



## Türkiye'deki Üniversitelerde Endüstri Mühendisliği alanında yapılan lisansüstü tezlerin analizi

### Analysis of post-graduate theses in Industrial Engineering area of Turkish Universities

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#### Abstract

Today, engineers make efforts for post-graduate programs far more than before. The main reasons can be increasing awareness of firms about education, decreasing job opportunities for undergraduate degrees, the increasing demand for being an academican or scholarship opportunities by government. Some firms want their post-graduate student engineers to solve the firm's problems in their master or doctoral thesis as case studies. In this regard industrial engineering is a field that adjusts almost with every sector because of its multidisciplinary nature. Thus, there are many post-graduate theses written in this area. The aim of this paper is to analyze 2,122 post-graduate theses (master & doctoral) which are carried out in the department of industrial engineering in Turkish universities. The data is obtained from the website of Council of Higher Education of Turkey. The time period is determined as 2010-2017 and only the 1780 "permission" theses are analyzed in order to reach keywords for solution approaches and keywords analysis. Nine different indicators are used to analyze the thesis such as; university status, page numbers, language, keywords etc. As a result, this study shows how the theses are clustered according to different indicators and which topics are studied more frequently in recent years. The inference of the paper is important because the results give an insight about the road map of industrial engineering thesis completed in 56 different Turkish universities.

**Keywords:** Doctoral, Industrial engineering, Master, Meta-analysis, Post-graduate thesis

#### Öz

Günümüzde, mühendisler lisansüstü programlar için eskisinden çok daha fazla çaba harcamaktadır. Bu durumun başlıca nedenleri arasında, firmaların eğitim hakkındaki farkındalığının artması, lisans derecesi için iş imkânlarının azalması, akademisyen olma talebinin veya burs olanaklarının artması gösterilebilir. Ayrıca, bazı firmalar lisansüstü eğitime devam eden mühendislerinden yüksek lisans veya doktora tezlerinde vaka çalışması olarak firmalarının problemlerini çözmelerini isteyebilir. Bu bağlamda, endüstri mühendisliği çoklu disiplinli yapısı nedeniyle hemen hemen tüm sektörlerde kullanılabilen bir alandır. Bu yüzden bu alanda yazılmış birçok lisansüstü tez bulunmaktadır. Bu çalışmada, Türkiye'deki üniversitelerin endüstri mühendisliği bölümlerinde yürütülmüş 2122 lisansüstü tezin (yüksek lisans & doktora) analiz edilmesi amaçlanmıştır. Veriler yükseköğretim kurumu web sitesinden elde edilmiştir. Zaman periyodu olarak 2010-2017 yılları belirlenmiş olup çözüm yöntemleri ve anahtar kelimelerin analizinde ise anahtar kelimelere ulaşılabilmesi amacıyla yalnızca 1780 adet "izinli" tez dikkate alınmıştır. Tezlerin analizinde üniversitelerin durumu, sayfa sayısı, dil, anahtar kelimeler gibi dokuz farklı gösterge kullanılmıştır. Sonuç olarak, bu çalışma tezlerin farklı göstergelere göre nasıl kümelendiğini ve son yıllarda hangi konuların daha sıklıkla çalışıldığını göstermektedir. Çalışmanın sonuçları, Türkiye'deki 56 farklı üniversitenin endüstri mühendisliği bölümlerinde tamamlanan tezlerin yol haritası hakkında fikir vermesi açısından oldukça önemlidir.

**Anahtar kelimeler:** Doktora, Endüstri mühendisliği, Yüksek lisans, Meta-analiz, Lisansüstü tez

## 1 Introduction

Industrial engineering deals with figuring out how to make or do things better. Industrial engineers are concerned with reducing costs, increasing efficiency, improving the quality of products or services, ensuring worker health and safety, protecting the environment and complying with government regulations. They try to eliminate waste of time, money, materials, energy and other commodities in their multi discipliner work fields [1]. There are 70 industrial engineering departments in Turkey however 56 of them give a graduate education. But, the more an engineer is educated, the more productive it becomes. Thus, post-graduate study is another opportunity to study a subject in more depth. People do further study for a number of reasons including; an interest in the

subject, to gain a career advantage, being a necessity for entry to a particular occupation, becoming an academican, obtaining patents etc. Although it was a privilege to have a bachelor's degree before, now it is a privilege to have a master or doctoral degree.

According to a scientific research by Erginel, Tekce, Küçük and Alper [2] the success of the post-graduate program on industrial engineering is found to be very successful with respect to the questionnaire. More than half of the attendants (51%) stated that they find these programs very effective both for their knowledge and success. Thus these findings show the necessity of industrial engineering post-graduate programs in Turkey.

But as long as the post-graduate studies focus on universal consent, they don't contribute to the solution of the problems

of our country thus remaining the theses on the shelves. In order to prevent this, it is inevitable to carry out all kinds of researches that solve the real problems. In this regard, taking precautions for concentrating on real problems or encouraging interdisciplinary studies will also debottleneck the post-graduate research [3]. According to Das and Handfield [4], although the academic maturity of any discipline can be assessed in a variety of ways (published articles, books and etc.), dissertation research provides a useful method of evaluating conceptual and empirical contributions to the field. Jack, Stephens and Evans [5] noted that dissertation research is typically leading-edge, often breaks new ground by filling in gaps in a body of knowledge, synthesizes a wide body of previously published research, and captures trends earlier than research published in typical archival journals. The aim of this paper is to analyze the post-graduate theses in industrial engineering field and determine the trends and reflect prior research topics for latter studies. Thus, it is expected that this study will help the researchers to understand the historical development of this field and find themselves appropriate research fields. In this regard, 2,122 post-graduate theses which are carried out in the department of industrial engineering between 2010 and 2017 are analyzed. Turkish Council of Higher Education website is utilized for obtaining the

data. Firstly a statistical map of Turkish post-graduate studies is shaped by using graphs; later the implications are lined up.

The remainder of this paper is organized in the following manner. A summarized literature review about the related studies is given in Section 2. In Section 3, we explain the research methodology with analyzing the data. The results for each major category are analyzed and discussed in Section 4. Finally, we present some brief conclusions of this work in Section 5.

## 2 Literature review

In the literature, there are many studies on the examination of post-graduate theses in different disciplines. These studies are very important in the sense that they provide guidance for future work by exposing the current situation and trends related to the field in which the work is done. Detailed information about the reviewed studies is given in Table 1. As can be seen from Table 1, dissertation analyses are conducted in different fields such as quality management [5]; public relations [6]; social studies education [7],[8]; human resources [9]; education sciences [10],[11]; marketing [12]-[14]. While some of the studies [5],[6] investigate only doctoral theses, some of them [14] examine only master theses.

Table 1: Literature review on the studies which investigate theses.

Description	[5]*	[6]	[7]	[9]	[10]	[8]	[11]
Discipline	Quality management	Public relations	Social studies education	Human resources	Education sciences	Social studies education	Education history
Number of thesis	523	62	100	2216	229	612	61
Master	0	0	100	1953	0	550	53
Doctoral	523	62	0	263	229	62	8
Scanned Years	1981-1998	1965-2004	2000-2007	1983-2008	2003-2008	1990-2010	1987-2010
Country	All the World	Spain	Turkey	Turkey	Turkey	Turkey	Turkey
Classification by							
Years	√			√		√	√
Universities		√		√		√	√
Accessibility						√	√
Keywords	√					√	√
Gender		√					√
Advisor							√
Methods	√			√	√		√
References							√
Country							
Context	√	√	√	√	√		
Language		√		√			

Description	[12]	[17]	[18]	[13]	[19]	[20]	[14]	Proposed study
Discipline	Marketing	Geography education	Tourism	Social marketing	Mathematics	Food beverage industry	Social marketing	Industrial engineering
Number of thesis	184	422	332	93	41	179	266	2122
Master	0	360	0	0	35	162	266	1771
Doctoral	184	62	332	93	6	17	0	351
Scanned Years	1994-2012	2000-2012	2000-2009	1971-2013	2004-2013	1988-2013	1971-2015	2010-2017
Country	Turkey	Turkey	United Kingdom; Ireland	All the World	Turkey	Turkey	All the World	Turkey
Classification by								
Years	√	√	√		√	√		√
Universities	√	√	√			√		√
Accessibility								√
Keywords	√	√		√			√	√
Gender								√
Advisor						√		
Methods	√				√			√
Country				√			√	
Context			√	√	√	√	√	√
Language								√
Province								√
Page number								√

\*: [5] Jack et al. (2001), [6] Xifra and Castillo (2006), [7] Oruç and Ulusoy (2008), [9] Benligiray (2009), [10] Karadağ (2010), [8] Şahin et al. (2011), [11] Uygun (2012), [12] Bakır (2013), [17] Kaya (2013), [18] Afifi (2013), [13] Truong et al. (2014), [19] Yenilmez and Sölpük (2014), [20] Aydın (2017), [14] Truong and Dietrich (2018).

When we focus on the industrial engineering field, there is a limited number of studies aimed at increasing the quality of education of industrial engineering and determining trends by examining theses done on this area. Köksal and Eğitman [15] presented a quality function deployment approach to improve the quality of education at the Middle East Technical University. Li and Ying [16] focused on enhancing the skills of industrial engineering undergraduate students with graduation theses. Erginel et al. [2] examined the existing situations of working industrial engineers at industry. To the best knowledge of the authors, it is the first study which conducts a meta-analysis on post-graduate theses carried out in industrial engineering area. In this context, the research intends to draw a chronological and geographical map of the theses awarded as well as identify major trends in industrial engineering masters/PhDs. Thus, this research may be significant for different stakeholders: first, Turkish universities, which may receive this research as an indicator to understand their locations on the industrial engineering post-graduate education map; second, planners of industrial engineering education who need to have an overview of the trends and gaps in industrial engineering post-graduate education in Turkey; third, international researchers, who can use the Turkey model as a benchmark when studying post-graduate in industrial engineering area in their countries; and finally, post-graduate students who want to have a broader view of the possibilities of conducting future industrial engineering theses.

### 3 Methodology and database

The past few years have seen an increase in the number of tools for identifying and cataloguing scholarly material. Particularly, the advent of the internet has allowed for the blossoming of online databases, making it much easier and quicker to search for theses and dissertations from most parts of the world [14]. As a result, researchers can conduct faster, more systematic and therefore more thorough analyses than ever before.

To identify master and doctoral theses that focused on industrial engineering, this study made use of the national thesis center database of The Council of Higher Education which is a major source of master's theses and doctoral dissertations in Turkey and has been utilized by previous studies [20]. To do so, a search query with the division "Industrial Engineering" and the year range "2010-2017" is used. While analyzing the solution methods and the keywords, the access type was scanned as "Authorized". The interface of the query screen is illustrated in Figure 1.

#### 3.1 Population and sample

This search strategy resulted in 2,122 theses which include 1,771 master and 351 doctoral theses carried out in Industrial Engineering Department of Turkish universities. It must be noted that 2,122 theses consist of theses with and without permission. Table 2 and Figure 2 show the distribution of all theses from 2010 to 2017. According to Table 2, number of master theses is five times greater than number of doctoral theses in total.

The screenshot shows the 'Thesis Center' search interface. At the top, there is a navigation menu with options: Home, Search, Legislation, Statistics, FAQ, Thesis Publishing Permit, Legal Notice, Contact, and Help. Below this, there are tabs for 'Detailed Search', 'Advanced Search', 'Recently added', and 'Preparing theses'. The 'Detailed Search' section contains several input fields and dropdown menus: University (Choose), Institute (Choose), Division (Endüstri Mühendisliği Anabilim Dalı), Discipline (Choose), Subject (Choose), Keyword (Keyword), Thesis type (Select), Access type (Select), Status (Select), Language (Select), Group (Select), Year (2010 <=Year<= 2017), Thesis No (Thesis No), Title (Title), Author (Author), Supervisor (Supervisor), and Abstract (Abstract). There are 'Search' and 'Clear' buttons at the bottom of the search form.

Figure 1: Interface of the query screen.

Table 2: Distribution of theses (both with and without permission) according to years.

Year	Master	Doctoral	Total
2010	217	42	259
2011	201	40	241
2012	208	38	246
2013	251	33	284
2014	227	52	279
2015	254	48	302
2016	217	58	275
2017	196	40	236
Total	1,771	351	2,122

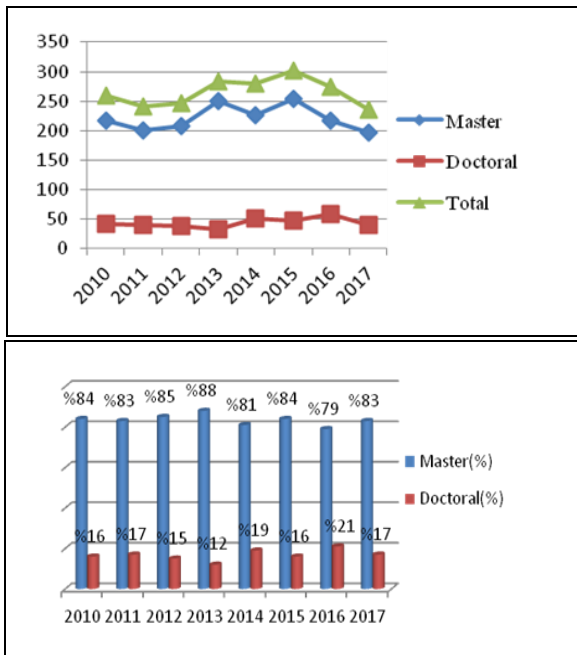


Figure 2: Number of thesis (up) and percentages (bottom) in each year.

This paper was limited to post-graduate theses made between the years of 2010-2017 on the website of The Council of Higher Education. Sample of the study for solution approaches and keyword analysis was taken as theses with permission access state in the database for in order to reach keywords. Hence, 1,771 master theses and 351 doctoral theses were examined in the study. Also, 1,518 master theses and 262 doctoral theses were examined for solution approaches and keyword analysis as the sample in the study. Distribution of accessible (with permission) theses based on years is given in Table 3 and Figure 3.

Table 3: Distribution of accessible theses according to years.

Year	Master	Doctoral	Total
2010	216	42	258
2011	198	39	237
2012	208	38	246
2013	249	32	281
2014	227	52	279
2015	191	22	213
2016	132	29	161
2017	97	8	105
Total	1,518	262	1,780

According to Figure 3, the number of master and doctoral theses with permission is started to decrease after 2014. Conversely, the number of theses which cannot be downloaded is increasing. The main reason is possibility of scientific publication of the authors and advisors. As we know that if a thesis is up-to-date, a paper from that thesis can be published in following years. For that reason, the authors choose to put a time limit to prevent the right of publication. Consequently, 83.88% of total theses (2,122) are chosen as the study sample for keyword analysis. The theses were added into a Microsoft Office Excel 2010 database. This data set included based on the indicators represented in Table 4. Then, results are tabulated and summarized using descriptive statistics given in following sub-sections.

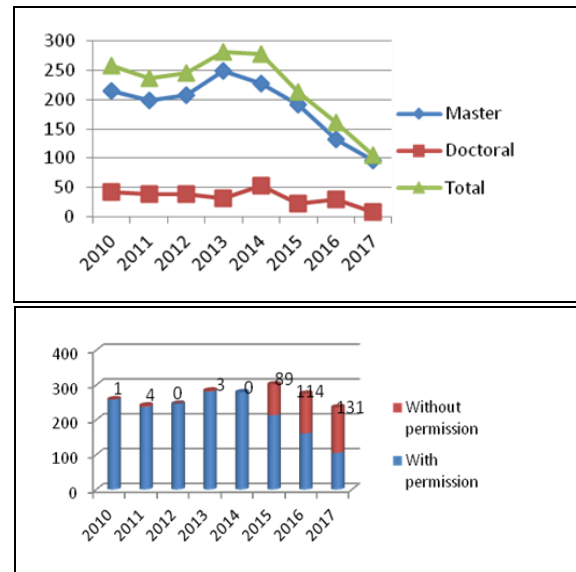


Figure 3: Distribution of accessible theses by years (up) and in total (bottom).

Table 4: Indicators in the study.

Indicator	Definition
University	University where the thesis was made
Province	City where the thesis was made
Status of university	University status (Public / Private)
Degree	Graduate degree (Master / Doctoral)
Gender	Gender of the author (Female / Male)
Language	Language in which the thesis is written (Turkish / English / French)
Page number	Page number of thesis
Content	The content of the thesis includes an application or it is theoretical (Theoretical / Applied)
Keywords	Keywords of thesis

## 4 Results

In this section, different descriptive statistics using created database file are presented. The results are organized into seven main sub-sections:

- (1) : Distribution of theses by universities and universities' status,
- (2) : Distribution of theses by provinces,
- (3) : Distribution of theses by gender,
- (4) : Distribution of theses by language and page numbers,
- (5) : Distribution of theses by content,
- (6) : Distribution of theses by solution approaches and
- (7) : Distribution of theses by keywords.

### 4.1 Distribution of theses by universities and universities' status

Post-graduate theses were carried out at 56 universities in total, and distribution by universities of these theses is presented in Figure 4. Three universities with highest numbers of the theses are İstanbul Technical University, Gazi University and Boğaziçi University, respectively. Sum of post-graduate theses made in these three universities constitutes 25.64% of the total.

The distribution of the number of theses according to the universities by master and doctorate is provided in

Figure 5 and Figure 6. Three universities with highest numbers of the master theses are İstanbul Technical University, Boğaziçi University and Gazi University. Three universities with highest numbers of the doctorate theses are İstanbul Technical University, Gazi University and Yıldız Technical University, respectively.

Results obtained by examination of university status (public or private) are presented in Figure 7. 41 doctoral and 537 master theses were carried out in private universities. So, total of 578

theses were completed in private universities. 310 doctoral and 1,234 master theses, eventually total of 1,544 theses were completed in public universities.

Interchange of thesis numbers by years based on university status is presented in Figure 8. As can be seen from Figure 8, while the number of theses in private universities is increasing, conversely, it is decreasing in public universities. The main reason of this situation should be explained with the increasing number of new private universities.

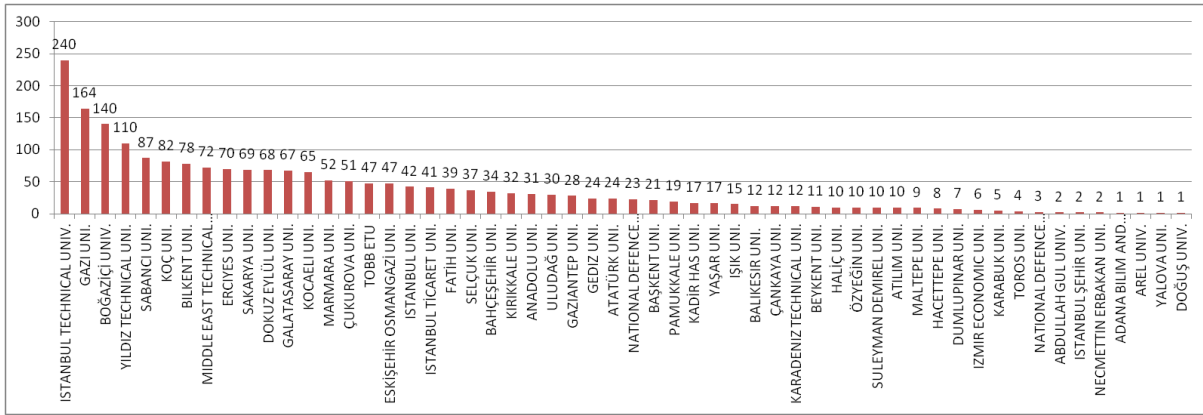


Figure 4: Number of theses by universities.

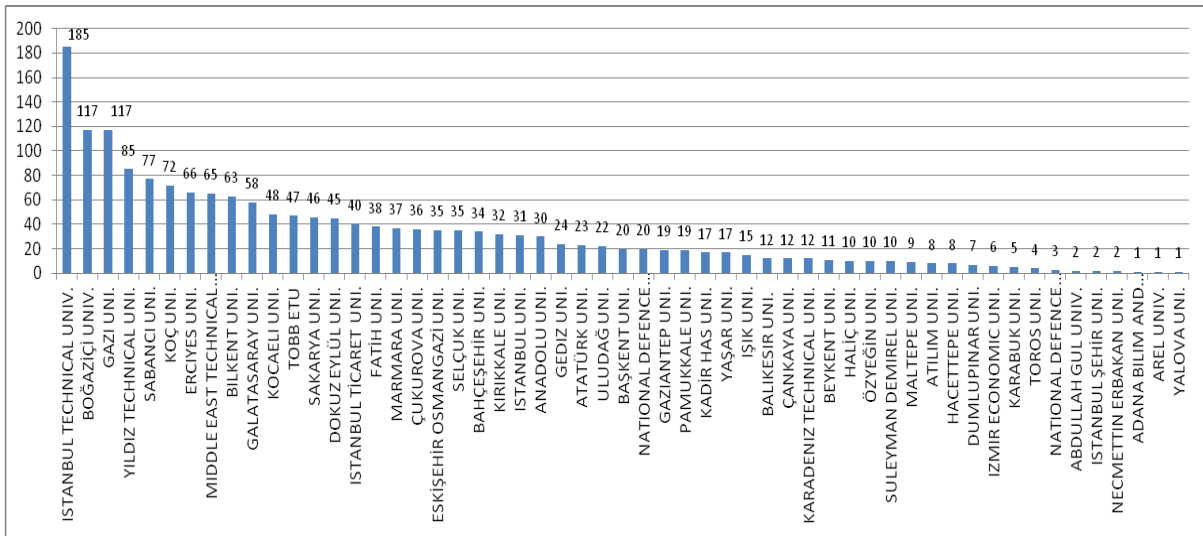


Figure 5: Number of master theses by universities.

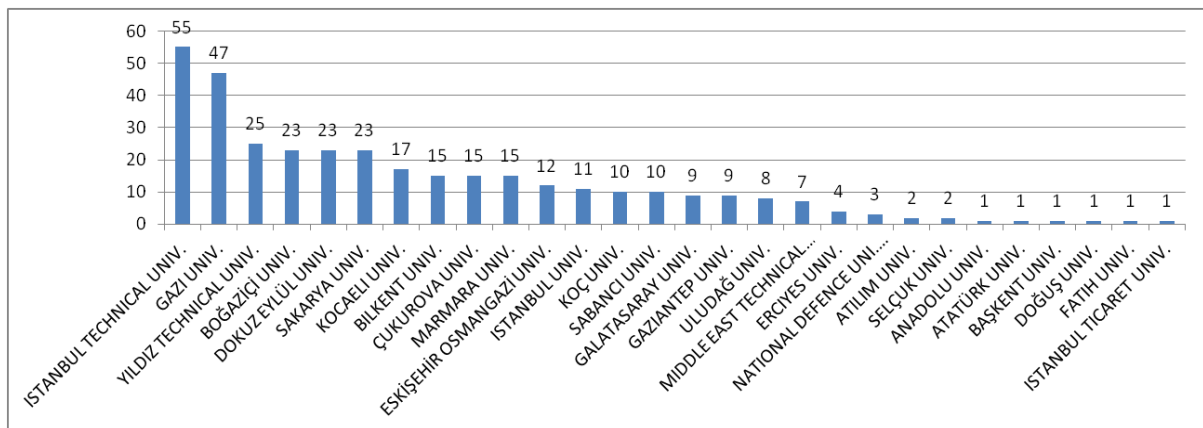


Figure 6: Number of doctorate theses by universities.

#### 4.2 Distribution of theses by provinces

Distribution of the theses by the province in which university is located is presented in Figure 9. Among 21 cities out of 81 cities, Istanbul was observed as well ahead of other cities. Following, Ankara and Izmir were observed to have the highest number of theses respectively. The ratio of the number of completed thesis in the provinces to the number of universities is represented in Table 5. Although Istanbul has 22 universities where students can write theses, Sakarya and Kocaeli have the highest ratio with only one university among other cities.

Distribution of carried out theses among the cities is also shown in Figure 10. According to Figure 10, half of all the theses are completed in Istanbul. Rest of the theses is distributed in the middle, south and west of Turkey. It means that the students who are living in north and east of Turkey and wish to conduct a thesis in industrial engineering area, they need to apply the cities which are shown in black. It must be noted that Figure 10 does not provide any insight about the relationship between geographical locations of theses and industrial zones. This figure only supports that there is a relationship between the number of theses and post-graduate programs.

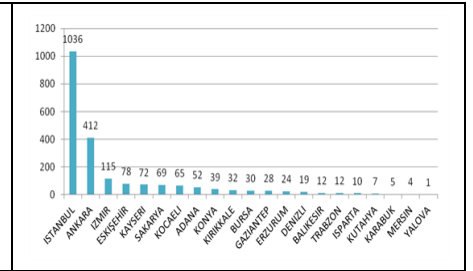
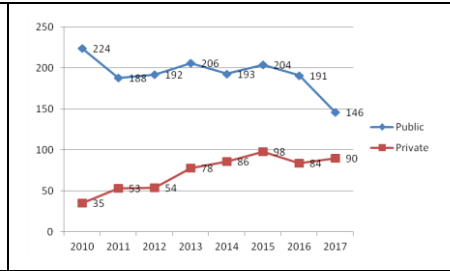
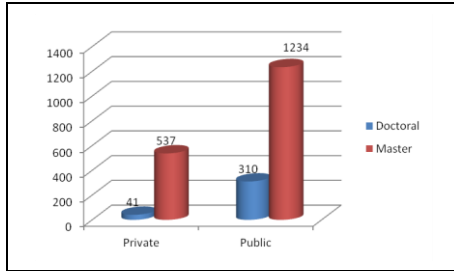


Figure 7: Classification of theses based on status of university.

Figure 8: Change of thesis according to university status over the years.

Figure 9: Number of theses by province.

Table 5: The ratio of the number of completed thesis in the provinces to the number of universities.

Province	Number of Universities	Ratio*	Province	Number of Universities	Ratio*
Sakarya	1	69.00	Erzurum	1	24.00
Kocaeli	1	65.00	Konya	2	19.50
Ankara	8	51.50	Denizli	1	19.00
Istanbul	22	47.09	Balıkesir	1	12.00
Eskişehir	2	39.00	Trabzon	1	12.00
Kayseri	2	36.00	Isparta	1	10.00
Kırıkkale	1	32.00	Kütahya	1	7.00
Bursa	1	30.00	Karabük	1	5.00
Izmir	4	28.75	Mersin	1	4.00
Gaziantep	1	28.00	Yalova	1	1.00
Adana	2	26.00			

\*: Number of thesis/number of universities.

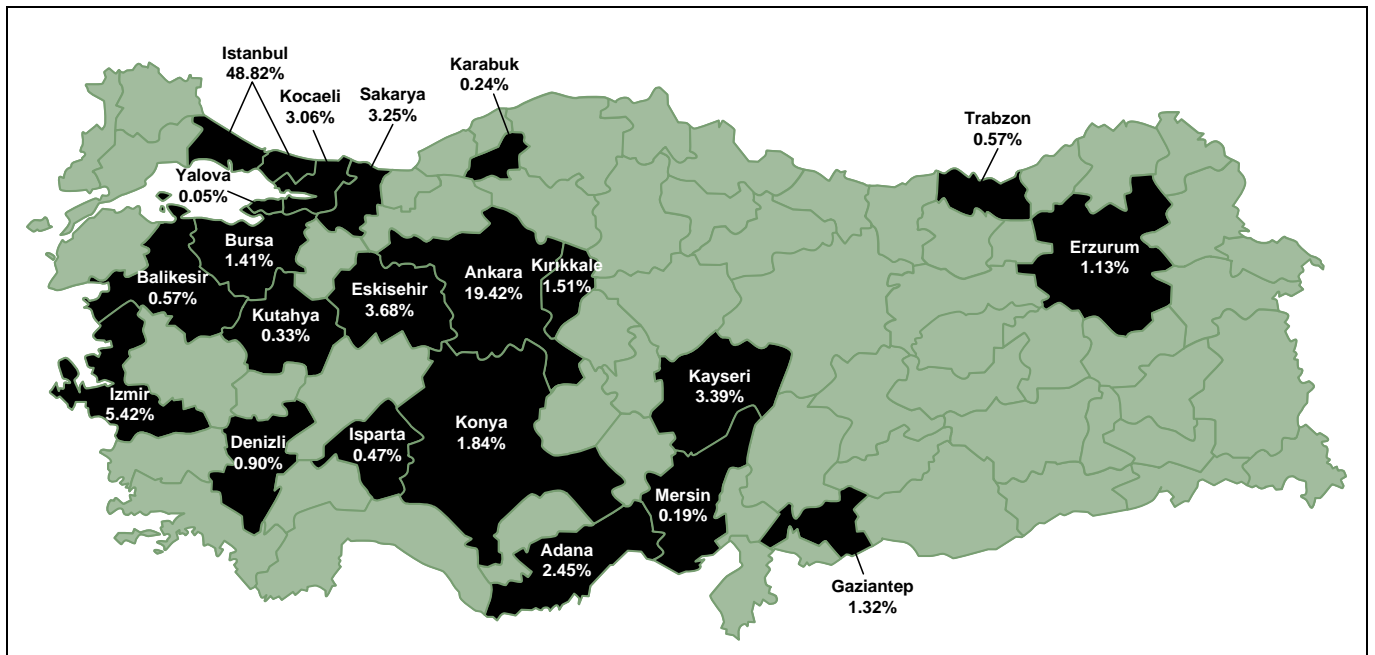


Figure 10: Geographical distribution of the theses.

### 4.3 Distribution of theses by gender

When classified by genders of authors, male / female ratio is observed as almost equal. 1,055 theses are written by male authors, while 1,067 theses are written by female authors. Numbers is shown in Figure 11. The study reveals that master and doctoral programs in industrial engineering area are not dominated by men, who account for 49.72% of theses written compared to 50.28% of women. If we look at the Figure 11, there is not a dominant side in terms of gender. The distribution of the authors by gender and years is shown in Figure 12.

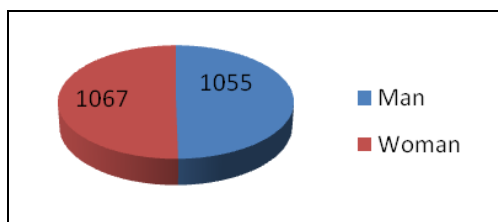


Figure 11: Gender of the authors by years.

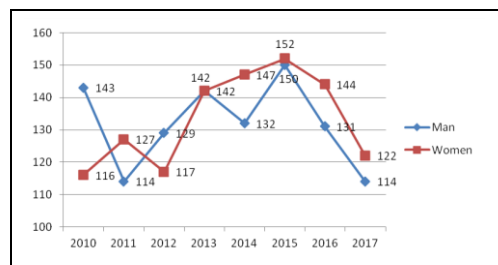


Figure 12: Distribution of authors by gender.

### 4.4 Distribution of theses by language and page numbers

Examined theses are written in three languages as in Turkish, English, and French. 1,239 theses are in Turkish, 880 theses are in English, and 3 theses are in French. The number of theses by language is presented in Table 6.

Table 6: Theses by written language.

	Master	Doctoral	Total
Turkish	1022	217	1239
English	746	134	880
French	3	0	3

61.82% of doctoral theses are written in Turkish, while 38.18% are written in English. 57.71% of master theses are written in Turkish, while 42.12% are written in English, and 0.17% is written in French. The distribution of thesis types by language is also shown in Figure 13.

When the theses are classified by the page numbers, results in Figure 14 are obtained. Accordingly, most common ranges of page number of the theses were [101-150] with 825 theses, and [51-100] with 814 theses. When master and doctoral theses are examined separately, it is observed that master theses consist of averagely 111.23 pages, while doctoral theses consist of averagely 178.34 pages.

It was comprehended that the master theses examined consisted of a minimum of 35 and a maximum of 402 pages while the doctoral thesis consisted of a minimum of 70 and a maximum of 470 pages. The distribution of thesis types by page numbers is represented in Figure 15.

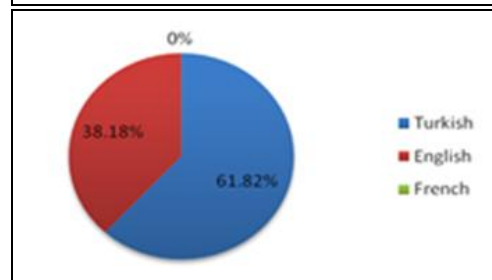
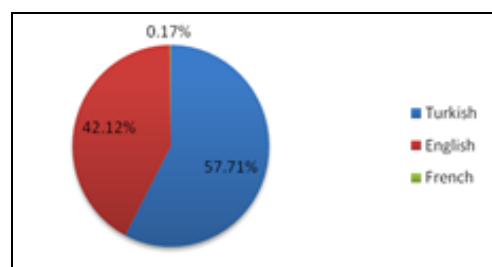


Figure 13: Distribution of thesis types (up: master, bottom: doctoral) by language.

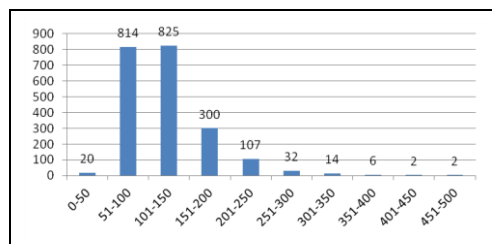


Figure 14: Classification of theses by page numbers.

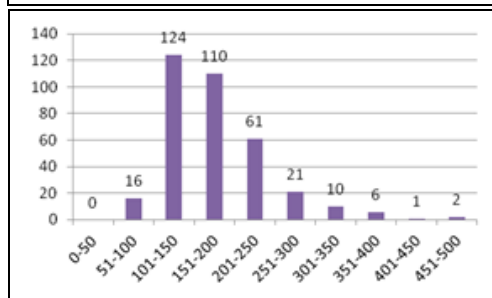
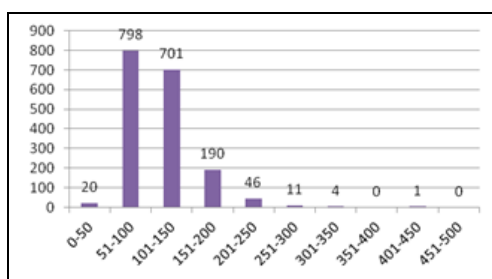


Figure 15: Distribution of thesis types (up: master, bottom: doctoral) by page numbers.

### 4.5 Distribution of theses by content

When the theses are examined in terms of their content (including theoretical or application), the results given in Table 7 are obtained. While 43.93% of the master's theses are theoretical, remaining 56.07% of them are applications. In addition, while 64.39% of doctoral theses are theoretical, remaining 35.61% of them are applications. Thus it can be

implied that while master theses focus on application studies, the theoretical studies have come to the fore in the doctoral theses.

The percentage distribution of theses in terms of their content is given in Figure 16. It is seen that there are a lot of studies in the master theses in all years. In 2013, the percentages of theoretical and application theses got closed to each other and a more balanced distribution was formed in the following years. In the doctoral thesis, it was observed that theoretical studies were more prevalent until 2014, and then there was a significant increase in the studies involving the practice. However, theoretical studies maintain their superiority.

#### 4.6 Distribution of theses by solution approaches

Solution methods are explained in Table 8. Utilized solution methods are classified as simulation, heuristic/meta heuristic methods, mathematical programming, multi-criteria decision making methods, artificial neural network, fuzzy and grey theory/modeling, statistical/data mining/time series methods, problem solving and lean techniques and others. Results of examination of theses in terms of solution methods are presented in Table 9. For theses that utilize more than one solution method, all methods are considered separately. Most frequently utilized methods were: heuristic/meta heuristic methods in 2010, multi-criteria decision making methods in 2011, multi-criteria decision making methods and mathematical programming methods in 2012, heuristic/meta heuristic methods in 2013, multi-criteria decision making methods in 2014, mathematical programming methods in

2015, mathematical programming methods again in 2016 and multi-criteria decision making methods in 2017.

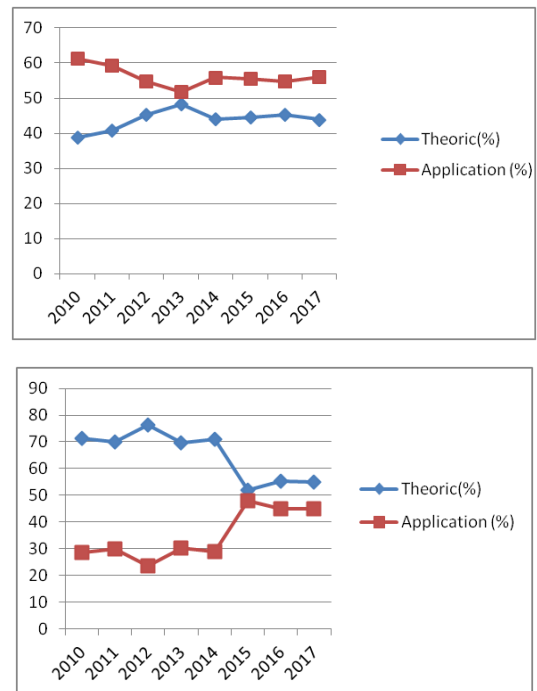


Figure 16: Distribution of thesis (up: master, bottom: doctoral) by content.

Table 7: Theses by content.

	Master		Doctorate	
	Theoric	Application	Theoric	Application
2010	84	133	30	12
2011	82	119	28	12
2012	94	114	29	9
2013	121	130	23	10
2014	100	127	37	15
2015	113	141	25	23
2016	98	119	32	26
2017	86	110	22	18

Table 8: A brief summary of solution methods.

Solution Methods	Explanation
Simulation	Simulation signifies the imitation of the operation of a system over time [21].
Heuristic/Metaheuristic	Heuristic methods without ensuring the best solution, are the methods that aim to grant nearly optimal solution with a shorter solution time. Meta-heuristics algorithms are the iterative generation process which guides a simple heuristic for exploring and exploiting the search space[22].
Mathematical programming	Mathematical programming is a language for describing optimization problems; it is based on parameters, decision variables, objective function(s) subject to various types of constraints [23].
Multi criteria decision making methods	Multi criteria decision making methods is the process of giving values to alternatives by evaluating many criteria at the same time[24].
Artificial neural network	Artificial neural networks have been developed by the idea of simulating the biological operation of the human brain on computers and constitute a data processing technology concentrated on the mathematical modeling of biological cells [25].
Fuzzy and grey theory	Fuzzy theory is based on the intuitive reasoning by taking into account the human subjectivity and imprecision [26].
Statistical methods / Data mining methods / Time series methods	Statistics reviews the collection, presentation, organization, analysis, and explanation of the data [27]. The aim of data mining is to extract valuable information from a large amount of data [28]. Time series analysis includes statistical analysis of data observed at regular intervals over time so that the data can be predicted reliably for the future periods [29].
Problem solving and lean techniques	Flow diagrams, cause-effect analysis, swot analysis, etc. are essential techniques for handling, analyzing and solving a problem.



Table 9 indicates that the identified solution methodologies on industrial engineering area were housed in a wide range of contexts, with multi-criteria decision making (MCDM) methods (17.99%) and mathematical programming (17.99%) being engaged in the largest number of these. The solution techniques of heuristics/meta-heuristics provided the study context for 16.42%, followed by statistical methods (14.02%). This finding confirms that the most popular solution techniques in industrial engineering area, namely MCDM, heuristic/meta-heuristic approaches and mathematical programming are the predominant approaches for industrial engineering related problems at both master and doctoral levels. As a result, very few these were housed and explored the potential of other

solution approaches in industrial engineering problem area such as simulation and artificial neural network. The detail list about the solution approaches is given in Table 10. Most considered 7 techniques are shown based on year under main solution approach in Table 10. According to this table, the most popular technique which is applied in both master and doctoral theses is analytic hierarchy process (AHP) under MCDM title. Among the heuristic/meta-heuristic approaches, genetic algorithm which is an evolutionary algorithm is the most preferred one. On the mathematical programming side, due to the nature of industrial engineering problem area, mixed integer models are very popular.

Table 9: Distribution of solution methods by years.

	Simulation	Heuristic / Meta heuristic	Mathematical programming	Multi criteria decision making methods	Artificial neural network	Fuzzy and grey theory / modeling	Statistical methods / Data mining methods / Time series methods	Problem solving and lean techniques	Others
2010	19	51	41	29	22	13	34	17	38
2011	12	41	38	67	16	14	30	20	30
2012	13	35	47	47	19	14	31	9	35
2013	11	65	38	39	12	16	47	15	41
2014	16	57	61	70	10	8	47	4	47
2015	8	23	51	37	5	10	41	8	33
2016	12	33	44	29	9	13	24	6	21
2017	9	9	24	26	5	7	14	5	20

Table 10: Applied techniques in the considered thesis.

MCDM Techniques	2010	2011	2012	2013	2014	2015	2016	2017	Total
AHP	8	31	20	11	27	12	12	9	130
ANP	9	14	8	3	8	6	2	1	51
TOPSIS	3	6	9	6	7	4	4	2	41
VIKOR	0	2	2	2	2	3	1	4	16
PROMETHEE	2	5	2	1	2	1	1	1	15
ELECTRE	0	1	1	1	4	2	1	0	10
MOORA	0	1	0	0	1	1	0	0	3
Total	22	60	42	24	51	29	21	17	266
<b>Heuristic/Meta-Heuristic Techniques</b>									
Genetic Algorithm	18	12	11	18	17	1	6	1	84
Simulated Annealing	3	6	1	2	9	2	2	0	25
Tabu Search	3	7	4	6	1	2	0	1	24
Ant Colony Optimization	4	4	1	3	2	1	1	1	17
Particle Swarm Optimization	2	3	2	1	3	2	0	0	13
Local Search	3	0	1	1	2	1	2	0	10
Bees Algorithm	1	0	2	4	2	0	1	0	10
Total	34	32	22	35	36	9	12	3	183
<b>Mathematical Modeling Techniques</b>									
Mixed Integer Programming	5	4	9	10	7	6	3	3	47
Integer Programming	3	3	4	4	7	1	6	2	30
Goal Programming	4	1	4	2	5	3	2	6	27
Linear Programming	3	2	5	1	5	2	2	1	21
Stochastic Programming	3	3	4	1	7	5	1	2	26
Decomposition Methods	1	1	0	1	2	5	5	0	15
Column Generation	5	1	0	1	4	1	1	0	13
Total	24	15	26	20	37	23	20	14	179
<b>Other Techniques</b>									
Simulation	19	12	13	11	16	8	12	9	100
Fuzzy Theory	12	11	11	9	7	7	10	7	74
Artificial Neural Network	15	12	10	6	8	4	4	3	62
Six Sigma	7	3	1	4	1	3	4	1	24
Quality Function Deployment	1	4	2	3	4	3	3	2	22
Data Mining	3	4	0	4	5	3	1	0	20
Data Envelopment Analysis	3	3	1	7	2	3	1	0	20
Total	60	49	38	44	43	31	35	22	322

#### 4.7 Distribution of theses by keywords

In this section, 12,573 keywords are analyzed to provide insights regarding to the most frequently used keywords. Due to the huge number of keywords, they are classified according to their context. The main and sub groups of keywords which are determined according to number of usage are shown in Table 11.

Usage frequencies of main-group keywords are given in Table 12 for each year. Obtained results indicate that subjects related to production and supply chain management were the most frequently studied subjects on post-graduate theses by industrial engineers. Followed by, scheduling and information management subjects came in third and fourth places. Least frequently studied subjects were marketing/human resources/customer relationship management. This issue seems normal when the scope of industrial engineering is examined. Although there are enough keywords related to the classical research areas in industrial engineering, it is believed that there should be more studies related to the “Information management and technology, decision support systems” main group because of current information age. The importance of information technology and business process redesign is critical for industrial engineers. Because the information technologies are used for analysis and modeling and industrial engineers are keen on applying these technologies to manufacturing processes. Especially the Industry 4.0 content forces to integrate all manufacturing processes with internet of things, big data utilization etc. But when the keywords are

analyzed, only a few topics are determined that focus on Industry 4.0 and/or up to date technologies. There were 1 “Big Data”, 2 “Cloud Computing” and 2 “3D Bioprinting” keywords within this context. It is expected that the post graduate thesis will focus on these topics in near future.

#### 5 Conclusion

The post-graduate studies are important from two points of views. The first one is about personal development, the programs gives education at higher levels thus helping the students develop their necessary skills for their work. Secondly, the educated workforce can result in economic development. The nations can make use of this educated workforce themselves or when the educated workforce becomes well-known, it can attract international investment. In this regard, motivation of this study is to figure out the dispersion of industrial engineers post-graduate theses to analyze the general situation and trends.

As a summary, in this study 2,122 post-graduate theses are analyzed which are carried out in the department of industrial engineering in Turkish universities. Nine different indicators are used for the analysis. To not to repeat ourselves all the findings of the paper is not written in conclusion and can be found in related sections of the study. But it is noted that heuristic/meta-heuristic and multi-criteria decision making methods are used in recent years more frequently in the theses. Also production and supply chain management related topics are determined as the most recent studied topics.

Table 11: Classification of analyzed keywords.

Main-group	Sub-group
Information management and technology / Decision support system	Decision Support System, ERP, Electronic Data Interchange, Mobile, E-Commerce, Information Management, Geographic Information System, RFID, Information Technology, Wireless
Quality	Quality, ISO/TSE, Statistical Quality Control
Production	Stock, Assembly Line Balancing, Assembly, Demand, Production Planning, Production, Inventory, Machine
Scheduling	Scheduling
Risk	Risk
Marketing / Human Resources / Customer Relationship Management	Marketing, Human Resources, Customer Relationship Management
Performance	Performance
Supply Chain Management / Logistics	Logistics, Supply, Supplier, Supply Chain, Transport, Vehicle Routing, Travelling Salesman Problem, Facility, Site Selection
Cost	Cost, Pricing, Finance, Accounting, Investment
Occupational Health and Safety / Ergonomic / Work study / Time Study	Occupational Health, Occupational Safety, Ergonomic, Safety, Job Evaluation, Work study, Time study

Table 12: Classification of analyzed keywords.

	Information management and technology, Decision support system	Quality	Production	Scheduling	Risk Management	Marketing, Human Resources, Customer Relationship Management	Performance	Supply Chain Management	Cost	Occupational Health and Safety, Ergonomic, Work study, Time Study
2010	16	11	35	27	6	3	10	57	15	3
2011	15	9	45	20	3	4	13	42	8	3
2012	19	7	47	24	12	4	10	40	18	4
2013	24	7	46	27	8	3	14	54	14	8
2014	15	9	44	29	21	2	9	59	20	2
2015	5	2	39	17	10	1	7	47	9	15
2016	9	11	32	11	10	1	8	38	12	3
2017	8	8	15	12	2	4	2	28	5	1

Since the analysis results are differing according to the universities, the developing universities can benefit from the role model ones. In this regard, especially the keyword analysis can help the researchers to find themselves a promising topic. Also analysis from other countries would be very helpful to understand how the topics are changing according to the countries. For the future studies, a statistical analysis should be conducted to investigate the relationship between geographical distributions of the theses and the potential jobs or population of provinces and the number of theses.

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