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Study of Trends of Industrial Engineering Research

Nafish Sarwar Islam
(Department of Industrial and Production Engineering, American International University – Bangladesh)
Corresponding Author: Nafish Sarwar Islam
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Abstract: Industrial engineering is an engineering discipline which, because of its multi-disciplinary nature, has played an important role in the development and optimization of different systems at macro and micro levels. In this paper, the results of a research to study the position and trend of Industrial Engineering research in recent years are described. The data from a sample of 7,000 IE-related articles from international journals during the last 50 years were used for the analysis. The results showed that the development of IE in many countries has a strong correlation with their industrial and economic development. However, IE research topics are spreading in other management and engineering departments and so there is a need to redefine the discipline and its specific areas of interest. According to the prediction made using time series analysis, the most favorite fields of IE research in future will be on subjects related to information technology, intelligent systems, optimization, quality, and supply chain management.

I. INTRODUCTION

Industrial Engineering is a relatively new discipline that tries to adopt a systemic approach to solve different problems whether related to manufacturing or services. According to the definition by Institute of Industrial Engineers (IIE): "Industrial Engineering is concerned with the design, improvement and installation of integrated systems of people, material, information, equipment and energy. It draws upon specialized knowledge and skills in the mathematical, physical and social sciences together with principles and methods of engineering analysis and design to specify, predict and evaluate the results to be obtained from such systems [12,15]".

Industrial Revolution was the starting point for the birth and initial development of industrial engineering profession. The studies of Fredrick Taylor, who is sometimes called as the father of IE, together with other pioneers like Henry Gant, Frank and Lillian Gilberta Henri Fayol made the initial building blocks of Industrial Engineering [12].

World War II was another milestone in IE history. The increasing needs of manufacturers for higher efficiency in production systems led to creating new methods like time study, methods engineering, operations research, and quality control. The enhancement of computers made an opportunity for industrial engineers to improve the effectiveness of IE techniques by applying the technology for industrial engineering problems such assimilation, machining process control, linear and non-linear models, management information systems, layout planning, and statistical quality control.

Development of information technology has opened a new vision for industrial engineers in recent years. Almost 2 decades ago, Davenport and Short [2] explored the implications and applications of IT on IE functions and predicted that the industrial engineers of the future, regardless of their formal title or the organizational unit, will focus on IT-enabled redesign of business processes. According to Koelling and et al [7], tremendous advances in computing, information, and communication technology are dramatically, and permanently, altering the landscape that constitutes what is known as "work". Preez&Pintelon [11] believe that industrial engineering is caught between the Industrial Revolution and the Information Revolution confronting with choosing between pragmatic improvements in productivity and the opportunistic modeling and reshaping of the networked `virtual enterprise' and `extended enterprise' to become more competitive in a global marketplace. Believing that the two societies (industrial and information) might have conflicting characteristics, they urge careful repositioning of industrial engineering to ensure that the benefits that can be obtained from the two societies are maximized.

Together with the recent growth of nontraditional industries, particularly information technology and service-related industries the percentage of industrial engineers working outside of the traditional manufacturing industries has exceeded the percentage of those working inside the field in the next several years, and so the types of roles and responsibilities of Industrial Engineers are subject to change [3]. While the borders of IE, as an interdisciplinary subject are broadening, there is a concern regarding core of the profession that distinguishes it from other disciplines.

This paper reports the results of a research aimed at analyzing the trend of industrial engineering research during the last 5 decades and the perspectives that can be foreseen for the future of this field.

II. LITERATURE REVIEW

A review of publications on Industrial Engineering in general showed that they may be categorized into four groups. The first group consisted researches that has focused on the curriculum. For example, in [3] the desired characteristics and emerging topic areas that should be incorporated in the undergraduate Industrial Engineering curriculum were identified. In another example, QFD (Quality Functional Deployment) technique was used to determine IE educational needs according to the viewpoints of students, faculty membersand future employers of the students [8].

In the second group, the position of IE in organizations has been studied. A comparison of IEin developing and developed countries [9], position of IE in a particular country [10,14],role of IE in education and society [13], and application of IE techniques in service industries [1] are among the papers. All the studies have shown an effective role that Industrial Engineers play in different positions.

The third group of researches has investigated the relationship between IE and other science and engineering fields. The impacts of computer and information technology on IE are among the main areas of interest in this group [2, 7, 11, and 6]. In the last group, the future of IE has been elaborated. Preez&Pintelon [11] for example, outlined the duties ofa successful industrial engineer in the future as: a) contribute in developing opportunities within existing environments b) facilitate in planning the inevitable changes that will be required c) become leaders in the interface between industrial engineering and information technology d) facilitate and improve knowledge sharing and e) understand and facilitate empowering of employees. According to Kolling&Beruvides [7], industrial engineers of the future will be working with and within high-technology systems that will greatly affect not only how they do their work, but also the work that they do. They concluded that the education and tools of IE should be revised according to the potential impacts of the technology changes. In a survey by Hodgson and Soyster [4], faculty members in IE departments were asked to classify their research on manufacturing side of IE. The results showed that the main categories of interest were manufacturing design, fabrication and material processing, information technologies, and production and scheduling.

III. METHODOLOGY

The aim of this research was to study the trend of IE research in the past on which basis the future can be predicted. The journal papers published on the fields related to Industrial Engineering were considered for the study since they well represent the active research. Due to the limitations of access and data processing, a sample was selected with the following criteria:

Country: No limitation was considered regarding the country in which research has been carried out. For those papers with more than one country, the first author's country was taken into account.

Date: Although IE history has a 60-year background, the majority of publications have been during the last five decades. For this reason, publications between 1970 and 2019 were considered for the study.

Department: It is obvious that all IE related researches are not necessarily undertaken in IE departments. In fact, because of the multidisciplinary nature of IE, many subjects related to this discipline are taught and researched in other departments like System Engineering, Manufacturing Engineering, and Management Science. Hence, no limitation on the department was considered in the study. For joint research between different departments, the department of the first author was taken.

Topics: IE research comprises a variety of managerial and technical subjects. Through a survey of keywords in the publications, themes of IE conferences, and ideas of experts in this field, the main topics were identified. Table 1 shows the IE topics and their corresponding subjects (keywords).

Journal: Considering the ease of access as well as the internationalization factor, papers for the study were limited to those published in English language journals. From international publishers providing electronic resources, 4 main publishers were selected. They were Pergamon, Elsevier, Springer, and Emerald. From the journals published by the publishers, those more relevant to IE were selected. Table 2 shows the list of the resultant25 journals.

Through searching the papers, items like title, author, journal, department, university or institution, country, year of publication, and subjects were derived and stored in the database. Other considerations were:

- Date of publication was considered as the date of research.
- In identifying the subjects, the keywords matching the specified keywords of this research were taken into account.
- In a few papers, items like the country and the department were not identified; these cases were regarded as missing data.

Main Topic	Subjects
Production Management	Lean Production, Agile Production, Maintenance, Reliability, Total Productive Maintenance, Kanban System, Production Planning
Information Systems and Technology	Information Technology, Knowledge Management, Information Systems, MIS
Operations Research	Mathematical Programming, AHP, MCDM, Simulation, Genetic Algorithm, Tabu Search, Simulated Annealing, Heuristic Algorithms, Decision Support Systems, Chaos Theory, Constraints Theory
Project Management	Project Management, Project Control, Value Engineering and Management
Supply Chain Management	SCM, ERP, MRP, EOQ, MRPII
Total Quality management	TQM, 6 Sigma & Lean 6 Sigma, Quality Assurance, Quality Control, Quality Awards, BSC, DEA, Taguchi method, DOE, QFD, FMEA, CRM, Benchmarking, Kaizen
Advance Production Systems and Technology	Cellular manufacturing, FMS, CIM, GT, Reverse Engineering
Intelligent Systems and Methods	Neural Network, Artificial Intelligence, Fuzzy Logic, Data Mining- Expert Systems
Methods Engineering	Ergonomy and Human factors, Work Study, Time Study, Productivity, Facility Layout, BPR, Line Balancing
Other subjects	TRIZ, Innovation and Creativity, Problem Solving, Technology Management

Table 1: Research Topics in Industrial Engineering

IV. RESULTS AND DISCUSSION

Out of 12,000 papers studied, 7,000 papers were found appropriate for the study. The data derived from the papers were analyzed according to the specified categories. The following sections describe the main results. Figure 1 depicts the trend of publications on IE related subjects during the last three decades. The increase of publications in the 90s comparing to the previous decade is quite significant while the 2000-2007 period shows a slight increase. The increase can be attributed to the development of the IE profession in many countries, recognition of its role in the companies, and the expansion of IE in non-manufacturing areas. In analyzing the countries, papers were categorized according to 9 world regions (Table 3). As seen, three regions North America, West Europe, and East Asia have contributed to more than 85 percent of publications with North America having 32 percent alone. This shows an unbalanced development of IE in different countries. The unbalanced development can be seen between countries within each region as well. The results support the hypothesis that there is a correlation between degree of development and the growth of IE in many countries. Focusing on individual countries, it can be found that Ten (10) countries contribute to 65 percent of publications with the US alone showing a significant share of 25 percent; Table 4 shows the results. The second position of Taiwan in the list is interesting when it is compared to more industrialized countries. This can be attributed to special attention given to the development of IE in this country. Besides, presence of four East Asian countries in the Top 10 list is consistent with impressive economic growth of these countries in recent years. Figure 3 compares the percentage of publications in different regions during the three periods. As seen, the share of East Asian countries during 1990-2000 has significantly increased while the share of North America has decreased.

This trend has been continued during 2000-2007 in which main Taiwanese papers have been published. Position of Turkey in the Top-10 list with the third position in Europe is also interesting and can show its jumping movement towards the development of IE research.

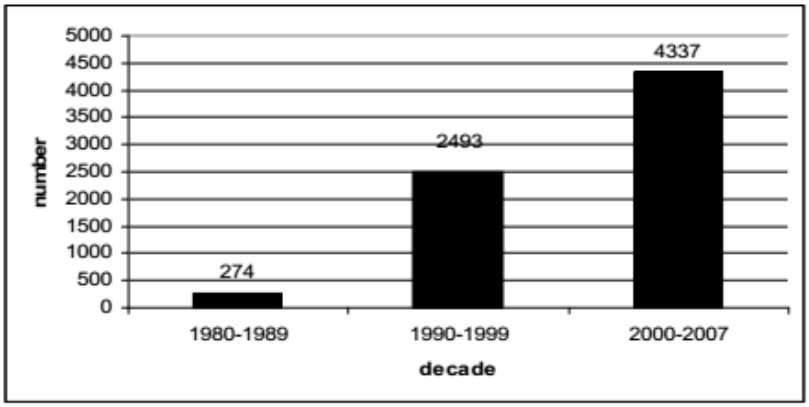


Figure 1: Number of IE publications in sample journals in recent decades

World Regions	North America	West Europe	East Asia	Scandinavia	West Asia	Oceania	East Europe	South America	Africa
Number	1 775	1 652	1 527	245	187	141	128	83	61

Table 3: Number of IE publications in deferent world regions

Country	USA	Taiwan	Britain	Canada	South Korea	Japan	China	Spain	Turkey	Germany
Number	1 467	476	429	269	228	222	193	176	170	169

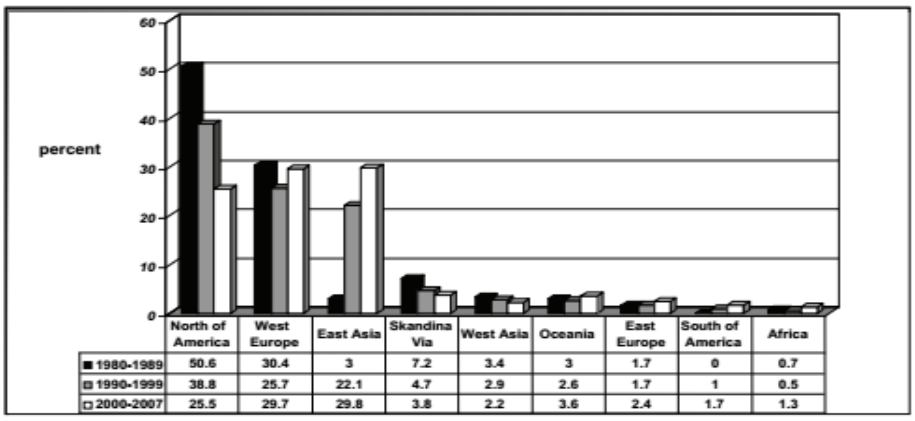
Table 4: Top 10 countries in IE publications

Taking the multi-disciplinary nature of IE into account, it can be predicted that not all of IE-related research has originated in IE departments. Having analyzed the data, the publications were categorized into 7 groups. Those publications that have not originated in university departments (schools, faculties, divisions etc.) were excluded from the analysis. Table 5 shows the groups and Figure 3 compares the number of papers in each group.

Although during 1970-2000 the main publications have been in IE departments, in the last Twenty 20 years, management and business departments has taken the first position. Although many topics are common or similar in these two groups of departments, but the difference found from the same source of data shows recent tendency of management departments towards the IE-related subjects. Another movement apparent from the analysis is recent growth of IE research in computer and information engineering departments.

This is the result of application of information technology in IE research in one hand, and development of IE techniques and models in computer departments on the other. Due to the role of modern mathematics in new IE techniques, the research in mathematics departments has also increased in recent years.

From the above results it can be concluded that the proportion of research on selected topics in IE departments is decreasing. This supports the hypothesis that the role of IE has been weakened during the last years and there is a danger of taking over the roles by other disciplines.

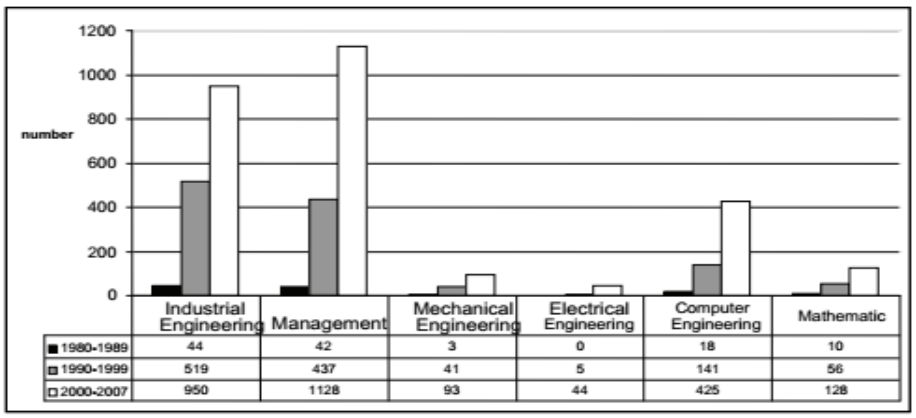


	North of America	West Europe	East Asia	Skandina Via	West Asia	Oceania	East Europe	South of America	Africa
1980-1989	50.6	30.4	3	7.2	3.4	3	1.7	0	0.7
1990-1999	38.8	25.7	22.1	4.7	2.9	2.6	1.7	1	0.5
2000-2007	25.5	29.7	29.8	3.8	2.2	3.6	2.4	1.7	1.3

Figure 2: Comparison of IE publications in the regions during the last three decades

Main department	Subsets
Industrial Engineering	Industrial Engineering, Industrial & System Engineering, Mechanical& Industrial Engineering, Industrial Engineering & Operations Research, Industrial & Manufacturing Engineering, Manufacturing Engineering, Production Engineering, Industrial Psychology, System Engineering, Decision Science, Other
Management & Business	Industrial Management, Technology Management, Production Management, IT Management, Information Management & MIS, Economy, Financial & Commercial Management, Accounting & Marketing, Other
Electrical Engineering	Electrical Engineering, Other
Mechanical Engineering	Mechanical Engineering, Other
Computer Engineering	Computer Engineering, IT Engineering, Computer Science, Other
Mathematics	Mathematic, Statistic, Other
Other Departments	Medicine, Apply Physics, Health Systems, Nuclear Energy, Mining Engineering, Metallurgy, Agriculture Engineering, Civil Engineering, Gas & Oil Engineering, chemical & Petrochemical Engineering, Geographic, Others

Table 5: Classification of university departments



	Industrial Engineering	Management	Mechanical Engineering	Electrical Engineering	Computer Engineering	Mathematic
1980-1989	44	42	3	0	18	10
1990-1999	519	437	41	5	141	56
2000-2007	950	1128	93	44	425	128

Figure 3: Comparison of publications in different departments

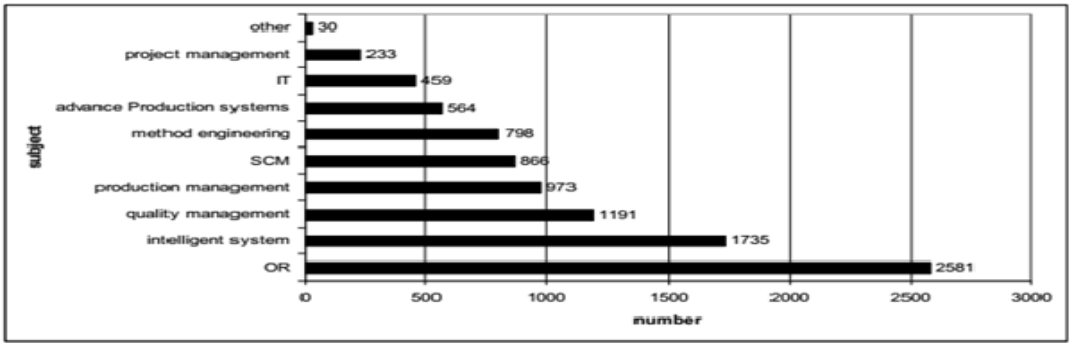
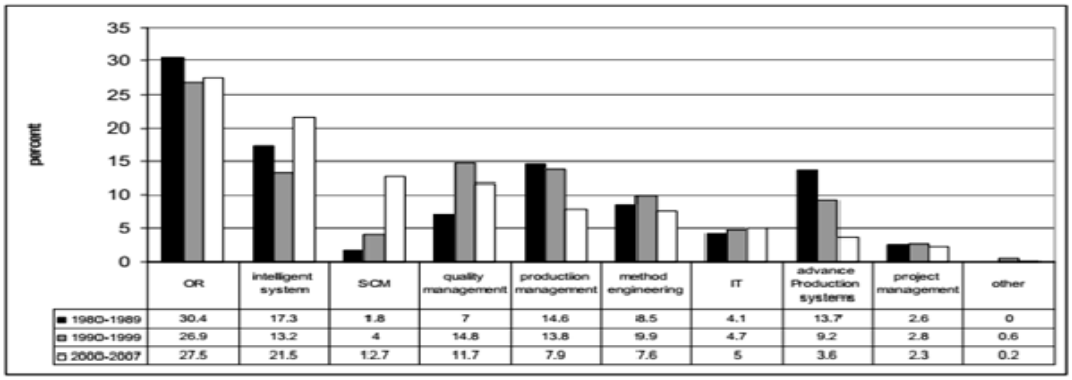


Figure 4: Comparison of publications in different subjects



	OR	intelligent system	SCM	quality management	production management	method engineering	IT	advance Production systems	project management	other
1980-1989	30.4	17.3	1.8	7	14.6	8.5	4.1	13.7	2.6	0
1990-1999	26.9	13.2	4	14.8	13.8	9.9	4.7	9.2	2.8	0.6
2000-2007	27.5	21.5	12.7	11.7	7.9	7.6	5	3.6	2.3	0.2

Figure 5: Proportion of research in different IE topics

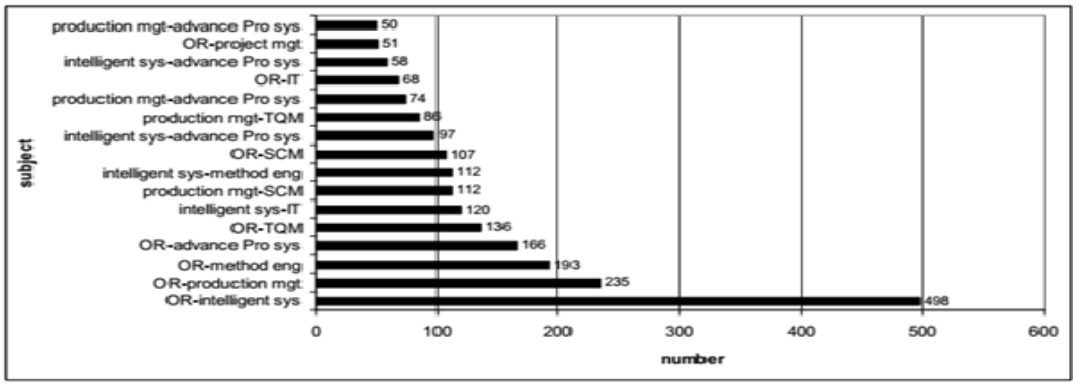


Figure 6: Interactions between IE research topics

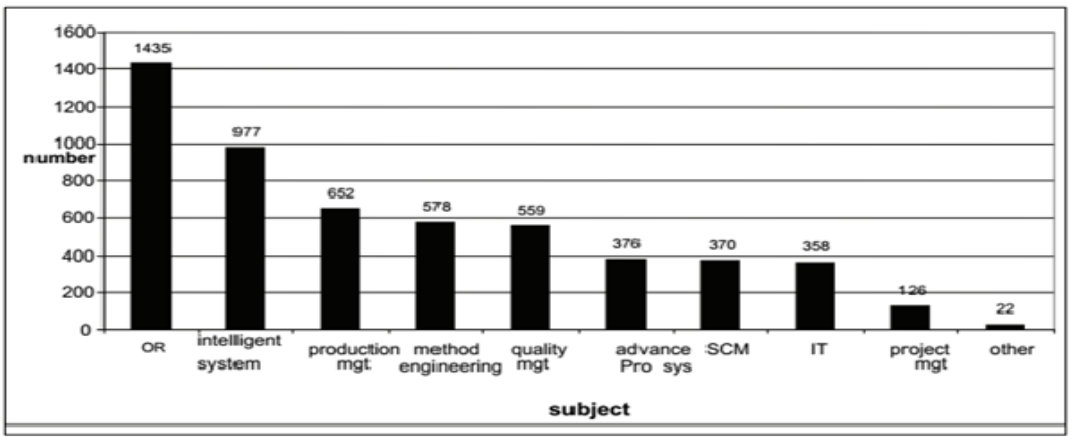


Figure 7: Potentials of IE topics for joint research

Using the grouping in Table 1, the papers were analyzed according to the main topics of IE research; Figure 4 shows the results. As seen, research on operations research, intelligent systems, and quality management has had the highest frequencies. This may be due to the diversity of these subjects as well as their applications in other fields of science and engineering.

The trend of research on subjects has also varied during different periods. While some subjects have grown up in recent years, the number of publications on some subjects has relatively decreased. The reason could be the changes in the research demand by the industry& society (pull factor) as well as the scientific interest of researchers (push factor). Figure 5 depicts the proportion of publications on the main subjects during the last decades. It can be observed that the proportion of papers on production management and systems has decreased while research on topics like intelligent systems, supply chain management, and information technology has been increasing. For other topics, despite slight fluctuations, the "proportions" have not changed dramatically.

Those papers with keywords in two or more topics were analyzed. Figure 6 shows the combinations that have received the highest numbers. It is clear that operations research and intelligent systems were the two topics that have had the highest level of interactions. This can be justified as many OR subjects have been focused on heuristic techniques on one hand, and many intelligent systems applications have used OR techniques on the other. OR has shown the highest interactions with other IE fields as well; this could be due to its generality when compared to more specific manufacturing subjects like production systems. Figure 7 shows the number of joint papers for the main topics in which operations research and intelligent systems have shown their high potentials for interactions with other fields.

As it can be observed the trends of different IE topics have been different. Subjects like intelligent systems, operations research, and supply chain management have shown an incremental and somehow stable trend while subjects such as production management and project management have had considerable fluctuation; topics like methods engineering, quality management, information technology, and advanced production &technology, despite some noise, have followed a moderate increasing trend. According to the results, it seems that, IE research in future will be focused on IS, OR, and SCM.

V. CONCLUSION

In this paper, the publications on different Industrial Engineering topics during the last 50 years were studied. The results show the growing importance given to the subject in many countries as well as significant role in industrial and economic development. However, IE research topics are spreading in other management and engineering departments and so there is a need to redefine the discipline and its specific areas of interest. IE departments should introduce new concepts and techniques if they are to maintain and enhance the profession.Other findings were:

- Operations research, intelligent systems, and quality management have had the highest frequencies in past research publications.
- While the proportion of papers on production management and systems has decreased during the last decades, research on topics like intelligent systems, supply chain management, and information technology has increased.
- Operations research and intelligent systems were the two topics that have had the highest level of interactions with other IE topics.
- It can be predicted that, in future, most IE research will be focused on subjects like information technology, intelligent systems, optimization, and supply chain management.

Taking an external viewpoint, it seems that the world main challenges like energy management (production and consumption), shortage of raw material, and the development of information technology and automation will also affect the future of Industrial Engineering. Although the data used for the analysis is a non-random sample of research publications on IE subjects, the large size of the sample and the time period used for the study make the generalizationsreliable. Future studies can complement this work by utilizing more data and addressing the limitations. Qualitative techniques can also be used to make predictions on future of IEaccording to expert views. The results of this research can also be used as a starting point in the development of curricula for Industrial Engineering programs.

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REFERENCES

[1]. Crandall, R. E. 1986. Applying Industrial Engineering Techniques in Service Industries. Industrial Management, 28(3), pp. 13-16.
[2]. Davenport, T.H. and Short, J.E. 1990. The new Industrial Engineering: Information Technology and Business Process Redesign. Sloan management Review, 31(4), pp. 11-27.
[3]. Eskandari, H. et al. 2007. Enhancing the undergraduate industrial engineering curriculum: Defining desired characteristics and emerging topics. Education and Training, 49(1), pp. 45-55.
[4]. Hodgson، T. J and Soyster A.L. 1994. Manufacturing research and the expandingrole of industrial engineering. Industrial Engineers, 26(7), pp. 69.
[5]. Hamilton, J.D. 1994. Time Series Analysis. Princeton University Press
[6]. Jocelyn Droplet and Lalshmanan. R. 1993. Computers and industrial engineering courses: A winning combination. Computers & industrial engineering.
[7]. Koelling, C.P., Beruvides, M.G. and Tankoonsombut, K. 1996. Technology's impacton the future of industrial engineering. Computers & Industrial Engineering, 31(1,2), pp. 5-8.
[8]. Koksal, G. and Egitman, A. 1998. Planning and design of industrial engineering education quality, Computers & industrial engineering, 35(3-4), pp. 639-642.
[9]. Malik, M.A.K. 1994 Developing countries: Industrial Engineering and its use. Industrial Engineering, 26(3), pp. 51-52.
[10]. Masin, I. and Vytlacil, M. 2001 Industrial engineering in the Czech Republic. WorkStudy, 50(5), pp. 194-196.
[11]. Preez, D.N. and Pintelon, L. 1997 The industrial engineer- caught between two revolutions. Production Planning & Control, 8(5), pp. 418-430.
[12]. Salvendy, G. 1992. Handbook of Industrial Engineering. John Wiley & Sons.
[13]. White, J.A. 1985 Strengthening the Role of Industrial Engineering in Education and Society. Industrial Engineering, 17(12), pp. 46-52.
[14]. Xu, W. and Wang, R. 1996. Applications and development of industrial engineering inChina. Computers & Industrial Engineering, 31(3, 4), pp.537-542.7

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