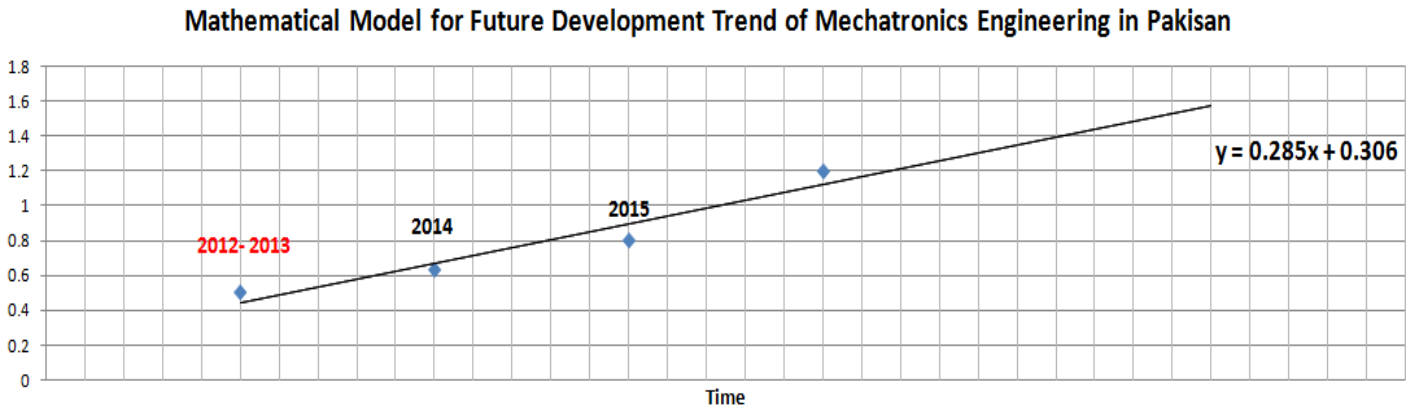

Figure 28. Mathematical Model for Future Development Trend of Mechatronics in Pakistan

9.1 Conclusion and Recommendations

The increase in the importance of mechatronics in the world is due to the power, uniqueness and versatility of mechatronics. This increasing worth of mechatronics urges engineers to think of being getting familiar with the basic theory and engineering practice of mechatronics. Mechatronics is so wide field that there is no end or limit to the application of mechatronics and to the contribution mechatronics is adding to the concept of inter-disciplinary areas. But the mechatronics engineers in Pakistan have to face many problems in seeking appropriate jobs because of the lack of awareness in the industries as well as society of Pakistan regarding mechatronics engineers. It is expected that in the years to come, Mechatronics will gain the status of most important engineering discipline in Pakistan from industrial point of view and mechatronics engineers will be in great demand.

Following recommendations are made on the basis of the research.

- Awareness campaign regarding Mechatronics by arranging seminars and using electronic media should be initiated immediately
- R & D department of the industries should be developed
- Industries should be motivated to sponsor research projects for universities in order to provide the opportunity to the graduate students to work for the benefits of industry as well as society
- A Survey should be conducted every year in order to know the future development trend of Mechatronics and by using previous and present data Mathematical Model for Mechatronics can be made easily

Appendix A: List of Universities offering Computer Engineering in Pakistan

Bahria University, Islamabad (Main Campus)

- Bachelor of Computer Engineering (From Intake of Batch Fall-2001 upto 2008).
- Bachelor of Software Engineering (Upto Intake of Batch 2008).

COMSATS Institute of Information Technology, Islamabad (Main Campus)

- B.Sc. Computer Engineering (From Intake of Batch 1999 upto Fall-2008).

COMSATS Institute of Information Technology Islamabad (Lahore Campus)

- Bachelor of Science in Computer Engineering (From Intake of Batch Spring-2002 Upto Fall-2008).

COMSATS Institute of Information Technology, Islamabad (Wah Campus)

- B.Sc. Computer Engineering (From Intake of Batch Fall-2001 upto Fall-2008).

College of Electrical And Mechanical Engineering, Rawalpindi Campus (NUST Islamabad)

- B.E. Computer (From Intake of Batch 1996 to 2008).

National University of Computer & Emerging Sciences, Islamabad (Lahore Campus)

- Bachelor of Science (B.S) in Computer Engineering (From Intake of Batch Fall-2003 upto 2008).

NFC Institute of Engineering and Technological Training, Multan (Bahauddin Zakariya University Multan)

- B.Sc. Computer Systems Engineering (From Intake of Batch 2001 upto 2008).

University College of Engineering and Technology, Multan (Bahauddin Zakariya University, Multan)

- B.Sc. Computer Engineering (Intake of Batch 2005 only and Intake of batch 2006- only such graduates who have completed remedial education/courses verified by the university).

University College of Engineering and Technology, Bahawalpur (The Islamia University of Bahawalpur)

- B.Sc. Computer System Engineering (From Intake of Batch 2005 upto 2007).

University of Engineering and Technology, Taxila (Main Campus)

- B.Sc. Computer Engineering (From Intake of Batch 2001 upto 2009).
- B.Sc. Software Engineering (Intake of Batch 2002 - only such graduates who have completed remedial education verified by the university), and Intake of Batch 2003 upto 2009.

University of Engineering and Technology, Lahore (Main Campus)

- B.Sc. Computer Engineering (From Intake of Batch 2003 upto 2010).
- B.Sc. Computer Science and Engineering (Intake of Batch 2001 and 2002 only).

COMSATS Institute of Information Technology, Islamabad (Abbottabad Campus)

- Bachelor of Science in Computer Engineering (From Intake of Batch Fall 2001 upto Fall 2008).

Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi - Swabi

- B.Sc. Computer Software Engineering (From Intake of Batch 2003 upto 2005).
- B.Sc. Computer Systems Engineering (From Intake of Batch 1993 upto 2008).

NWFP University of Engineering & Technology, Peshawar (Main Campus)

- B.Sc. Computer Information Systems Engineering (From Intake Year 1999 to 2000).
- B.Sc. Computer Systems Engineering (From Intake of Batch 2001 upto 2009).

N.W.F.P. University of Engineering and Technology, Peshawar (Mardan Campus)

- B.Sc. Computer Software Engineering (From Intake of Batch 2003 upto 2010).

Bahria University, Islamabad (Karachi Campus)

- B.Sc. Computer Engineering (From Intake of Batch Spring-2001 upto 2005).
- B.Sc. Software Engineering (From Intake of Batch Fall-2000 upto 2008).

Hamdard Institute of Information Technology (HIIT) Karachi (Hamdard University, Karachi)

- B.E. Computer System From Intake of Batch Fall-2000 upto 2008 (excluding Intake of Batches 2005 to 2007, which were not inducted by the university).

Mehran University of Engineering and Technology, Jamshoro

- B.E. Computer System (Upto Intake of Batch 2007).

National University of Computer & Emerging Sciences, Islamabad (Karachi Campus)

- Bachelor of Science (B.S.) in Computer Engineering (From Intake of Batch Fall-2003 upto 2006).

NED University of Engineering and Technology, Karachi

- B.E. Computer Systems (Upto Intake of Batch 1998-99).
- B.E. Computer & Information Systems (From Intake of Batch 1999-2000 upto 2008-09).

Quaid-e-Awam University of Engineering, Science & Technology, Nawabshah

- B.E. Computer Systems (From Intake of Batch 1997 upto 2008).

Sir Syed University of Engineering & Technology, Karachi

- B.S. Computer Engineering (Upto Intake of Batch 2008).

Usman Institute of Technology, Karachi (Hamdard University, Karachi)

- B.E. Computer Systems (From Intake of Batch 1995 upto 2008 (*excluding Intake of Batch 2006, which was not inducted by the university*).

Balochistan University of Engineering & Technology, Khuzdar

- B.E. Computer System (From Intake of Batch 2002 upto 2007).

Balochistan University of Information Technology, Engineering and Management Sciences, Quetta (Takatoo Campus)

- B.Sc. Computer Engineering (From Intake of Batch 2002 upto 2008).

Mirpur University of Science and Technology, Mirpur (AJ&K)

- B.Sc. Computer System Engineering (From Intake of Batch 2005 upto 2007), including enrolment at Ali Ahmed Shah-University College of Engineering and Technology, Mirpur Campus (The University of Azad Jammu & Kashmir, Muzaffarabad).

Appendix B: Mechatronics Industry Survey Questionnaire

MS Thesis topic: Dynamics of Mechatronics Engineering – A Future Vision

College of Electrical and Mechanical Engineering, NUST, Rawalpindi

Mechatronics Industry Survey

Name: _____ Age: _____ Qualification: _____

Company Name: _____ Job Title: _____

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1. Company Profile : Private/Public

2. Industry

☐ Phosphate fertilizers & minerals ☐ Petroleum products ☐ Food processing ☐ Metal Products

☐ Cement & Building materials ☐ Animal feed ☐ Clothing ☐ HVAC systems

☐ Oil & Gas ☐ Plastic products ☐ Aircraft repair ☐ Pharmaceuticals

☐ Paper & Cardboard ☐ Cosmetics ☐ Chemical Industries ☐ IT

3. Services

☐ Training / Consulting ☐ Manufacturing / Production ☐ Maintenance

☐ Design & Development ☐ Sales ☐ Training

☐ Education ☐ Instrumentation ☐ Freight

☐ Other (Mention) _____

4. Number of Employees

○ <10 ○ 10-49 ○ 50-99 ○ >100

5. Number of Engineers

○ <10 ○ 10-30 ○ >30

6. What are the main duties of the engineers at your company?

☐ Research ☐ Design & Development ☐ Production ☐ Testing & Maintenance

☐ Sales ☐ Consulting ☐ Management ☐ Other (Mention) _____

7. Does the company perform Research & Development?

Please specify area

8.Would your company be interested in common projects or research with universities? If Yes , what areas?

9. Are engineers at your company interested in obtaining master degrees? Yes/No

10. Does your company have difficulty in finding qualified engineers? Yes/No

11. Rate the following areas in terms of their importance in your company.

Areas	Not Important	Somewhat Important	Important	Very Important
Mechanical Design				
Hydraulics and Thermo-fluids				
Electronic Design and Testing				
Electrical Power and Drives				
Control				
Modeling and Simulation				
Robotics				
Industrial Automation				
PLC+SCADA				
Embedded Systems				
Computer Aid Manufacturing (CAM)				
System Interface and Integration				
Software Programming and Packages				
Production and Project Management				
Quality Control				
HVAC systems				

12. Do you have knowledge about 'Mechatronics Engineering' ? Yes/No
If Yes then kindly write what you know about it.

_____
_____
_____

13. Do your company advertise job vacancies having title ' Mechatronics Engineer' ? Yes/No

14. How many Mechatronics Engineers do you have in your company/industry? _____

15. Do you hire female mechatronics engineers as well? Yes/No

16. What are the reasons for hiring Mechatronics engineers in your company?

_____
_____
_____

17. How would you compare the performance of mechatronics engineers at your company with that of the electrical and mechanical engineers ?

_____
_____

18. Are you willing to recruit more Mechatronics engineers in the future? Yes/ No

19. Do the technicians at your company/industry have mechatronics training or background? Yes/No

20. Do the technicians or engineers at your company/industry require mechatronics training? Yes/No

Appendix C : List of Companies that participated in the Mechatronics Industry Survey

Nestlé Good Food, Good Life	TODAY TOMORROW TOGETHER
INTECH PROCESS AUTOMATION	Weatherford
Coca-Cola Beverages Pakistan Ltd.	Atlas Honda
ueccontrol.com UEC (Pvt) Ltd.	powersoft nineteen — After all, it is all about People
SprintecH packaging	NISHAT

Appendix D: Mechatronics Society Survey Questionnaire

MS Thesis topic: Dynamics of Mechatronics Engineering– A Future Vision

College of Electrical and Mechanical Engineering, NUST, Rawalpindi

Mechatronics Society Survey

Name: _____ Age: _____ Qualification: _____

Occupation : _____

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1. What is your family occupation?

a. Engineering **b. Medical** **c. Business** **d. Academics** **e. Other**

2. Is any of your family members an Engineer? **Yes / No**

3. Have you ever heard about Mechatronics Engineering? **Yes / No**

4. How much knowledge do you have related to Mechatronics Engineering?

a. Very Little **b.Sufficient** **c. Complete** **d. No knowledge**

5. According to your knowledge, Mechatronics Engineering is related to:

a. Robotics **b. Controls** **c. Automation** **d. All of these**

6. Do you know how many universities in Pakistan are offering Mechatronics Engineering?

a.3 **b.5** **c.7** **d.15**

7. Can you name any two universities which offer degree in Mechatronics Engineering?

_____

_____

8. Can you name any two industries where Mechatronics Engineers are working or in demand?

_____

_____

-Thank You-

Appendix E: Survey - Future Development trend of Mechatronics Engineering in Pakistan

Name : _____ **Profession: _____**

Rate the following parameters according to their effect on the future development of Mechatronics Engineering in Pakistan

Dependent Parameters	Agree	Strongly Agree	Disagree	Strongly Disagree
Market demands				
Industrial Demands				
Society Needs				
Technological Development				
Mechatronics as a discipline choice				
Interest of people in carrying out research in multidisciplinary areas				
Trend of acquiring multi-disciplinary skills and knowledge				
Increase of awareness regarding mechatronics in industries of Pakistan				
Increase of awareness regarding mechatronics in society of Pakistan				