The Next 50 years of Industrial Management and Engineering

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***Abstract* - Three interwoven threads of background trace the path that leads to the challenges and questions about IE: Where is IE practiced, what outcomes are expected from the profession, and what techniques form the skills IEs bring to an IE practice.**

Accordingly, finding answers for the next 50 years of industrial management and engineering, discussions have been done with distinguished and authoritative industrial engineers, managers, and educators with international experience in manufacturing, distribution, office and service work.

The purpose of the paper was to provide guidance for young people entering the industrial engineering profession. Primary goal was to identify trends, directions and likely changes in the field and profession that may be helpful in career planning. A secondary goal was to help current practitioners and educators adapt to future demands.

To students, I hope that you will find the paper insightful, stimulating and useful as you plan your education and your future career in industry.

To educators, I hope that the reflections, predictions and discussions contained here will help you in developing our next generation of professionals.

To practicing managers and engineers, I hope that you also will find value and guidance as you plan for continued personal and professional development.

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I. Introduction

IE originated in manufacturing near the end of the 19th century and remained focused primarily on the shop floor until the middle of the 20th century. Since the 1950s, the areas where IE is practiced on a regular basis have increased exponentially in all segments of society – education, financial institutions, health care, think tanks, military, charity organizations, natural resource extraction, government agencies – and at all levels and in most of the functions of the entities.

Paradoxically, this explosion of areas of IE applicability has contributed to the difficulties in recognizing its value. Most people associate themselves with and "make their mark" in specific functions or areas of human and organizational concern, such as marketing, accounting, information and knowledge management systems, manufacturing, operations, public works, health care services, etc.

The motivations and stimuli at the start of IE were efficiency driven. Specific aspects of efficiency, such as performance time, motion patterns, and pay, were the focus of the pioneers. Costs were added to the efficiency mix when the initial outcomes were found to be affected by materials and inventory, and then quality was identified as part of overall efficiency. Productivity improvement and waste elimination are the latest incarnations of how the efficiency outcome is expressed.

As the arenas of IE practice expanded, many practitioners were expected to take part in earlier decision making about how the processes in the functional area were to be set up rather than only be concerned with improving the productivity and quality of existing processes. It didn't take very long for organizations to recognize that IE should be involved even in the invention, design and planning of the products and services as well as the processes to produce those outputs.

Put another way, the outcomes expected of IE should be, to paraphrase Peter Drucker, to plan to do the right things as well as develop ways to do things right.

Any applied profession develops and advocates a particular set of techniques, however much some of them overlap with other fields. Those in IE started with formulations of successful past practices, the time studies of Taylor and the motion analyses of Gilbreths. Various techniques have been added since then – engineering economics, quality control, statistics, operations research, computer programming, simulation, decision analysis, ergonomics, quality circles, and many function-specific adaptations of these, such as scheduling and production control, facilities location and planning, transportation analysis, supply chains, mass customization, and lean manufacturing. Of course, the emergence of new technologies, such as transistors, computers, fiber optics, and wireless capabilities very often change the way the techniques are defined and used.

One of the most telling characteristics of these techniques for the IE profession is that most were developed by people who did not claim they were IEs! That is, IE was "behind the curve" and often had to be pulled into adopting most of them, especially the Operations Research techniques that were developed during World War II. This characteristic of IE techniques is a major reason IE has been unable to establish its uniqueness.

Offering seminars, conferences, publications, and definitions based mainly on techniques, without an overall frame of reference for the profession, exacerbates the difficulties. The medical, architectural, and other engineering professions, as examples, have their distinctive tools, but they each identify themselves in broader terms. Einstein noted that "The intuitive mind is a sacred gift and the rational mind is a faithful servant". IE similar to other professions, must foster the intuitive and creative mind and not only "honor the faithful servants."

II. WHAT DO OUR CUSTOMERS WANT?

Although there may be other ways to classify "customers", we will focus on two broad groups: (1) organizations that employ Industrial Engineers and (2) high school students (and their career counselors) who we would like to attract to IE.

Companies and organizations at the end of the 19th century sought efficiencies and then over the years added the other outcomes described above. Note that each of the earlier outcomes was not discarded as a new outcome was added; the earlier outcomes were just considered necessary, but not sufficient. For example, the Dell Company still seeks time efficiencies on jobs even though the change may be as small as seconds, and lean manufacturing or lean management continues the inclusion of efficiency efforts.

Automation, total quality management, best practices, six-sigma, and lowered levels of decision making, eventually loses its top billing while still remaining a part of organizational requirements for productivity and quality improvement, or efficiency. These will remain important, yet there is a perceptible shift in emphasis toward being competitive and a market leader beyond only cost, time, ROI, and quality measures.

The outcome marker for this new emphasis is called "innovation". It is a word that impacts and could be sought in many functions of an organization; after all, innovation can lead to radically changed functional areas, such as marketing, distribution, finance, and customer relationships as well as new products, manufacturing processes, and service delivery methods.

III. WHAT ARE THE MOST SIGNIFICANT DEVELOPMENTS IN THE PAST 50 YEARS OF INDUSTRIAL MANAGEMENT & ENGINEERING?

First is the broadening of skills sets required of graduating industrial engineers from what they used to be. We began with work measurement and work simplification and have now added quality control, human factors, manufacturing systems, ergonomic statistics, operations research and more. All of those tools and skill sets have really broadened what an industrial engineer is capable of doing. This expansion of skill sets to the broadening or the deepening of the practice domains for industrial engineering. It's no longer just industrial engineering for manufacturing – it is banking, finance, warehousing and distribution, healthcare, and transportation services.

As Mr. Muther stated, the biggest movement or change that has come into whole industrial complex is the significance of systems analysis and the computer. That tool and device has changed the whole profession in terms of getting away from the shop floor and getting into the aspects of software. Rise of interest in and abilities to deal with the "whole" (systems concept.) This has changed the way IE is practiced and thus to redefining IE. On the other hand, the integration of the available technology through enterprise information systems makes full information possible to anyone who needs to know.

The focus on information processing side today is coming out of IT departments and systems people as opposed to industrial engineers. In many cases, the IT people are often reinventing tools and process analysis that has already existed in the realm of IE, but for them it's a new discovery.

One troubling change that was perhaps bound to happen has been the disbanding of large, centralized corporate industrial engineering departments. These, by and large, do not exist anymore. Or if they do, they're very few and far between.

The recognition of the people doing the work is of significance as well. This has been showing up in leadership texts for decades, but it has taken a front seat with Lean-Sigma.

Therefore, the two most significant developments affecting industrial management and engineering are:

- The broad recognition of and acceptance of "process" as a crucial focus in work improvement.
- The acceptance of and increasingly effective use of employee teams in work improvement.

The other change that is perhaps less encouraging and that is the uncertainty of industrial engineering as a term. We have danced around that by changing the names of departments at various universities to management engineering, to manufacturing engineering, to systems engineering, to industrial engineering, etc. So it's a little bewildering to those who are not close to the profession as to just what it is that industrial engineers do.

IV. HAS THE RATE OF TECHNICAL INNOVATION PERMANENTLY SLOWED IN MATERIAL HANDLING, WAREHOUSING, AND FACTORY AUTOMATION?

So much change has occurred in this area and is still going on, much of it driven by controls and the information revolution, but also by a lot of clever engineering. But so much change is on the material handling, you just have to look under the hood to see it. Most observers think a forklift has three or four wheels and a fork that goes up and down, "so what else is new?" There are a lot of new innovations in drive systems, maintenance and ergonomics. These improvements are happening on a daily basis across many different technologies to enhance reliability, speed and functionality. There are still tremendous challenges in material handling that will drive innovation.

Certainly a lot of change is occurring in the distribution realm in how we organize distribution centers. They're becoming more centralized and larger. Every year, the industry is trying to improve the way we do order picking and fulfillment. Innovation in material handling applies to warehousing, distribution and also manufacturing.

For example, RFID technology will revolutionize the factory and the life cycle management of durable goods. Developments such as RDIF, embedded materials, nano-technology, and telecommunications can produce surprising and unexpected changes in all fields. Wal-Mart started using RFID in the retail business and forced their suppliers to do the same. But those suppliers are just now starting to understand the benefits of RFID to their own processes. RFID benefits them on the shop floor and in the handling of goods.

There is also a big evolution occurring in the warehouse management system. So many of today's warehouse management systems don't have all the capabilities that large centralized warehouses really need. If you look at them, every one of them has a drawback and there is tremendous opportunity for improvement. Warehouse Management System and warehouse automation applications are readily found in businesses handling high volume and/or easily handled products, but applications for hard to handle or bulky products are too expensive. As we apply more integrated solutions through enterprise systems we will be able to broaden the applications to a wider array of products.

The question today seems to center on how we can minimize the amount of space needed for storage. We've already enhanced the manufacturing process so that we can make them as they are needed. As a result, the amount of storage needed was reduced by perhaps 80 to 90 percent. Now we're bringing things in by the container lot. And they have to be distributed and tracked. The rate of change in technology and improvements will be more rapid and we're going to see that more and more.

V. IS INDUSTRIAL MANAGEMENT SIMILARLY MATURE?

Technological innovation has not slowed, nor is industrial management mature. Today's industrial manager needs to know a great deal more about a specific process or business while mastering an understanding of external pressures. Yet the large numbers of management programs (e.g. total quality management, ERP, performance management) that appear every year or so make it appear that changes are occurring. Industrial management is relatively mature and people think they have developed a new paradigm of management. However, businesses are still trying to figure out how to develop and retain the right people.

Industrial management includes leadership. It's enabling somebody to see what a civilization is doing and where it's going. It's building a vision and recruiting, training, and enabling people to work together. In that sense it's a long way from being mature.

We have a situation in the existence of mankind that can be classified as either hard or "physical," procedural or "mental," emotional or "personal." Most things in the world will automatically fit into those three categories. It's very easy to look at something physical, as engineers have been doing, and measure it and think about it and design something new. It's more difficult to do that in the procedural or mental sense, in what's typically called software today. Software has grabbed that name to bring it into the realm of the mind and the mental action. But the process of thinking, the process of solution finding, the process of planning needs to be analyzed by industrial engineers. Why can't we do it better, faster, more effectively?

The third category of the emotional or personal touches on the question of why can't man talk to man more constructively? And while that may not be an industrial engineering problem per se, it certainly is a management problem. In management, you always have the questions of is it a physical or a mental decision? A procedural or an emotional/personal decision? If you don't answer all those questions as a manager, you're really not a whole part of the world.

In summary, the physical (the visible, tangible) aspect of industrial management may be maturing, but it's mental (the procedural, process) and its personal (the emotional, service) aspect is far from maturity. It is easier to "see" the physical aspect of things, so they tend to arrive and mature earlier. The softer mental aspect" and the sensitive emotional aspect arrive and mature later. So, in the whole view -- hard, soft and sensitive -- management still is a long way from maturity.

VI. ARE LEAN MANUFACTURING AND SIX SIGMA THE FINAL EXPRESSIONS OF INDUSTRIAL ENGINEERING? IS THERE ANYTHING MORE TO KNOW OR DO?

Lean and Six Sigma are nothing more than a new label applied to the old principles of traditional scientific management and industrial engineering; i.e., work measurement, the elimination of wasted motion and work, and quality control, with a strong measure of marketing thrown in for good measure.

This brings us back to the recommendations from industrial engineers 100 years ago to standardize the process. Most of us realize that the emphasis on standardization originated with Gilbreth and Frederick Taylor before that. But in the modern world, many people not trained as industrial engineers think that term, “the one best way,” came to us via Toyota. The techniques that we’re using today borrow a lot from things that we were doing 30, 40 even 50 years ago. They have added some new elements. On the other hand, 70% of Six Sigma process-oriented projects fail.

Why Toyota keeps adding their own acronyms to the “Toyota Production System” every year? The Toyota Production System is a set of written engineering instructions or anything similar along those lines. It made a big difference that the Toyota system and things like that emerged from the culture as a way to do things, rather than a set of techniques independent of the culture. The Toyota Production System as it relates to the outside world is really an expression of the culture of Toyota to eternally chase waste out of the system – which they have not yet succeeded in doing. They keep finding new problems to address. So within Toyota, the Toyota Production System is only a start.

As someone with 30 years of experience in this profession, today it looks as if I could go on the Internet and in five days learn everything that it took me 40 years to learn. So is a Lean Sigma program that you can attend in a week or take as a correspondence course on the Web the sum total of industrial engineering education? Is that what’s happened to our field? Are we that mature? Or is there something more?

There is much more to know and to do. The whole area of systemization of the planning process -- of improving the way we improve things -- has barely been touched.

- How to see -- to observe, to envision, to discern
- How to plan – to understand, to devise, and to decide.

These are skills yet to be developed and accepted, and they are a long way from the "tools and techniques" with which we continue to get infatuated.

In terms of more to do, environmental consciousness and sustainable practices provides a lot of room for industrial engineering to make its mark in ways it has not yet done. The industrial engineer always finds a better way.

VII. WHAT ARE THE FUNDAMENTAL TECHNICAL SKILLS NEEDED BY INDUSTRIAL ENGINEERS AND MANAGERS?

Industrial engineering is the process by which you take the physical and mathematical sciences and engineer the highest possible performance out of an operating system. The objective of industrial engineers is to get the best possible performance out of an operating organization or operating system.

Therefore, we need to teach them the basic fundamentals so they can adapt intelligently to solve new problems. The core engineering curriculum is in the sciences, centering on engineering statistics and operations research tools and modeling, and ergonomics:

- Basic sciences – physics, chemistry, biology, math, statistics
- Basic engineering – materials, electronics, controls, computers and data processing
- IE tools – human factors and ergonomics in terms of the organization of work and the design of modern work systems, modeling and simulation, financial engineering, quality assessments, especially design methods and applications
- Systems – elements and dimensions, systems thinking and architecting, risk and failure analysis and management, role of people and politics in getting results

You were expected to become competent in these subjects, but you didn’t go too deep within any one of them. Somewhere along the line industrial engineers got caught in the trap of wanting to be all things. Since IE curriculum doesn’t have sub-specialties, maybe that’s part of the problem. Plus, not every engineer can be a Renaissance man. There will be too many things to learn, and IEs won’t be able to do any of them well. If we expect industrial engineers to know everything, it's not going to happen.

Businesses make IEs responsible for things like how to sell a project and how to work effectively in teams. To be successful, you must know who you are working for, what they expect and how best to communicate your ideas. Many schools have adopted teaching techniques that emphasize interpersonal communication. Another thing that is fundamentally necessary is to provide a much broader and global educational experience.

Industrial engineering and industrial management, or the whole field of problem solving does not have to have a problem to start with. This is going to be a big change in the current century as we learn how to get to solutions that we would like to have without bothering to look at what we have. Now that doesn’t mean that the solution we’re going to have is going to be some idealist solution. It has to function. It has to perform. It has to solve cost problems. It has to be effective. So it is beyond the question of looking at the problem to start with, but rather looking at the situation to start with, and the environment, and the surrounding situations, and then deciding conceptually what you would like to have and driving your solution toward that outcome.

Years ago, appliance and electronics companies like Motorola would give an industrial engineer a walkie-talkie and ask, “How much is it going to cost to build this?” That industrial engineer had to visualize how the walkie-talkie would be made, what processes would be used, how many people would be required, what that factory would look like? He had to envision those solutions and be technically confident in what the processes would consist of before he could even dream of what the walkie-talkie would cost the consumer. In that kind of environment, industrial engineers really had to know their business and how to envision solutions. That is missing today in most of the industrial engineers. They can solve a problem you give them, but they can’t develop the processes on their own.

This is a skill that is really lacking – it’s the understanding of existing process. Today there is a lot of focus on implementing ERP or business process management solutions. But people still don’t understand or examine the existing process before they start the ERP or BPM projects.

In short, they need to learn How to measure (at all levels); How to plan; How to decide; How to work with others involved in contributing to, affected by, and approving of their work.

VIII. WILL INDUSTRIAL ENGINEERING EXIST AS AN ACADEMIC DISCIPLINE IN 50 YEARS?

It may not be called by the same name – industrial engineering – but the activity and service the profession provides will still be taught in 50 years. In some ways, “systems engineering” is perhaps a better term since people always get hung up on the word “industrial” and wonder how it applies in a bank or a hospital.

The curriculum will be moved away from tools and techniques, which industrial engineers have tended to become infatuated over in recent years. Moving forward, we need to see “the bigger picture” at the academic level.

There will be industrial engineering departments at the undergraduate level as long as the market continues to pay a premium for the Bachelor of Science in Industrial Engineering degree versus a Bachelor’s degree in Business Administration or Operations Management. That is true today. There is something either in the way we select our students or train our students that enables them to demand a premium in the market when they graduate. As long as we continue that, regardless of what we might teach them and how we might argue about what we teach them, the market will continue to support the need for the degree.

IX. WILL INDUSTRIAL ENGINEERING EXIST AS A SIZEABLE AND WELL-DEFINED PROFESSION IN 50 YEARS?

Industrial engineers are finding success in all areas of business. Their skills are crucial to the success all across the enterprise. For example, twenty years ago the retailer would have traditional industrial engineering positions in the distribution center. The IE’s would be responsible for labor planning, labor standards and capacity planning. In addition, the more advanced retailers were using IE’s for quality assurance and SKU analysis. IE’s were just becoming to be appreciated for what they could offer in store labor management and projects in distribution. Twenty years ago the IE’s were infiltrating the business.

Now, the large retailer will be using IE’s to integrate their supply chain, manage simulation studies for network design, implement inventory management systems, and create retail operating (labor) models. IE’s will be part of the business process design and Lean-Sigma initiatives.

It is difficult to think of an industry where IE’s are not needed, if the profession defines itself to achieve the purpose of “designing and improving systems.” The emergence of enterprise systems engineering should be another reason for the continued existence of IE. Both perspectives recognize that an innovation and design leadership environment is a potent role for IE. Plus, there has been a tremendous growth in all of the service industries in addition to the traditional manufacturing and healthcare applications of IE’s.

X. WHAT WILL BE THE MOST SIGNIFICANT DEVELOPMENTS IN THE NEXT 50 YEARS OF INDUSTRIAL ENGINEERING AND MANAGEMENT?

The most significant development in the next 50 years will be Systematic Planning. What interchangeable parts was to the 19th century, and scientific management was to the 20th century, Systematic Planning will become in this 21st century.

Three hundred years ago, interchangeable parts were the next big thing, then came mass production and industrial engineering. And now systematic planning is on the horizon. There is a great lack of support for the science of planning. In the future, the trend is going to be toward the mental process of thinking about things and how to do that better, rather than the physical process of how to put things together.

"A bushel of tools and techniques -- helpful as they may be -- does not make a comprehensive process of planning." If we get lost in tools and techniques and fail to see the future that lies in the industrial engineering of the mental process – of learning how to plan effectively – then we are going to be subjugated to has-been status. Industrial engineering will get left behind if it fails to be large enough in its thinking. If IE doesn't encompass a school of planning that teaches people how to arrive at decisions better – which is what we claim to be teaching ourselves – then we will miss the opportunity that presents itself.

XI. WHAT ADVICE WOULD YOU GIVE TO A YOUNG PERSON ENTERING OUR PROFESSION TODAY?

Industrial engineering is a great field with boundless opportunity, where the human factor in the operation of systems is like no other engineering field. When we talked earlier about innovation, it's that our field is anything but stagnant. The rate of change is phenomenal.

Industrial engineering studies teach the engineer something about almost everything. Eventually everyone needs to specialize. The young person make sure they make a conscious choice in what they specialize in. The following habits are important for continued success:

- Confront reality: Sometimes the facts will be different than what your boss would like them to be. Stick to the facts. Don't be intimidated to go along with an idea if you think it is wrong. You will get more respect if you learn how to, respectfully, voice a divergent opinion.
- Learn how to describe complex problems simply, but understand the complexity.
- Build and practice personal habits: Ask probing questions; read and build-up your knowledge in your field; learn how to present a vision.
- Build your collaboration skills. When working with others, make sure you neither dominate nor withdraw.
- Trust your instincts.

Mr. Muther challenges the young people here today by posing a question to them. How many of you think of your life as an industrial engineering project? And if not, why not? So learn how to plan it, execute it and set up how to control it and operate it more effectively. Specifically, build a plan that brings the future to you more effectively and with more comfort:

- Are you technologically capable?
- Do you like working with people?
- Are you willing to take part in a life-long broad range of professional development and association activities that is necessary in today's global economy?
- Are you willing to consider all societal sectors as potential career activities?

Take pride in the work that you do and enjoy what you do. Make sure you work at a place that appreciates you and that allows for and encourages divergent thinking. The best ideas are usually those that come from a combination of ideas. Every time, the best solution came from the discussion and evaluation. It was never one that we entered the room with. So, find an organization that allows and encourages that divergent thinking.

Broaden your vision of the world, learn about and be adaptive to different cultures. Find some way to get abroad and get into manufacturing plants. Get into a company that will move you around and expose you to people and other cultures, plants in other locales, and the way things are getting done in other places. Along the way, you will pick up the key issues in global logistics which are what the future has in store. Our future is going to be in logistics and material handling. We're going to make less and less of what we use on a day-to-day basis. But we're going to have to bring it all in somehow and get it to where it's needed. Keep going until you get some perspective from the rest of the world and then look back.

One last recommendation. Always keep looking over the horizon at where you can go next, what you can do next and what you can be next. Things are always going to change, and those of you that stay ahead of that crashing wave are the ones that are going to be the most successful and hopefully the most happy in that process.

BIOGRAPHY

Dr. Hakan Bütüner received his B.Sc. in Industrial Engineering from Middle East Technical and MBA from Bilkent Universities; and Ph.D. in Engineering Management from the University of Missouri-Rolla. He has been active both in academic and professional lives for several years in Turkey and overseas such as a strategic planning and business development director; as an operations & profit improvement program manager, and as a general coordinator. Currently, he is lecturing in Business Schools and Industrial Engineering Departments of well-known universities. Also, he is acting as the affiliates of several companies in industrial management and engineering consulting, training and software solutions field. Additionally, he is acting as the founder-president of Institute of Industrial Engineers – Turkish professional chapter, and as the board member of Institute of High Performance Planners in USA. Author has several publications and books, and at the same time honored by the decision sciences society Alpha Iota Delta.