On the Bridges Between Two Disciplines: Technology Management-Industrial Engineering

Türkay Dereli[1], Gülhan Toğa[2], Alptekin Durmuşoğlu[1]
[1] Gaziantep University, Industrial Engineering Dept., Gaziantep, TURKEY
[2]Erciyes University, Industrial Engineering Dept., Kayseri, TURKEY

Abstract--**With the beginning of industrial engineering (IE), roles of the industrial engineers have been continuously expanding depending upon the requirements of the modern world. Up till now, many different fields have been the major studying areas of IE discipline, such as production planning, quality control, optimization and etc. Obviously, it has been impossible to manage and monitor these fields without taking the technology into account. In this respect, as an outstanding research area and business field, technology management (TM) knowledge and skills have been requested in the favor of industrial engineers. Thereby, this study outlines possible roles and expectations on industrial engineers in TM field. With this purpose, content similarities of related educational curriculums, common tools and techniques used by the both disciplines are analyzed. In addition to that, some sample cases from job announcements for IE qualifications are presented to indicate the relations between IE and TM. Finally, this study focuses on academic similarities of both fields by examining the academic publications with IE affiliation in the field of TM.**

I. INTRODUCTION

Industrial Engineering is a multidisciplinary field which aims the continuous improvement of the systems by using the techniques such as optimization, modeling, statistical process control, simulation and many others. To have a clear conception about IE, definition of The Institute of Industrial Engineers (IIE) should be considered: "IE is concerned with the design, improvement, and installation of integrated systems of people, materials, information, equipment, and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems." [45].

When we consider the birth of the IE as a profession, origin may be defined as "The Industrial Revolution". Consuming of the resources effectively and efficient production became as an issue for engineers with the usage of energy in industry [20]. A new concept called as "mass production" was applied at the first time after the Industrial Revolution. But there was something missing which didn't take into account by the capitalist world, power of the labor. Studies showed that considering the physical and psychological conditions of labor was increasing the productivity dramatically. Method study and work design concepts were mentioned in the first time after the Industrial Revolution. Time and motion studies can be considered as the second important development in IE area [21]. Subsequently, Operations Research (OR) has been introduced in IE discipline as a scientific development at the time of World War II, while the nations needed more efficient production and more technological improvements in the scarce of resources [14]. Technological progresses show a non-stop change in information age and it is impossible for industrial engineers to be unaware of this development [29]. On the other hand, industrial engineers are being forced to be a part of technology and manage it to achieve their comprehensive mission. Technological improvements such as personal computers, telecommunication, networks and internet have enhanced the IE on the way of continuous improvement. IE discipline has been widening depending on the developments in science and technology away from its origin and has a broad engineering perspective which includes many areas mentioned below:

- Organization and job design.
- Methods engineering.
- Performance measurement and control of operations.
- Evaluation, appraisal, and management of human resources.
- Ergonomics/human factors.
- Manufacturing engineering.
- Quality assurance.
- Engineering economy.
- Facilities design.
- Planning and control.
- Computers and information systems.
- Quantitative methods.
- Optimization [43].

Also some capabilities and characteristics must be needed for engineers who have been working in these wide ranges of areas: A focus on formal organizations engaged in production, concerned with the interaction between management and engineering, commitment to creating improvement and interest in the wider impacts of new technology are the main characteristics of an industrial engineers to deal with these wide ranges of studying areas [10].

If we define "technology" as knowledge to manipulate nature to produce products, energy, and services, and "engineering" as to understand of the manipulation process that seeks to satisfy human social and economic needs, it can be said both engineering and technology deal with mathematics, physical sciences, social sciences, and humanities [18]. However, all processes need to manage to be sustainable and substantial, especially if the subject is technology which shows great improvements in a short manner. IE is the unique position that it is a link between

technology and management, technology and economics and technology and science [38].

Industrial engineers must be major agents of the change with their knowledge about system engineering, information technology and manufacturing technology. They are responsible from process redesign which needs a TM and innovation management capability. Main goals of process redesign are reducing cost and time for a product, increasing output quality and quality of work life. All these goals can be achieved by an IE's profession [15]. Also, basic expectation of a firm from an industrial engineer is performing tasks with the best possible manner with least possible resources. On the other hand, TM meets the same goals with IE in many fields. Alignment of researches, development, planning, engineering, machines, software, production, and communication factors and make them work together in the most efficient way to produce profit for the company in the long-term is the main goal of TM [32]. Accordingly, firms must have competitive advantages to get long run success by combining high quality, reliability, timely delivery, enhanced customer service, rapid new product introduction, flexible system and rapid capital deployment [22]. When TM is integrated to firm's strategy, it brings competitive advantages [9]. Right TM strategy yields technological progress. By the way, technological progress lowers costs, improves quality, creates new products and helps to introduce new markets. Technological progress also includes doing same things better with fewer resources. So, outputs and goals of TM and IE have been overlapped in a wide selection of fields.

TM includes five generic processes; identification, selection, acquisition, exploiting and protection of technology [24]. From the identification to protection, each steps need a great interaction between engineering and management and all the processes are need radical innovation decisions in the firms. If there is a radical innovation about technology or management, there is a greatest need for IE [10]. TM and IE are interpenetrating with many points because of their goals. On the other hand, methods and approaches of technology management are not very clear in IE [44]. Best to our knowledge, current studies in literature do not focus on the linkages between IE and TM. In this respect, possible intersections of both TM and IE still require to be investigated.

II. STUDY

In this study, we try to define the characteristic similarities of IE and TM from different perspectives. As it is mentioned before, firstly, we handle the content similarities of related educational curriculums, than common tools and techniques used in the both fields are analyzed. In addition to that, some sample cases from job announcements for IE qualification will be presented to indicate the relations between IE and TM. Finally, study will focus on academic similarities of both fields by examining the academic publications with IE affiliation in the field of technology management.

A. Common Educational Content of TM and IE

TM is a discipline defined as "a field of study and a practice concerned with exploring and understanding technology as a corporate resource that determines both the strategic and operational capabilities of the firm in designing and developing products and services for maximum customer satisfaction, corporate productivity, profitability, and competitiveness" [4]. TM education has a long history in academia. Firstly, it was just concerned with engineering field, but then it has been integrated to business schools in the 20th century [25]. On the other hand, TM programs are still located in engineering schools more than business schools [3]. There have been many researches that evaluate the evolution of TM education: Some studies such as [3], [4], [25], [28], [37] and [39] documented how TM programs have been expanded in the worldwide. TM programs have been mentioned with different names in the world, such as "Engineering Management", "Management of Technology", "Industrial Engineering and Technology Management" and etc. For example, Hong Kong University has a department in the name of "Industrial Engineering and Technology Management". Additionally, 32% of "Management of Technology" (MOT) programs are given by IE department in the world [39]. On the other hand, the educational perspectives of TM and IE have many similarities. In one of his study about educational programs of MOT, Kocaoglu mentioned IE with this sentence: "The different programs do not represent discrete disciplines. They belong in the same continuum. That continuum is bounded by IE at one end, and public policy at the other end." [27]. This statement represents the connection point of IE with TM as a discipline, clearly. Also TM is defined as one of the main topic of IE study field [14].

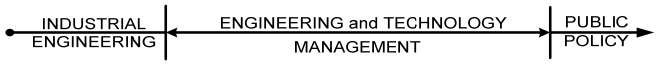
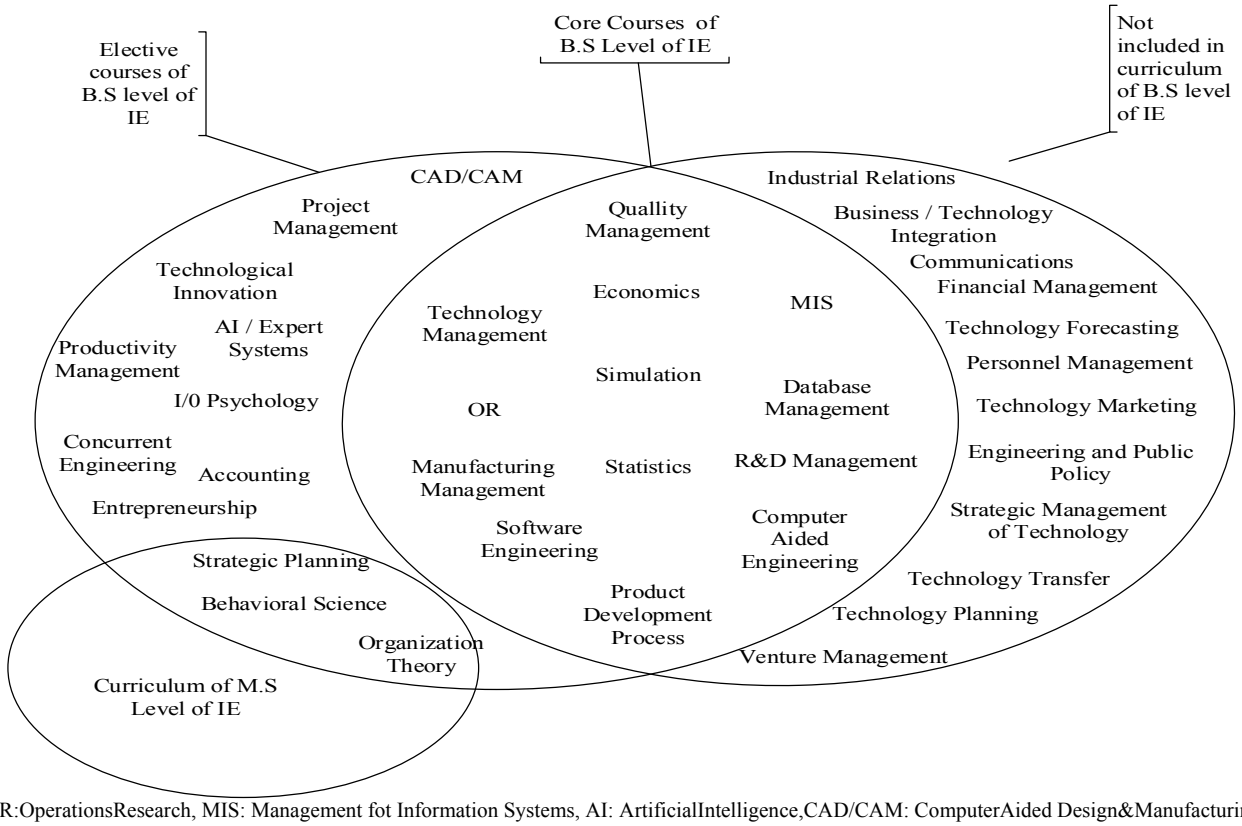


Figure I. IE and TM [27]

A variety of degrees from B.S to Ph.D. as well as certificates have been offered by TM programs, but the most of the degrees given are at the master's level (M.S) [3]. On the other hand, IE also offers B.S to Ph.D. degree for students. When curriculums are considered, course contents can be matched for TM and IE. Master program curriculums of TM have approximately 70% contextual similarity even with the undergraduate curriculums of IE (Fig. II). It is an advantage for IE to have a qualification of TM at the undergraduate level. Badawy [4] announced a list for graduate level of TM which contains four kinds of course clusters: Prerequisites, fundamentals, specialization and emerging areas [4]. We compare this list with the curriculum of IE Department of University of Gaziantep [17]. Fig. II illustrates the similarities of undergraduate level of IE and graduate level of TM.



OR:OperationsResearch, MIS: Management fot Information Systems, AI: ArtificialIntelligence,CAD/CAM: ComputerAided Design&Manufacturing, I/O psychology: Industrial / OrganizationalPsychology, R&D Management: Research and Development Management

Figure II. Curriculum similarities of B.S level of IE and M.S level of TM

Some courses, Organization Theory, Strategic Planning and Behavioral Science belong to M.S degree of TM have been given at the M.S degree of IE. This juncture is a proof of that, TM shouldn't be thought as a separated scientific discipline than IE. A qualification of industrial engineers may not be sufficient for being a technologist, but it is essential for a technologist having required knowledge and skills of an industrial engineer, even though in B.S degree. Most of the courses are not included in the curriculum of IE are belong to the specialization and emerging areas of TM education which had been defined by Badawy [4]. Therefore, a TM degree can be offered for IE students by additional specialization. On the other hand, service management, data analytics, social networks, knowledge management and global innovation subjects are the new disciplinary fields offered as a supplement to the TM education [25] and some of these have been already included in the IE curriculum [17].

B. Common Methods / Techniques Related With Both Discipline

TM has been developed in a wide range of methodologies and applications for both academic research and practical applications in the past few decide [33]. By the way, a technologist can be related with business, management, engineering, and many different disciplines, tools/techniques/methods which are expanding in many areas.

Terminology of tool and technique are mostly confused by practitioners. To avoid this confusion, a clear identification is made by Phaal about technique and tool [40].

- A 'technique' is a structured way of completing part of a procedure.
- A 'tool' facilitates the practical application of a technique [40]. On the other hand, method can be defined as the upper class of different techniques related with a methodology. For example AHP, TOPSIS and ELECTRE are the different techniques of Multi Criteria Decision Making method.

In this context, TM tools have been discussed by many authors fairly for a long time [8, 26,40]. Besides that, methods employed in TM discipline have been analyzed in many papers, but there is not a comprehensive study covers all TM frameworks, so far. There have been some studies to select methods of specific TM fields as innovation management and technology assessment [7, 8, 48]. Also, there has been a literature review performed to classify TM methodologies using eight categories, which are "TM framework", "General and policy research", "Information systems", "Information and communication technology",

"Artificial intelligence/expert systems", "Database technology", "Modeling", and "Statistics methodology" [33]. Cetindamar classified TM techniques / methods depending on the relation with TM activities [11].

On top of all this, we try to construct a guiding methods/techniques catalog for industrial engineers who study in TM discipline. The reason that motivates us to perform, most of the methods/techniques used in the TM field are the basic methods/techniques of IE, evidently. By the way, we construct a list which includes the basic methods/techniques of TM by gathering the studies mentioned above [7, 8, 11, 26, 33, 41, 48], and we try to demonstrate the similarities between two disciplines. Methods/techniques of TM are listed in the Table I.

As seen on the Table I, IE and TM have many common methods/techniques. This can be another proof of TM is not a discrete discipline, it is continuum of IE [27]. On the other hand, some methods/techniques as capability maturity model, patent analyze and technology roadmapping, are not mentioned basically related with IE, however it doesn't mean that these methods/ techniques have not been used by industrial engineers in their researches [16, 19, 31].

C. Job Announcement for IE as a Technologist

After the introduction of new technologies and changes to industry, IE has been expanded the traditional working area where the discipline was originally founded [23]. Rapid changes in the technology, creates need for an immediate applications for being competitive. And these changes create new occupation positions for industrial engineers different from manufacturing engineering. Firms have been announced the need of technologist with IE qualifications at the job search websites for a while. Social networks and websites are the greatest places for job providers to find proper employee and for job hunters to find best position depending on their qualifications. Many social networks and websites are being a bridge between job seekers and providers. Indeed, Monster and Career Builder are the three of most popular employment websites [1], and LinkedIn is the 5th of the most popular social networks about professional occupations depending on the web traffic which is a combination of user's numbers and page views [2]. LinkedIn allows users to create a profile based on their professions and offers to contact with people in a relationship manner. Qualification refinement is another advantage of LinkedIn for job searching. By the way, we analyze the TM related job announcements from LinkedIn depending on the need of IE qualification. Some representative examples from the LinkedIn are given in Table II.

TABLE I. COMMON METHODS/ TECHNIQUES IN IE AND TM DISCIPLINES

After-sales Services [43]	Matrices/Diagrams/Charts/Lists/Histograms (Affinity diagram, Cause effect Diagram, Checklists, Control Charts, Dimensional Matrix, Success Matrix,
Artificial Intelligence [14]	Flow Charts, Pareto, Tree Diagram, Value-success probability matrix, Maturity matrix) [42]
Benchmarking[14]	Methodological Forecasting Techniques[43]
Brain storming[43]	Modeling[43]
Business Intelligence[43]	Monitoring[43]
Business Process Re-engineering [14]	Multi Criteria Decision Making (MCDM) (AHP, ELECTRE, TOPSIS) [14]
Capacity and Bottleneck Calculations [43] [50]	Object Oriented Programming [43]
Computer Aided Design (CAD) systems[43]	Process Environment Risk Assessment[50]
Concurrent Engineering[43]	Portfolio Analyze and Management[43]
Continuous Improvement[43]	Production Planning (Just in Time-MRP) [14]
Corporate Culture[43]	Project Management (CPM, PERT) [14]
Cost-Benefit Analyze [43]	Rapid Prototyping[43]
Customer Relationship Management (CRM) [14]	Reverse Engineering [14] [6]
Data Mining (Web Mining/Text Mining) [14] [49]	Risk- return analysis[43]
Decision Support System (DSS) [14]	Scenario Building [43]
Decision Trees[14]	Simulation[14]
DELPHI[43]	Statistics[43][36]
Document Management[43]	Supply Chain Management (SCM)[43]
Education for Professional Development [43]	Survey[43]
e-Learning [43]	SWOT Analyzes[50]
Expected Value [43]	Team Work[43]
Expert Systems[14][29][30]	Technology efficiency analysis[43]
Force Field Analysis (FFA) [43]	Technology life-cycle analysis[43] [50]
Groupware[43]	Teleworking [43]
Information Management/monitoring[14]	Total Quality Management (TQM) (QFD, Quality circle) [14]
Innovation[14]	Trend extrapolation[43]
Intellectual Property Management [43]	TRIZ[14]
Knowledge Management (Knowledge audits, mapping) [14]	Usability Approaches[50]
Licensing [43]	Utility Model[43]
Market Analyzes and Research [43]	Value engineering[14] [43]
Mathematical Programming techniques[14]	Work flow[43]

TABLE II. JOB POSITIONS FOR IE

Company Name	Job description	Job ID	Country	Needed qualification
Baker Tilly Virchow Krause	Technology Risk Services Consultant	9505098	USA	Bachelors Degree in Industrial Engineering, or related program. Experience assessing or performing technology management processes
Gtech-Google	Technology Managers	9533713	USA	B.S. Computer Science, Statistics, Industrial engineering or related technical field or equivalent practical experience. 5 years' experience in the technology industry.
All DePuy Synthes, J&J Locations and external suppliers	Manufacturing Engineering, Science & Technology Manager International Assignment	9602777	China	A minimum of 8 years overall industrial engineering experience and minimum of 3 years' experience managing engineers or other technical personnel.
Canadian Oil Sands Innovation Alliance	Technology Integration Coordinator	6865250	Canada	Industrial Engineering, MBA degree or a degree with similar application

First two positions especially put emphasis on experience in technology related fields for industrial engineers. If a periodic search is done for the popular employment web sites, many technologist announcements can be seen for IE qualification.

D. Scientific Publications Prepared By IE in TM Discipline

TM has an extensive framework related with many fields and researchers of TM are academically diverse in many areas including engineering, economics, management, entrepreneurship, marketing, and strategy [35]. When considering all the linkages of TM and IE, it is worth to analyze the status of industrial engineers' scientific publications in the TM studies. To see the contribution of IE in TM, an analysis is carried out. The data used in this study include publication years and countries of industrial engineers' scientific publications in the source of the ten leading TM specialty journals (Research Policy, Journal of Product Innovation Management, Research-Technology Management, Technovation, R&D Management, Industrial and Corporate Change, IEEE Transactions on Engineering Management, Journal of Technology Transfer, Technological Forecasting and Social Change, and Journal of Engineering and Technology Management) for a thirteen years period of 2000-2013. There are many studies try to identify leading journal's list in TM field [5, 13, 35, 34].In this study, we are using the list of major ten journals identified by [47]. The data were collected from the ISI Web of Science SCI-EXPANDED, SSCI, A&HCI databases on 16 December 2013. After the first set of results had been received, using the menu on the web page, the results were refined to include only the "industrial engineering" addressed. Publication counts depending on the journal list and trend are given in Table III and Fig. III. It is shown in the Fig. III that IE has an increasing publishing trend about TM subjects.

Furthermore, it can be seen in Fig. IV "Technovation", "Technological Forecasting and Social Change", and "IEEE Transactions on Engineering Management" are the most popular journals within IE who studies in the field of TM, respectively (Fig. V).

Turkey and China are classified as "upper middle income economies" and other countries belong to "high income economies" by the World Bank [46]. These results prove that there is a positive correlation between the number of studies in TM field performed in a country and income level of the country and the TM field is dominated mainly by developed countries [12].

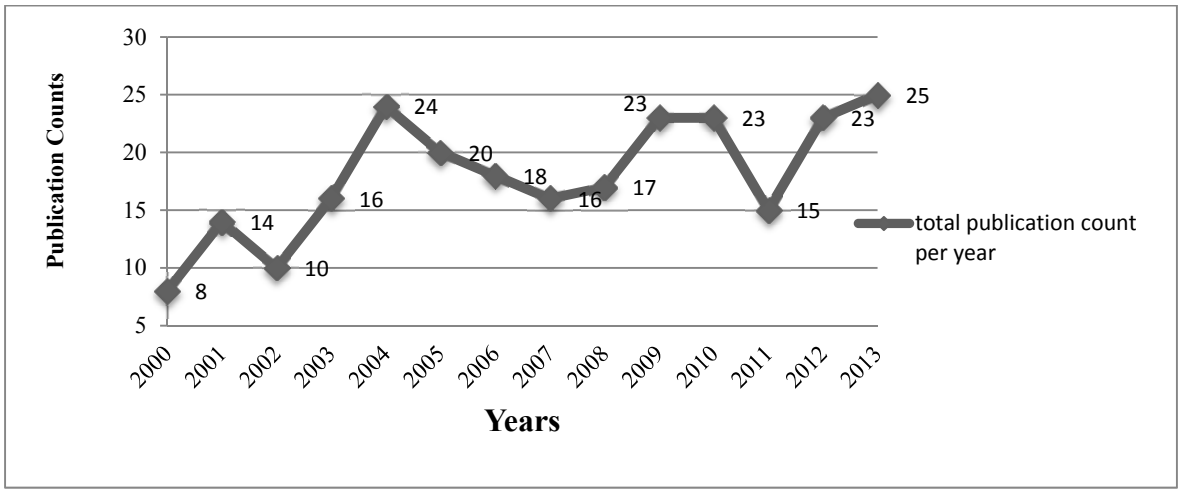


Figure III. Total scientific publication trend of IE in TM

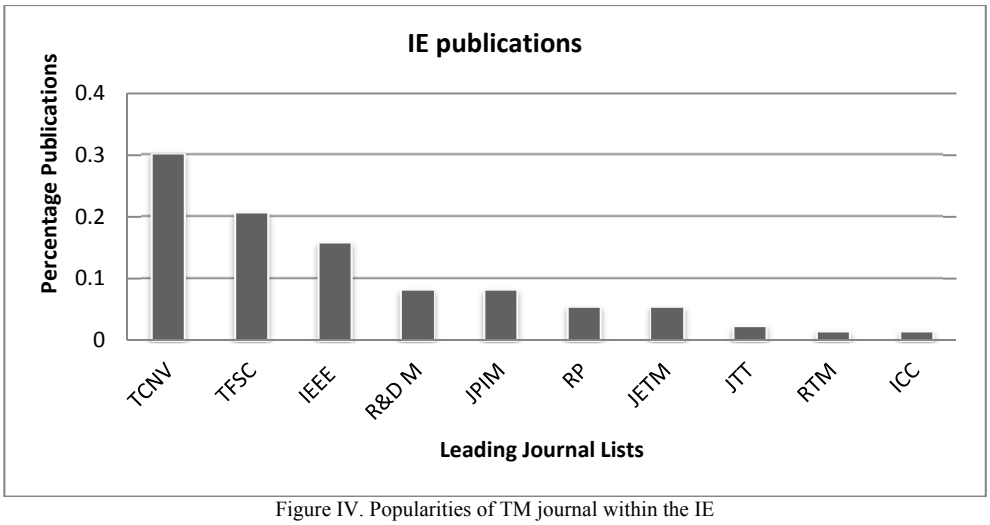


Figure IV. Popularities of TM journal within the IE

TABLE III. SCIENTIFIC PUBLICATIONS DEPENDING ON THE JOURNAL LIST

Year	TCNV	IEEE	TFSC	RP	R&D M	RTM	JETM	JPIM	ICC*	JTT**
2000	3	2	1	1	1	-	-	-		
2001	7	5	1	-	1	-	-	-		
2002	6	1	-	-	3	-	-	-	-	
2003	12	2	-	-	2	-	-	-	-	
2004	14	5	4	-	1	-	-	-	-	
2005	10	2	6	1	-	-	1	-	-	
2006	9	2	4	2	-	-	1	-	-	
2007	4	3	3	-	1	-	3	1	1	-
2008	2	4	5	1	2	-	1	2	-	-
2009	4	1	9	2	3	-	1	3	-	-
2010	2	3	9	1	2	2	-	2	1	1
2011	1	1	1	2	1	-	2	5	-	2
2012	-	3	8	3	2	1	2	1	1	2
2013	2	6	1	1	2	1	3	7	1	1
Total IE publication	76	40	52	14	21	4	14	21	4	6
Total publication	1095	716	1357	1630	702	1363	269	1015	583	280

(TCNV: Technovation, IEEE: IEEE Transactions on Engineering Management, TFSC: Technological Forecasting and Social Change, RP: Research Policy, R&DM: R&D Management, RTM: Research-Technology Management, JETM: Journal of Engineering and Technology Management, JPIM: Journal of Product Innovation Management, ICC: Industrial and Corporate Change, JTT: Journal of Technology Transfer) (*Since 2002; **Since 2007)

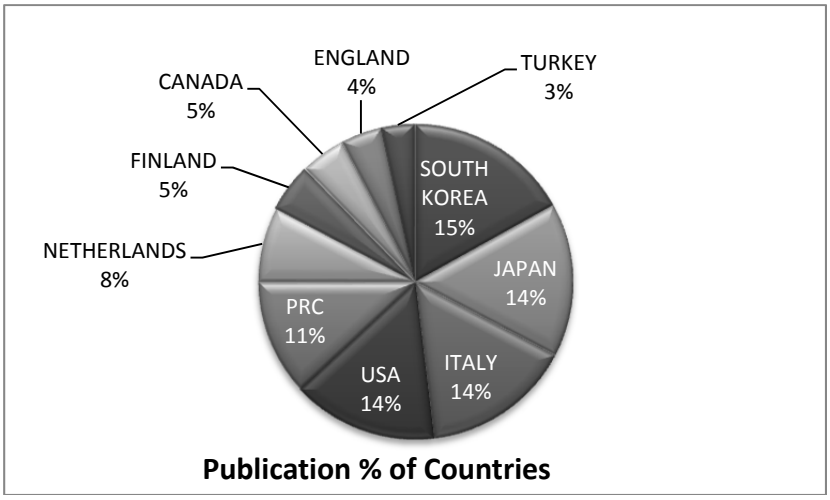


Figure V. Rank of Countries

III. CONCLUSION AND REMARKS

Fast technological change is a nonstop progress in this century. Technology becomes the most essential key factor for manufacturing and service organizations and also society. And people who can manage different types of technological assets assumed a critical role [36]. At this point industrial engineers with enough capability and capacity to handle with the problem in TM field can be an alternative for technologists. This paper presents an overview to relation between IE and TM from different perspectives. We focused on educational curriculum contents, scientific studies, common methods/techniques and job announcements to prove similarities of IE with TM. On the other hand, popularity of TM within the IE is not sufficient, yet. So, Industrial engineers must be encouraged about working in the TM field. TM related subjects must be included to IE discipline immediately.

As expected from all studies, we have some limitations, also. Firstly, educational curriculum content of IE is compared with TM based on a specific university curriculum. This can be expanded to global level by counting the most repeated courses in curriculums of different universities. Secondly, a general literature survey can be done for TM related scientific studies of IE in the perspective of methods and techniques used, than a comparison can be done for better results. Thirdly, we selected ten leading journals of TM while analyzing the scientific publications of IE. This selection is a constraint for detecting the real number of scientific paper.

As a future research, we would like to analyze a bibliographic research about IE scientific studies related with TM.

REFERENCES

[1] Alexa, The Web Information Company, "Top Employment Sites", Retrieved 24/12/2013 World Wide Web, http://www.alexa.com/topsites/category/Top/Business/Employment

[2] Alexa, The Web Information Company, " Top On-The-Web Sites" Retrieved 24/12/2013 World Wide Web, http://www.alexa.com/topsites/category/Top/Computers/Internet/On_the_Web

[3] Alvear, A., G.R. Rueda, I.P. Hernandez, D.F. Kocaoglu, "Analysis of engineering and technology management (ETM) educational programs," in *Papers presented at PICMET 2006*: Technology Management for the Global Future, vol. 3 pp. 1325–1331, 2006.

[4] Badawy, M.K., "Technology management education: alternative models," *California Management Review*, vol. 40(4), pp. 94–115, 1998.

[5] Ball, D.F., J. Rigby, "Disseminating research in management of technology: journals and authors," *R&D Management*, vol. 36(2), pp. 205–216, 2005.

[6] Bidanda, B., Hosni, Y.A., "Reverse engineering and its relevance to industrial engineering: a critical review," *Comput. Ind. Eng.,* vol. 26(2), pp.343-348, 1994.

[7] Brady, T., "Tools, management of innovation and complex product systems," *Report prepared for CENTRIM/SPRU project on Complex Product Systems, EPSRC Technology Management Initiative,* CoPS Publication 3, 1995.

[8] Brady, T., et al., "Tools for technology management: an academic perspective," *Technovation*, vol. 17(8), pp. 417-426, 1997.

[9] Burgelman, R.A., C.M. Christensen and S.C. Wheelwright, "*Strategic Management of Technology and Innovation*," 4th edition, New York: McGraw Hill/Irwin, 2004.

[10] Buzacott, J. A.; "The future of industrial engineering as an academic discipline," *IIE Transactions,* vol.16(1), pp. 35-43, 1984.

[11] Cetindamar, D., O. Can and O. Pala, "Technology management activities and tools: The practice in Turkey," in *Papers presented at PICMET 2006*, Portland, OR: PICMET, 2006.

[12] Cetindamar, D., S.N. Wasti, H. Ansal, and B. Beyhan, "Does technology management research diverge or converge in developing and developed countries?," *Technovation,* vol. 29(1), pp. 45-58, 2009.

[13] Cheng, C.H., A. Kumar, J.G. Motwani, A. Reisman and M.S. Madan, "A citation analysis of the technology innovation management journals," *IEEE Trans. Eng. Manage.,* vol.46 (1), pp. 4–13, 1999.

[14] Dastkhan, H., and M. S. Owlia, "Study of trends and perspectives of Industrial Engineering research," *South African Journal of Industrial Engineering,* vol. 20(1), pp. 1-12, 2009.

[15] Davenport, T.H. and J. Short, "The new industrial engineering: information technology and business process redesign," *Sloan Management Review,* vol. 31(4), pp. 11-27, 1990.

[16] Dereli, T.,and A. Durmusoglu, "A trend-based patent alert system for technology watch," *Journal of Scientific & Industrial Research*, vol.68(8), pp. 674-679, 2009.

[17] Department of Industrial Engineering, "Course Catalog", Retrieved 24/12/2013 World Wide Web, http://www.gantep.edu.tr/en/ab/dersler.php?bolum=&bolum_id=105

[18] Dhillon, B. S., *Engineering and Technology Management: Tools and Applications.*Artech House, 2002.

[19] Dooley, K., A., Subra, and J. Anderson, "Maturity and its impact on new product development project performance," *Research in Engineering Design-Theory Applications and Concurrent Engineering*, vol.13(1), pp. 23-29,2001.

[20] Du Preez, N., Pintelon, L. "The Industrial Engineer: Caught Between Two Revolutions?," *The South African Journal of Industrial Engineering,* vol. 8(2), pp. 1-24, 1994.

[21] Elsayed, E. A., "Industrial engineering education: A prospective," *European journal of engineering education,* vol. 24(4), pp. 415-421, 1999.

[22] Erensal, Y. C., Öncan, T., and Demircan, M. L. "Determining key capabilities in technology management using fuzzy analytic hierarchy process: A case study of Turkey," *Information Sciences*, vol. 176(18), pp. 2755-2770, 2006.

[23] Eskandari, H., et al., "Enhancing the undergraduate industrial engineering curriculum: Defining desired characteristics and emerging topics," *Education+ Training*, vol. *49*(1), pp. 45-55, 2007.

[24] Gregory, M. J., "Technology management: a process approach," *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture,* vol. 209(5), pp. 347-356, 1995.

[25] Horwitch, M. and E. A. Stohr, "Transforming technology management education: Value creation-learning in the early twenty-first century," *Journal of Engineering and Technology Management*, vol. 29(4), pp. 489-507, 2012.

[26] Kerr, C., C. Farrukh,, R. Phaal and D. Probert, "Key principles for developing industrially relevant strategic technology management toolkits," *Technological Forecasting and Social Change*, vol. 80 6), pp. 1050-1070, 2012.

[27] Kocaoglu, D.F., "Research and Educational Characteristics of the Engineering Management Discipline," *IEEE Transactions on Engineering Management*, vol. 37, pp. Editorial, 1990.

[28] Kocaoglu, D. F., H. I.Sarihan, I.Sudrajat and I. P. Hernandez, "Educational trends in engineering and technology management (ETM)," in *Papers presented at PICMET 2003:* Technology Management for Reshaping the World, Portland, OR: PICMET, 2003.

[29] Koelling, C.P., M. G. Beruvides and K. Tankoonsombut, "Technology's impact on the future of industrial engineering," *Computers & industrial engineering,* vol. 31(1), pp. 5-8, 1996.

[30] Kumara, S. R., S., Joshi, R. L., Kashyap, C. L., Moodie and T. C., Chang, "Expert systems in industrial engineering," *International Journal of Production Research*, vol. 24(5), pp.1107-1125, 1986.
[31] Lee, S. and Y. Park, "Customization of technology roadmaps according to roadmapping purposes: Overall process and detailed modules," *Technological Forecasting and Social Change*, vol.72 (5), pp.567-583, 2005.
[32] Li-Hua, R. and T.M. Khalil, "Technology management in China: a global perspective and challenging issues," *Journal of Technology Management in China*, vol.1 (1), pp. 9-26, 2006.
[33] Liao, Shu-hsien, " Technology management in China: a global perspective and challenging issues," *Technovation,* vol.25 (4), pp. 381-393, 2005.
[34] Linton, J. and N., Thongpapanl, "Perspective: ranking the technology innovation management journals," *Journal of Product Innovation Management,* vol. 2 (2), pp. 123–139, 2004.
[35] Linton, J., and M., Embrechts, "MOT TIM journal rankings 2006," *Technovation,* vol.27 (3), pp. 91–94, 2007.
[36] Makrymichalos, M., J., Antony, F., Antony and M. Kumar, "Statistical thinking and its role for industrial engineers and managers in the 21st century," *Managerial Auditing Journal*, vol. 20(4), pp. 354-363, 2005.
[37] Mallick, D.N. and A. Chaudhury, "Technology management education in MBA programs: a comparative study of knowledge and skill requirements," *Journal of Engineering and Technology Management*, vol. 17(2), pp. 153-173, 2000.
[38] Manek, N. J., *Comperensive Industrial Engineering*. Firewall Media, 2002.
[39] Nambisan S. and D.Wilemon, "A global study of graduate management of technology programs," *Technovation*, vol. 23(12), pp. 949-962, 2003.
[40] Phaal, R., C.J.P. Farrukh and D.R. Probert, "A framework for supporting the management of technological knowledge," *Int. J. Technol. Manag.*, vol. 27(1), pp. 1–15, 2004.
[41] Phaal, R., C.J.P. Farrukh, and D. R. Probert, "Technology management tools: concept, development and application," *Technovation,* vol. 26(3), pp. 336-344, 2006.
[42] Salaam, H. A., S.B. How and M. F. Faisae, "Productivity improvement using industrial engineering tools," in *Papers presented at IOP Conference Series: Materials Science and Engineering*, IOP Publishing, 2012.
[43] Salvendy, G., ed. *Handbook of industrial engineering: Technology and operations management*. John Wiley & Sons, 2001.
[44] Seino, T., N. Kyomasu, T. Nomura, "Proposal of manufacturing technology management as a new research framework in technology management," in *Papers presented at PICMET'11* [CD-ROM], eds.: D.F. Kocaoglu, T.R. Anderson, T.U. Daim, Portland, OR: PICMET, July 2011.
[45] The Istitue of Industrial Engineers, "About IE", Retrieved 24/12/2013 World Wide Web, https://www.iienet2.org/details.aspx?id=282
[46] The World Bank, "Country and Lending Groups", Retrieved 24/12/2013 World Wide Web, http://data.worldbank.org/about/country-classifications/country-and-lending-groups
[47] Thongpapanl, N. T., "The changing landscape of technology and innovation management: An updated ranking of journals in the field," *Technovation,* vol. 32(5), pp. 257-271, 2012.
[48] Tran, T. A. and T. Daim, "A taxonomic review of methods and tools applied in technology assessment," *Technological Forecasting and Social Change,* vol. 75(9), pp. 1396-1405, 2008.
[49] Triantaphyllou, E., T.W Liao and S.S Iyengar, "A focused issue on data mining and knowledge discovery in industrial engineering," *Computers & Industrial Engineering*, vol. 43(4), pp.657-659, 2002.
[50] Zandin, Kjell B. *Maynard's industrial engineering handbook*. New York, NY: McGraw-Hill, 2001.