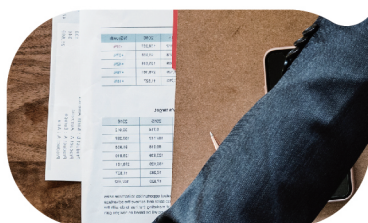


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ARTICLE

Factors Affecting Selection of Elective Courses: The Use of Multi-Criteria Decision Making Model

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ABSTRACT

Elective course selection has always been a serious and important decision making process for students in institutions. The aim of this study is to determine weights of factors affecting elective course selection from students' perspective. So as to solve the problem, Analytic Hierarchy Process (AHP) based model was used. Factors which affect the elective course selection from students' point of view include five main criteria and 13 sub-criteria which were indicated by students. An online questionnaire containing demographic questions, enabled each student to compare the relative priority of criteria with all of the other criteria. The responses were evaluated via Super Decisions software, and priorities were determined using the Analytic Hierarchy Process (AHP). According to the analysis of 40 experts (i.e., graduate students studying in engineering programs), course schedule and teaching staff related factors are the two most important factors affecting the elective course selection. A real-life situation which will help students who are indecisive and hesitates while selecting an elective course was observed. AHP contributes to develop an analytic and comprehensive framework decision making. The method should be considered by faculty member involved in decisions about curriculum update and offering new courses.

1. Introduction

Decision making is the process of selecting one or more options based on at least one target direction and accordingly at least one criterion among the available options. The decision-making process mainly involves decision makers, decision-making alternatives, criteria, environmental factors, and decision results in the direction of the decision-maker's priorities. The process ends with the decision maker sorting the alternatives and

choosing one among them. In order to make the right decision in this decision process, very specific decision making methods come to the forefront^[1].

Multi-criteria decision-making is the whole set of practices that help people make the right decision under multiple criteria that conflict with one another in the direction of their preferences. It can be said that multi-criteria decision making is a process in which a complex problem can be analyzed in detail and then broken down into smaller, comprehensible parts^[2].

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In almost all universities, students have to choose courses from among many elective courses in the teaching process. Decision making within this course selection process is not easy since it is not possible to select the most appropriate choice among the many different courses in the decision making process. The aim of the study was to select the most appropriate courses by means of multi-criteria decision making methods in accordance with the criteria determined by the graduate students.

Selection of an elective course is a multi-criteria decision making (MCDM) problem, constitutes an advanced field of operations research, since it involves many conflicting multiple criteria, goals or objectives. A variety of decision making approaches and tools are available to support education decision making. The intent of MCDM methods is to improve the quality of decisions about elective course selection involving multiple criteria by making choices more explicit, efficient and rational. MCDM Methods have six basic functions:

- structuring the decision process,
- displaying trade-off among criteria,
- helping decision makers reflect upon, articulate, and applying value judgments concerning acceptable trade-offs, resulting in recommendations concerning alternatives,
- helping people make more consistent and rational evaluation of risk and uncertainty,
- facilitating negotiation,
- documenting how decisions are made.

The Analytic Hierarchy Process is one of the most widely used MCDM tools in the last 30 years; it has been used in almost all the applications related with decision making [3-8]. This approach enables the decision maker to construct problems in the system of a hierarchy: the objective, the criteria, and the alternatives. The main benefit of the AHP is its use of pairwise comparisons to measure the impact of items on one level of the hierarchy on the next higher level. Its flexibility, ease of use and wide applicability attract decision-makers and researchers in different fields including health care, education, management, manufacturing, political, and finance. There have been numerous research published based on AHP which include applications of AHP in various areas such as selection, evaluation, resource allocation, decision making, etc. A bibliographic review of the MCDM tools is provided [9].

In this study, a multi-criteria decision making methodology is proposed to determine weights of factors affecting elective course selection from students' perspective. In the proposed methodology, graduate students' opinions on the relative importance of the selection criteria are determined by the AHP procedure. Although there have been

several applications of AHP method in education, to the best of knowledge, this is the first study where a multi-criteria decision making tool, is used to examine the determinants affecting the selection of elective course selection from the perspective of students.

2. Methodology

2.1 Identifying Main Criteria and Sub-criteria

The problem to be implemented is the selection of elective courses belonging to the engineering department. The research focuses on the criteria that students have taken into consideration in the assessment process during the pre-course selection phase. Evaluation criteria for elective course selection were identified and grouped into five main categories: course schedule, teaching staff, course content, course requirements, friend-environment factor. In this paper the main and sub-criteria in Table 1 are obtained by taking into account the students' experience and opinions.

Table 3. Main criteria and sub-criteria taken into account to select the best elective course

Main criteria	Sub-criteria
C1: Course Schedule	C11: Course hours C12: Schedule in curriculum
C2: Teaching Staff	C21: Relationship with course instructor C22: Lecture teaching style
C3: Course Content	C31: Practicality of the course in real life C32: Interest in course content
C4: Course Requirements	C41: Obligation to attend the course C42: Project-homework assignment C43: Midterm exam-Final exam-Homework points % distribution
C5: Friend-Environment Factor	C51: Comments of the students previously taken the course C52: Passing grade in past semester C53: Number of people to choose course C54: Friend factor

2.2 Multi-criteria Decision Making

Decision-making is the process of choosing among the available alternatives. This phenomenon, which emerges from the moment when man is born, continues throughout all life in a wide variety of forms and environments [1].

The decision-making process is the implementation of the methods used to achieve the decision and the way it is applied. A successful decision-making process should meet the following six criteria:

- Focus on what is important,
- Logical and consistent,
- Using objective and subjective factors and bringing together analytical and intuitive thinking,
- Need information and analysis as needed for solution,
- Encourage and guide relevant information and thinking,
- Accurate, reliable, easy to use and flexible ^[10].

Decision makers live in every environment where chained decision making occurs. The factors that make up the ring that makes up this decision-making chain are:

- Experts
- Resolution environment (constraints)
- Objectives (criteria, targets)
- Alternatives
- Resources ^[1].

In the decision-making process, strategies are developed to find a number of solutions with existing problems. Different types of decision criteria can be applied while selecting the most appropriate strategy. These criteria are:

- Decision making under certainty,
- Decision making under risk,
- Decision making under uncertainty ^[11].

The Multi-Criteria Decision Making defines the decision-making process that will lead to a probing solution when multiple and often inconsistent criteria exist. In daily life, a very wide area is encountered with the problems of MCDM. Under the many criteria, the MCDM is able to reach the optimal solution from various alternatives. It is able to make the right decision even in any complex problem. For this reason, many areas include methods that provide application possibilities ^[12].

2.3 Analytic Hierarchy Process

The Analytic Hierarchy Process is a multi-criteria decision-making technique as described by Thomas L. Saaty ^[3]. The AHP is considered for decisions that necessitate incorporation of quantitative data with less tangible, qualitative considerations such as values and preferences. The AHP method is an effective and easy-to-understand that allows individuals and groups to process all the quantitative and qualitative factors together in the decision-making process. The AHP identifies the set of criteria that can be influenced by multi-criteria decisions in real life, and the significance of these criteria to be given to the experts. The AHP approach has a wide range of applications. The difference between AHP and other decision-making methods is that the decision-maker's own ideas can be evaluated directly in the process ^[13]. The technique, is an Eigen value approach to the pair-wise comparisons, has been

applied to many areas including education and medical decision making. An AHP method involves the following key and basic steps:

- state the problem,
- identify goal of the problem,
- identify the criteria, sub-criteria and alternatives under consideration,
- construct the problem in a hierarchy of different levels-goal, criteria, sub-criteria and alternatives,
- conduct a series of comparisons among each element in the corresponding level and calibrate them on the numerical scale,
- calculate the maximum Eigen value, consistency ratio (CR), and normalized values for each criteria/alternative
- determine the relative ranking or the best alternative.

The selection hierarchy for the best elective course selection is illustrated in Figure 1.

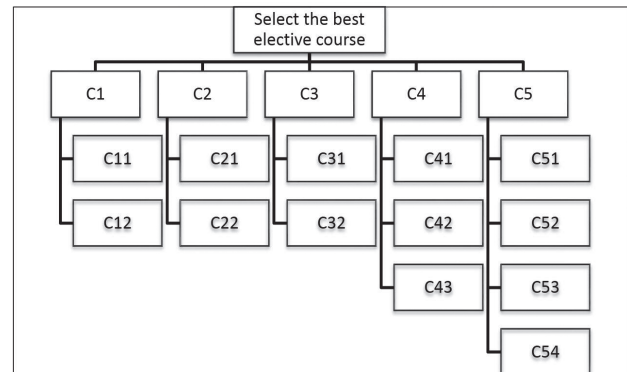


Figure 1. A hierarchy for selection of the most appropriate elective course

3. Data Collection

This study is a descriptive cross-sectional study for the purpose of assessing and identifying the importance of aforementioned criteria affecting elective course selection from students' perspective. A questionnaire, containing demographic questions, enables each student to compare the relative priority of criteria with all of the other criteria within the same category. Before conducting the survey, a pilot test was conducted with few students in the university. Based on the input received, the questionnaire was modified. The resulting questionnaire was e-mailed to the respondents. Hence, the questionnaires were applied to all 40 students individually. Students with the following demographic characteristics of experts are provided in Table 2. The average age of the students is 24.8 of which 52.7 % are male, 47.3 % are female.

Table 2. Demographic characteristics of the students

Gender (%)		
Female: 47.3	Male: 52.7	
Age (year)		
Max: 26	Min: 22	Avg: 24.8

In order to detect the relevant criteria, Saaty's pairwise comparison was applied. For each pair of criteria, the students were asked the following question: "in the selection of an elective course, considering merely "course schedule", how important is each element on the left compared with each element on the right?" The respondents were asked to rate each factor using the nine-point scale shown in Table 3.

Table 3. Saaty's nine-point scale

Intensity of importance	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2,4,6,8	For compromises between above

The personal judgments of each decision maker were converted to joint group decision by means of geometric mean and their weights were calculated in Super Decision software, and the consistency ratios of the paired comparisons were analyzed. An example of survey questionnaire is provided in Figure 2.

In the selection of an elective course, considering merely "course schedule", how important is each element on the left compared with each element on the right?

1 = Equal 3 = Moderate 5 = Strong 7 = Very Strong 9 = Extreme

Course hours	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Schedule in curriculum
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Figure 2. An example of survey questionnaire

4. Results

In order to determine the relative importance of various criteria affecting elective course selection from students' perspective in the analytic hierarchy, the data gained from the sample was analyzed using AHP method. The responses concerning the ranking of the criteria were computed using the software, and the consistency ratios of the paired comparisons were analyzed. The primary step was to assess the relative priorities of the main criteria at level 1; the priority weights of the main criteria influencing the selection of elective course are provided in Table 4. The re-

sults indicate a good consistency with a CR of 0.1, which represents more than 90% confidence level.

Table 4. Priority of criteria at level 1 of AHP

Criteria	Priority weight
Course Schedule	0.28
Teaching Staff	0.20
Course Content	0.20
Course Requirements	0.14
Friend-Environment Factor	0.18

Consistency ratio (CR): 0.02 (values at 0.1 or below represent 90% or higher confidence level)

Among five main criteria, "course schedule" is the most important criteria with the highest weight and "course requirement" is the least important with the lowest weight value. All responders achieved the threshold for coherence ($CR \leq 0.1$). According to the students, "teaching staff" and "course content" are indifferent.

Next, the relative priorities of the sub-criteria at level 2 were assessed, and the results are available in Table 5. The CRs for different comparisons range from 0.01 and 0.02, implying well over 90% confidence levels. Good consistency ratios imply that the responses expressed by students are not arbitrary, and well thought responses. CR is "not applicable" if only two criteria are being compared as transitivity would not be an issue ^[14].

According to Table 5, "course schedule" includes two sub-criteria where "course hours" is the most influential sub-criteria with the priority weight of 0.68, and "schedule in curriculum" is the least important one with the weight of 0.32. "Teaching staff" includes two sub-criteria; "relationship with course instructor" and "lecture teaching style" have the same importance with the priority weight of 0.5. "Course content" has two sub-criteria, "Practicality of the course in real life" has the higher priority with the weight of 0.65 than "interest in course content" with the weight 0.35. "Course requirements" includes three sub-criteria, "obligation to attend the course" has more priority than "project-homework assignment" and "mid-term exam-final exam-homework points % distribution". Finally, "friend-environment factor" includes four sub-criteria that "comments of the students previously taken the course" is the most influential with the priority weight of 0.34.

The global priority of each sub-criterion, which enables comparison of relative importance of different sub-criteria across criteria, was also calculated by multiplying the priority weight of the sub-criterion with its higher level criterion in the hierarchical path. The global priorities for

the sub-criteria at level 2 are provided in Table 6 after rescaling the fractional weights by multiplying with 100^[15].

Table 5. Priority of sub-criteria at level 2 AHP

Criteria	Priority weight	Global priority	CR
Sub-criteria for Course Schedule			
Course hours	0.68	0.19	Not applicable
Schedule in curriculum	0.32	0.09	
Sub-criteria for Teaching Staff			
Relationship with course instructor	0.5	0.10	Not applicable
Lecture teaching style	0.5	0.10	
Sub-criteria for Course Content			
Practicality of the course in real life	0.65	0.13	Not applicable
Interest in course content	0.35	0.07	
Sub-criteria for Course Requirements			
Obligation to attend the course	0.42	0.06	0.01
Project-homework assignment	0.29	0.04	
Midterm exam-Final exam-Homework points % distribution	0.29	0.04	
Sub-criteria for Friend-Environment Factor			
Comments of the students previously taken the course	0.34	0.06	0.02
Passing grade in past semester	0.22	0.04	
Number of people to choose course Friend factor	0.22	0.04	
	0.22	0.04	

CR values at 0.1 or below represent 90% or higher confidence level)

Table 6. Global priority weights for level 2 Sub-criteria (Scaled to 100)

No	Criteria	Global priority level 2
1	Course hours [course schedule]	18.69
2	Practicality of the course in real life [course content]	13.21
3	Relationship with course instructor [teaching staff]	10.21
4	Lecture teaching style [teaching staff]	10.21
5	Schedule in curriculum [course schedule]	9.34
6	Interest in course content [course content]	6.60
7	Obligation to attend the course [course requirements]	6.42
8	Comments of the students previously taken the course [friend-environment factor]	6.16
9	Midterm exam-Final exam-Homework points % distribution [course requirements]	4.45
10	Friend factor [friend-environment factor]	4.38
11	Passing grade in past semester [friend-environment factor]	3.62
12	Number of people to choose course [friend-environment factor]	3.62
13	Project-homework assignment [course requirements]	3.09

The higher-level criteria are specified in square brackets for easy reference

5. Discussion

This study aims to prove a mathematical method for a real-life situation which can help people make their decisions accurately. The situation of selecting an elective course is a problem for the students as they want to select the best option for them. There is a need to develop feasible decision-support tools that can provide feedback to facilitate this decision-making process. This study can be a baseline for a decision-support system for students assisting in making multi-criteria decisions. It will help students who are indecisive and hesitates while selecting an elective course.

With this study, the students can compare their options in a fairly simple way and find an optimum result. Other than the criteria aspect, it is shown that AHP method is an appropriate method for this kind of problems. The results propose the importance of issues in elective course selection from the perspective of graduate students. The priority weights stated in this paper may be useful in the elective course selection process for classifying various potential course by taking a weighted average of the calculated scores on different criteria.

Students give the highest priority to course schedule in selecting an elective course with a weight of 0.28 as provided in Table 4. Faculty members pay attention to the quality of the courses which are important for qualified curriculum and students' satisfaction. Therefore, they prefer to offer the best elective course available subject to their availability. Our results show that the students search for the appropriateness through course schedule. In order to be successful in a graduate program, students have to take several courses during the semester. Since their weekly programs become quite busy, finding out a course that is in the curriculum and fits their schedule is very crucial. The next criterion in importance is teaching staff with a weight of 0.20. In addition to course schedule, it is revealing that the students pay attention to the relationship with course instructor and lecture teaching style through teaching staff. Students tend to take the courses offered by the instructors whom they have known from other courses, or have an easier connection with compared to the other instructors. Moreover, instructors not boring during teaching and utilizing proactive teaching tools are preferred by the students. Similar to the teaching staff, students give priority to course content with a weight of 0.20. Students always tend to ask for the applicability of a course in practice. Therefore, they prefer to take the courses that they are interested in and they observe the practicality in real life. Friend-environment factor is the fourth important criteria with weight of 0.18. In every course registration period, if the course was previously offered,

students get the opinion of their friends on this specific course who have taken the course earlier. If the number of students who are taking a course is high, the course is considered as "popular" or "easy", which motivates them to add it to their program. In addition to that, students tend to take the courses whose average passing grade are higher. Finally, course requirements received the lowest priority from the graduate students with a weight of 0.14. Since in majority of the courses the course requirements are similar, for instance, expectations from the course, attendance requirements and grade distributions for mid-term, final, homework, project, course requirements are considered to be the least important factor while selecting an elective course. Discussion of the AHP results with the students verifies that their views are the same: first course schedule, followed by teaching staff and course content, friend-environment factor and course requirements.

6. Conclusion

Selection of an elective course plays an important role in course registration, is a multifaceted problem due to number of stakeholders, criteria and alternatives. This study identifies a set of criteria for elective course selection based on input from graduate students, and provides useful insights into students' preferences. A set of criteria are identified based on the inputs from students, and organized into a rational hierarchical framework consisting of the five main criteria and thirteen sub-criteria. In order to classify the relative importance of various criteria in the hierarchy, surveys were conducted in order to get responses from experts for the AHP method. Results show that students give the highest priority to the course schedule related factors such as course hours and schedule in curriculum. Teaching staff and course content related factors such as practicality of the course in real life, relationship with course instructor, Lecture teaching style are considered important discriminators by students in elective course selection, next to the course schedule. On the other hand, students are less concerned with course requirement related factors. Moreover, good CRs indicate that the responses are not random, and they are well thought. Given the multiple, competing criteria for the selection of an elective course, the results of this study can be useful for decision-makers in ranking and selection of elective course.

This study has limitations. Our sample was limited to graduate students in Turkey. Future research in a more culturally diverse geographical region could be completed and compared with the results of this paper since preferences may differ by country. Furthermore, for further research, the other multi-criteria decision making approaches such as TOPSIS, PROMETHEE II and VIKOR can be

used and compared with the results of this paper.

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ARTICLE

An Empirical Analysis of Defense-Economic Growth Relationship

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ABSTRACT

Most of the developing and developed countries try to make peace and promote it but still it is seen that large portion of the overall global GDP is spent on the defense sector. This study surveys defense-growth nexus by incorporating openness to trade, external debt, gross capital formation and labor force in production function. The study uses annual time series data over the period 1972-2016. For estimation purposes, the study employed ADF unit root test and P-P unit root test for testing stationarity properties, ARDL Bound test to cointegration used for testing long run relationship. The empirical evidence of the study reveals that Economic growth is positively affected by spending on defense sector, capital investments, labor force, and openness to trade in long run while external debt has a negative effect on economic growth. Apart from this, empirical evidence also suggests that in short run; there is positive imperative role of capital investment, defense spending, and openness to trade in growth process, while external debt retards the pace of economic growth. Results of the study indicates that defense spending could be used as a fiscal tool for achieving sustainable growth, government should invest high R&D in defense.

1. Introduction

The impact of defense spending on economic development differs from one country to another. It is a common phenomenon that a significant amount of GDP is spent on the defense sector worldwide because advance technology in defense of country played a significant in national development^[1]. Whether it is developed or developing country, defense sector spending is on the rise since last few decades. Due to this high portion of budget spending on defense sector, the growth of the economy is

affected and it results in crowding out of the country's capital. As per Benoit^[2] economic growth depends on the portion of budget the countries spend on defense, the heavy spending on defense may have some kind of impacts on the overall economy of any country. Due to peaceful environment of any country, it attracts foreigner to invest in any country. It may be one of the reasons for investment opportunities. The defense-growth nexus was first studied by Benoit (1973)^[2] who focused on this specific issue and establish that spending on defense is helpful to economic

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development. Later, several other researchers examined the relationship among defense sector expenditure and economic growth^[3]. They argue that defense spending is conducive to economic growth by positive spillover effects of spending on defense as mentioned by Feridun et al., (2011)^[4]. There are some other studies too which support this phenomenon, but some studies proved that this help in economics growth in developed countries while it retards the economic growth in the developing countries. On the other hand, some argues that high defense spending crowd-out investment from development to non-developmental purpose thus impede economic growth^[5]. From theoretical point of view, there are two approaches through which defense spending effects economic growth i.e. Keynesian, and Neoclassical. From Keynesian point of view, an increase in defense spending effects growth process positively through the enhancement of aggregate demand, employment creation, provision of peaceful environment for investments and so forth. Apart from this, positive spill-over effects of defense spending affect economic growth positively through engaging resources in R&D, human capital development, education, technological advancement and so forth^[6,7&8]. On the other hand, neoclassical economists argue that defense spending negatively affect the economic growth. Increasing in defense sector spending diverts resources from developmental to non-developmental purposes. This appears to crowd-out both private and public-sector investments which decrease economic growth^[9,10]. Defense spending in developing countries is unfriendly as compare to the developed countries^[11,12]. Defense spending in developing countries hinders the growth process and has adverse effect on the growth. The main reason of this adverse effect is that defense spending diverts the developing country resources from development to non-development sector. These developing countries try to fulfill defense sector needs by importing defense related products from more developed countries. The developing country can utilize these resources on technological progress, development in infrastructure and can also reduce the heavy taxes imposed on poor people. After the 80's the world observed incredible increase in terrorism and its negative impact on the overall economy of the countries in some countries. So, to eradicate this problem, proper policies were required to strengthen the overall security system and to eradicate the terrorism. For this, increase in defense spending was mandatory in most of the countries who were suffering from terrorism; Pakistan was also part of it. Defense spending can also promote the economic growth of a country if defense products are exported to other countries. Countries like US earn handsome earning by exporting the

defense spending to other countries as it is the highest supplier of defense products. Its products for defense are too expensive and for developing and poor countries it is almost impossible to purchase the defense products. For those developing countries there are opportunities to invest in defense sector research and development (R&D) so they can produce their own low-cost defense products. In his research work, Benoit (1973) defense spending by any country results in stimulating the economic growth through positive spillover effects. Spending in defense sector lowers the cost of resources, increase the profits, decrease unemployment, increase in the overall demand. It can be said that defense sector encourages the economic growth of country through increasing employment, aggregate demand and production^[13]. Geographically, Pakistan lies in a prime strategic position, but over the years it has lost too much due to its location, rather than cultivating any benefits. The geopolitical hostilities, strategic and political positioning is making Pakistan to spend more on its defense sector since independence. The armed confrontation and the political rivalry between Pakistan and India are one of the main factors of increase in the military sector spending. Pakistan is a country which faced more terrorism, to curb this menace of terrorism the government has to have increase defense spending and it was inevitable. To curb these hostilities and terror attacks it is mandatory for governments to spend on defense sector. Defense spending might affect economic growth both positively or negatively^[14]. As a direct effect it can spin-off the investment from defense spending to other sectors of the country. While as an indirect effect it might reduce the overall economic growth simply by reducing the saving ratio, lack of social expenditure, lack of public expenditure on health, education and sometimes severe balance of payment deficit of the country. Hence, defense spending and economic growth has both negative and positive impacts on the overall economy in the countries. Foreign and domestic investment, peaceful environment for production activities contributes towards the positive impact of defense sector spending on economic development. Economic growth further contributes to technical skills, advancement in research activities, infrastructure development and educational training for constant development of economic growth^[15,16]. While on the contrary, a negative impression of defense sector expenditure on economic growth might be observed. Defense expenditure might distort the allocation of resources by crowding-out the private investment. It can also negatively affect the economic growth by diverting the resources from productive projects to unproductive projects^[17,18]. The main objectives of the study are (i) To investigate the relationship between

defense spending and economic growth (ii) To investigate the causality among economic growth and other independent variables like capital, labor, defense spending, trade openness and external debt and to suggest some policy implication.

2. Theoretical Framework

The debate regarding the theory of defense expenditure mainly consists of two schools of thoughts. The one backing Keynesian, while the other against it. The group backing Keynesian school of thought put forward that in Keynes Military Hypothesis, military sector expenditure aids the overall economy of the country which encourages and lifts the overall economic development by multiplying its effect^[19,20,21,22]. These theories support that defense sector expenditure encourages the economic growth over various routes. Defense sector spending assures a peaceful atmosphere which boosts the local as well as the foreign investors. These local and private investments increase the exports of country; create employment opportunities and aggregate demand. All the firms within the country will adopt modern techniques and technologies of production^[23]. In further studies, the authors argue that defense sector spending contributes in enhancing the overall growth through improving educational training, provision of employment opportunities, infrastructure and engaging country resources in high development and research events. Similarly, manufacture of highly inventive military sector products can play important part in accelerating the economic development and are positive spillover impacts of defense sector spending^[24,25,26]. These authors say that defense sector spending is harmful for economic growth and it hinders the overall growth of country because of countless reasons. Defense spending hampers the growth process of the country by crowding out the useful resources from creative to non-creative activities. Military sector expenditure damages the government expenditure for progressive purposes like roads, dams, railways tracks, electricity and many other infrastructure developments which are essential for maintenance of economic development^[27,28,29]. For developing countries that rely on deficit budgeting by borrowing money to meet their defense spending are prone to distort the credit market. This distortion result in further enhancement of expenses on defense, as the interest rates would soar. Following it would impede the private investments that would hamper the economic progress^[30]. Hence, defense spending vis-a-vis crowding out and distortion effect would lead to deviation of resources from civil to defense purposes, and would retard the economic growth, technological advancement and long-term productivity.

3. Methodology

For testing stationarity properties, ADF unit root test and P-P unit root test has been employed. In order to test cointegration relationship among the variables, ARDL bound testing approach has been used. The data on variables GDP per capita, capital, labor force, defense spending as share of GDP, trade openness (exports + imports) as share of GDP and external debt is obtained from World Bank (WB), SIPRI and various Economic Surveys of Pakistan of period 1972-2016.

3.1 Econometric Model:

Feder (1983)^[31] established the empirical model to examine the effect of military sector expenditure on economic development. The empirical modeling for probing the association among defense expenditure and economic development was established by Feder (1983). Following the lead of Biswas and Ram (1986)^[32], who first adopted Feder (1983)'s model of export-growth nexus in less developed countries for testing the connection among expenditure and economic development, numerous empirical assistances to the guns-and-butter debate have employed alternatives of the same approach. Deger and Sen (1995)^[33] characterize the Feder model as "a splendid empirical workhorse to investigate the impact of military expenditure as an explanatory variable in a single-equation growth regression analysis, which is grounded in the neoclassical theory of growth" (Mintz and Stevenson 1995), or at least "fairly well grounded in the neoclassical production function framework"^[34]. The popularity of the approach lies in the arrival of a direct connection from theoretical model to econometric requirement. Alexander (1990)^[35] also employed Feder model and later on, Feder model was used by Yildirim et al. (2005)^[13] to test the impact of military expenditure on economic development in case of 58 developing countries. Recently, by employing Feder (1983)^[31] model, Kumar and Shahbaz (2012)^[36] examined military-economic growth nexus. This study also uses Feder (1983) defense expenditure model to explore the nexus between economic development and military expenditure by including capital, labor force, trade openness and external debt for Pakistan.

Given for the economy of two sectors with a defense M production function as:

$$M = m(L_m, K_m) \quad (i)$$

And a civilian G productions function:

$$G = G(L_G, K_G, M) \quad (ii)$$

In addition, the inputs L_m , L_G , K_m , K_G are labor and capital share for the military and civil sector respectively. Following Wilkins, we include M in equation (ii) to allow an externality effect from the defense sector to civilian

sectors. Aggregate labor (L), capital (K) and national income (Q) are given in equation (iii), (iv) and (v) respectively.

$$L = L_m + L_G \quad (\text{iii})$$

$$K = K_m + K_G \quad (\text{iv})$$

$$Q = M + G \quad (\text{v})$$

Considering the above relationships, and taking the total difference of equation (v) and then dividing by Q we obtain equation (vi):

$$\frac{\partial Q}{Q} = \frac{\partial G}{\partial L} \frac{dL}{Q} + \frac{\partial G}{\partial K} \frac{dK}{Q} + \frac{\partial G}{\partial M} \frac{dM}{Q} \quad (\text{vi})$$

Then multiply the first term of RHs of (vi) by L/L and then third term by M/M.

$$Q = F_L L + F_K \frac{dK}{Q} + F_M M \frac{dM}{Q} \quad (\text{vii})$$

The above equation (vii) is the simplest form of the Feder Ram model and it shows that how economic growth depends on capital and labor growth.

3.2 Research Design

This study examines the impact of defense spending on economic development for both long run as well as short run by using Keynesian model by including trade openness and external debt in production function for the Pakistani economy. The study changed the series into natural logarithm due to inefficient and unreliable estimates by simple linear series^[37]. According to Sezgin (2001)^[16] better and unbiased empirical results are provided by log linear specification. Following is the empirical equation for the function of production:

$$\ln G_t = \beta_0 + \beta_1 \ln K_t + \beta_2 \ln L_t + \beta_3 \ln DS_t + \beta_4 \ln TR_t + \beta_5 \ln EXD_t + \mu_t$$

Where, $\ln G_t$ is natural log of GDP per capita proxy for economic development, $\ln K_t$ is natural log of capital, $\ln L_t$ is natural log of labor force, $\ln DS_t$ is natural log of defense spending as share of GDP, $\ln TR_t$ is natural log of trade openness, which include imports and exports as share of GDP and $\ln EXD_t$ is natural log of external debt.

In this research study GDP is used as dependent variable. While on the other side capital, labor, defense spending, trade openness and external debt are incorporated as some independent variables. The purpose to choose GDP as our dependent variable is to understand the effect of the said independent variables on the dependent variable and to see that how these variables are affecting the overall GDP of Pakistan.

4. Estimation and Analysis of Results

Descriptive statistics is illustrated in following Table 1. The descriptive statistics shows that mean and standard

deviation of $\ln(G)$ is 10.54 and 0.27 respectively, whereas the minimum and maximum value of $\ln(G)$ is 10.04 and 10.98 respectively. The mean and standard deviation of $\ln(K)$ is 2.85 and 0.11 while max and min values are 3.03 and 2.55 respectively. The mean and std. deviation of $\ln(DS)$ is 1.63 and 0.26 respectively. While the minimum and maximum value of $\ln(DS)$ are 1.18 and 1.98 respectively. The mean of $\ln(TR)$ and $\ln(L)$ is 3.49 and 17.78 and their standard deviation is 0.11 and 0.37 respectively. Whereas, the minimum value of $\ln(TR)$ and $\ln(L)$ is 2.99 and 16.75. Similarly, the maximum value of $\ln(TR)$ and $\ln(L)$ is 3.66 and 18.01 respectively. The mean of $\ln(EXD)$ is 23.78. Its standard deviation is 0.792. While, minimum and maximum value of $\ln(EXD)$ is 22.12 and 24.90 respectively. Table results show that economic growth, capital, defense spending, trade openness and external debt are left skewed while labor force is skewed right. From the kurtosis data, the variable $\ln(DS)$ show that it has the lowest kurtosis while the highest kurtosis value is of variable $\ln(TR)$. While all the other variables have positive kurtosis, which means that the distribution has "fat tail" right. All the series in Jarque-Bera are normally distributed.

Table 1. Descriptive statistics

	Ln(G)	Ln(K)	Ln(DS)	Ln(TR)	Ln(L)	Ln(EXD)
Mean	10.54	2.85	1.63	3.49	17.78	23.78
Median	10.59	2.88	1.70	3.50	17.35	23.98
Maximum	10.98	3.03	1.98	3.66	18.01	24.90
Minimum	10.04	2.55	1.18	2.99	16.75	22.12
Std. Dev.	0.27	0.11	0.26	0.11	0.37	0.79
Skewness	-0.22	-0.91	-0.41	-1.8	0.06	-0.43
Kurtosis	1.95	2.1	1.75	9.26	1.82	2.16
Jarque Bera	2.36	6.15	4.08	98.35	2.54	2.64
Probability	0.30	0.04	0.12	0.00	0.28	0.26

It is mandatory to examine the properties of variables that are stationary so that no false regression is observed. After that, long run relationship will be examined among the variables. P-P unit root test and ADF unit root test used to check the stationarity of variables. In Table 2 and Table 3, the properties of time series of the variables Log of GDP, log of capital, log of labor force, log of defense spending, log of trade openness, and log of external debt are given. The results of (ADF) and (PP) unit root test confirms that variables capital, economic growth, labor force, trade openness, defense spending and external debt are non-stationary at levels while all these variables are stationary at the first difference. On the other hand, the only variable

which is stationary at level is trade openness. From the results it can be conclude that all the variables are mixed integrated i.e. I(0) and I(1). So, we can say that the series of these variables may also be co-integrated.

Table 2. Augmented dickey fuller unit root tests

Variables	Only Intercept		Intercept and Trend		Outcome
	Level	1ST Diff	Level	1ST Diff	
LnG	-0.90	-5.26***	-1.67	-5.19***	I(1)
LnK	-2.17	-6.27***	-2.40	-6.68***	I(1)
LnL	-0.50	-4.48***	-1.99	-4.45***	I(1)
LnDS	-0.31	-7.93***	-1.86	-7.82***	I(1)
LnTR	-5.47***	---	-5.07***	---	I(0)
LnEXD	-1.69	-4.50***	-2.79	-4.91***	I(1)

*, ** and *** shows the rejection of Null hypothesis at 10%, 5% and 1% level of significance respectively. Critical values are MacKinnon (1996) one sided p-values.

Table 3. Philips-Peron unit root test

Variables	Only Intercept		Intercept and Trends		Outcomes
	Level	1st Diff	Level	1st Diff	
LnG	-0.84	-5.27***	-1.90	-5.19***	I(1)
LnK	-2.23	-6.27***	-2.30	-6.67***	I(1)
LnL	-2.23	-6.27***	-2.30	-6.67***	I(1)
LnDS	-0.44	-7.65***	-1.98	-7.58***	I(1)
LnTR	-5.72***	---	-5.38***	---	I(o)
LnEXD	-2.84	-3.59***	-2.42	-3.57***	I(1)

***, ** and * indicates the rejection of Null hypothesis at 1%, 5% and 10% level of significance respectively. Critical values are MacKinnon (1996) one sided p-values.

From the above table the empirical results of these tests indicate that all the variables are combined with mixed order of integration. For such case, the ARDL test is used in order to check the association among all variables. However, before apply the ARDL bound testing approach; lag length should be appropriately selected.

Table 4. Bound testing to cointegration

F-Bounds Test Null Hypothesis: No levels Relationships

Test Statistic	Value	Signif.	I(o)	I(1)
F-statistic	6.408418	10%	2.08	3
k	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

The F-statistics of cointegration are given in Table 4. The empirical results in the table suggests that calculated F-statistics is F=6.408 which is more than the upper critical bound value i.e. 3.38 at 5% level of significance reported by Lee, K., Pesaran, M. H., & Smith, R. (1997). Results of the bound testing to cointegration shows that there is a long run relationship between economic growth,

capital, labor force, defense spending, trade openness and external debt for Pakistan over the period 1972-2016.

Table 5. Estimated long run coefficients using ARDL approach

Dependent Variable: LnGDPt			
Regressor	Coefficients	Standard Error	T-Statistics
Constant	-6.27	0.733	-8.560
LnK	0.306	0.048	6.261*
LnL	1.036	0.099	10.481*
LnDS	0.130	0.031	4.182*
LnTR	0.215	0.051	4.229***
LnEXD	-0.125	0.733	-8.560***

Diagnostic Test

Test	Statistics	Probability
R ²	0.998	
F-Statistics	753.786	0.000
χ^2 Normal	0.34	0.84
χ^2 Serial	0.22	0.69
χ^2 ARCH	0.10	0.74
χ^2 White	3.43	0.52

Note:

① χ^2 Normal (Jarque–Bera statistic for normal residuals)

② χ^2 (Breusch–Godfrey LM test for no first-order correlation of serial)

③ χ^2 ARCH (for no autoregressive conditional heteroscedasticity)

④ χ^2 WHITE (for homoscedastic errors)

* Test statistics are significant at 10Percent(level of significance).

** Test statistics are significant at 5 Percent(level of significance).

*** Test statistics are significant at 1 Percent(level of significance).

Long run coefficients of the (ARDL) bound approach are given in Table 5. The projected long run coefficient of capital has positive effect on economic development in case of Pakistan. Capital is significant at 1%. The results concluded that 1% increase in the capital will also increase the GDP by 0.30% which results in rejection of the hypothesis that capital does not affect the economic growth of Pakistan. The results are in line with the findings of (Beckaert et al. (2005)^[38]. Similarly, for Pakistan, labor force has a positive and highly significant impact on economic development in the long run. The estimated re-

sult recommends that an increase of 1% in labor force will also increase the GDP by 1.0 percent. This results in the rejection of hypothesis that labor force does not affect the economic growth for Pakistan. These outcomes are similar with the new growth models that incorporate a knowledge producing sector can be interpreted as incorporating the role that investment in human capital (e.g. expenditures on education and training) could have a more permanent impact on the growth process if high skills and training go hand-in-hand with more intensive research and development and a faster rate of technological progress, or if the adoption of new technologies is facilitated by a highly skilled workforce.

Similarly, the long run coefficient of military expenditure has highly significant positive influence to GDP in case of Pakistan. The evidence shows that an increase of 1% in military expenditure will also result in an increase of GDP of the country by 0.13 percent. This empirical evidence, results in rejection of the null hypothesis that military expenditure has no impact on the overall economic development. Thus, the above results provide validation of Keynes military Hypothesis which is, that military expenditure serves as an injector in the economic growth of the country and it excites and enhances the economic growth through its multiplier effects in case Pakistan. These results of our study are similar to that of Hassan, M. K. (2004)^[39]. The author reported that military expenditure boosts the economic development in case of Pakistan. However, the projected coefficients are different than that study due to the different time span used in both the studies. However, the empirical results of this study are similar with findings of Asghari, M. (2017)^[40] for Guatemala economy, who found that military spending and economic growth both are positively associated. Moreover, the long run relationship between trade openness and economic development is positive for Pakistan and trade openness is significant at 10 percent. 1 percent increase in trade openness will automatically increase the overall GDP by 0.21 percent, which results in the rejection of null hypothesis that trade openness does not significantly affect the economic development process. The results of our study are according to that of new growth theory. The theory claims that trade will expand the market, encourages the research and developmental projects, reallocates employment to more innovative activities that require more human capital and increases knowledge flow among countries.

Whereas the long run coefficient of external debt has a destructive impact on the economic development of Pakistan. The results further suggest that external debt retards the economic activity in Pakistan and the result of this study are similar with the findings^[41]. The empirical evi-

dence of the study is consistent with the findings of Ali, B. M., & Mshelia, S. I. (2007)^[42] that external debt causes poverty in the country which is debtor. In their view external debt is the main cause of hampering economic growth. The long run estimations of the model, given in Table 6 show that four out of the five independent variables (capital, labor force, defense spending, and trade openness) show a positive impact in encouraging the growth process in case of Pakistan. While only one independent variable (external debt) has a negative impact in promoting the overall growth process. Further, we will explain the Impact of the parameters as: The capital has a positive effect on the overall growth process in long run for Pakistan. This suggests that an increase in the capital stock will promote the economic growth of Pakistan by providing the basic infrastructure facilities i.e. energy, education and transport and dams. To the economic progress, labor force is considered as highly advantageous. By increasing the productivity, it contributes towards the development of economic sector. Enhancement of labor force result in overall demand as the buying power rises. The skilled labor is an attraction for the foreign investors that would accelerate the economic activity in the country. Though, it is also mandatory that a comprehensive policy regarding the skilled labor should be in place that can further improve the skills of labor and encourage the technological advancements towards the higher productivity. Investment on labor would reduce the cost of production and result in increased overall market activity of any country. Similarly, military sector spending has positive role in overall economic growth in long run in Pakistan. Conducive environment portrays a promoting role of defense sector spending on the Pakistan economy. Conducive environment results in foreign investment well as local investment. Positive spillover impact of military spending on Pakistani economy also plays a promoting role. Producing own defense products and then exporting these defense products to other countries also contributes positively on the overall economic growth of a country. Other positive impacts of defense spending are like engaging the population in R&D, educational skills and providing technical skills for sustainability of overall economic growth. In case of Pakistan, trade is an imperative policy tool to speed up the economic progress. Due to trade, the exports of the country surge which results in capital inflow. By creating the balance between imports and exports, trade deficit can also be scaled down. Export enhancement can lead to rise in production which would help in keeping the production cost at low. Due to low production cost, the prices of commodities would be in reach, and will create further demand. In addition, trade enhances market competition

that would compel the producers to work on R&D, which would bring about the technological innovation in the market. An innovative market has capacity to support the economy and keep the production cost in control. The effect of external debt on the overall economic development of Pakistan is negative. An increase in the external debt will result in downfall of economic development. Ali, H. E. (2011)^[43] also studied the effect of external debt on economic growth for Pakistan and found that external debt retard the economic growth and it has negative impact on the overall productivity of capital and labor which thereby adversely affects the economic growth of the country. The remedy to overcome external debt is that the country should increase its savings and trade (increase exports and decrease imports) as the policy measure. This will result in the less dependency on the external debt.

Table 6. Error correction representation for the selected ARDL model

DEPENDENT VARIABLE: ΔGDP_t			
Regressor	Coefficients	Standard Error	T-Statistics
Constant	-2.707	2.067	-1.309
ΔK	0.103	0.028	3.622***
ΔL	0.221	0.162	1.365
ΔDS	0.039	0.033	1.170***
ΔTR	0.100	0.027	3.648***
ΔEXD	-0.202	0.043	-4.655***
ECM (-1)	-0.856	0.113	-7.566***

$$ecm = LNGDP - 0.306 * LNK - 1.036 * LNL - 0.130 * LNSD - 0.215 * LNTR + 0.125 * LNEXD + 6.271 * C$$

NOTE: Significance of 10%, 5% and 1% are represented as *, ** and *** respectively.

To examine the short run relationship among variables, Error Correction term of OLS is used. Table 6 shows the results of short run relation. It gives an idea about the adjustment speed a variable would take to converge from short run disequilibrium to long run equilibrium. Banarjee et al (1998)^[44] stated that the formation of long run relation among variables is calculated through the significance of lagged error term having a negative sign. It can be confirmed from the results as reported in Table 6, that lagged error term is -0.85 and represent a high significance. It can be deducted from the stats that convergence rate from a previous year shock to current year is nearly 85 per cent. In case of short run, capital, labor force, military spending and trade openness have encouraging effect on the overall economic development of Pakistan. While on the contrary, external debt has an overall harmful influence on the overall economic growth of the country. External debt has stronger impact as compared to the capital, labor force, trade openness and military spending, whereas the impact of defense sector spending and labor force has irrelevant or insignificant effect in the short run. Similarly,

in both short and long run, labor force has a strong impact on economic growth. Capital and trade openness both are strongly significant and have an encouraging impact on economic development. So, from the empirical evidence of the study, it is confirmed that there is short run impact of capital, defense spending, trade openness and external debt. While there is a long run impact of all the variables on economic growth in case of Pakistan.

The estimates of short run of the study suggest that, capital, trade openness and military spending effects growth positively while labor has insignificant impact. While external debt has a negative effect on the economic development in the short run. This declares that policy makers in Pakistan should use capital, military spending and trade openness as a tool for encouraging the economic growth and achievement of economic goals in the short run. Since the start of War on terror, Pakistan is playing a frontline ally role. As a backlash, terrorists targeted government institutions, public places and property causing invaluable loss to the state. Resultantly, the environment turned out to be unfriendly for trade and economic activity. To counter such active threats, many offensives were launched against the terrorists. These measured required an updated military gear, technological advance surveillance systems and on ground military operations, that incurred a huge cost. With effective policy measures, a peaceful conducive environment was intended that can facilitate and attract the investors and lay grounds for economic acceleration and sustainability. Model used for study has reflected satisfactory results for diagnostic test applied such as serial co-relation, normality, model specification and auto regressive heteroskedasticity. In addition, to test the longer and short run dynamics, cumulative sum (CUSUM) and the cumulative sum of square (CUSUMSQ) tests (Figure 1).

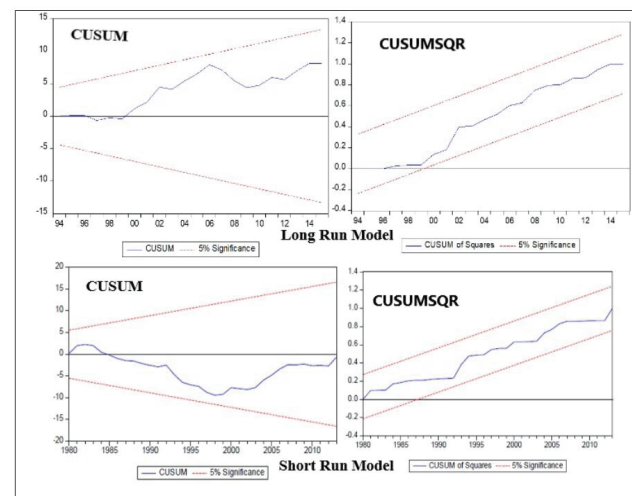


Figure 1. Longer and short run dynamics

5. Conclusion

The empirical evidence of the unit root test indicates that the order of integration of trade openness is $I(1)$, while all the other variables, such as, GDP, capital, labor force, defense spending and external debt are integrated at $I(0)$. Apart from this, long run relationship between the aforesaid variables has been confirmed by cointegration analysis. From the results of Unit Root tests, it was revealed that variables used in the study possess integration of mix order. Hence, for the mixed order of integration, the ARDL Bound testing approach was chosen to analyze the cointegration among the selected variables. From the results long run relationship was confirmed between the economic growth, capital, labor force, defense spending, trade openness and external debt. In the long run, economic growth had positive affect on capital, labor force, defense spending and trade openness. On the other hand, external debt had negatively affected the economic growth. It was also revealed from the results that defense spending and trade openness had a positive contribution towards the economic development in the short run, while labor demonstrated insignificant. Further the Causality analysis reflected a unidirectional causality running from government's expenditure on defense to development of growth, confirming the applicability of Military Keynesian hypothesis in case of Pakistan for the period under investigation. Results confirmed that defense expenditure is a useful policy tool which stimulates the economic growth through its multiplier effect. The results of this study imply that external debt retards the economic growth. External debt always weakens the growth of economy and effect the investment adversely. Too much reliance on debt should be discouraged by the policy makers. Therefore, the debt policy be revised and to counter the deficit budgeting practice the government should widen the base of income generation ventures.

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ARTICLE

A Mathematical Methodology for the Preventive Study of the Failure Rate to Optimize the Maintenance Program of a Public Work: Economic-Management Aspects for Safety and Quality

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ABSTRACT

In this paper we analyze the problem of the assessment of the failure rate of the complex public work system and the engineering part of it (bridge, tunnel, etc.), examining the case of serious maintenance problems, such as those which occurred in the recent disaster of the "Morandi bridge".

The original mathematical methodology envisaged makes it possible to optimize the safety and quality scenarios of the operation and infrastructure in question, also from an economic-management point of view, evaluating every aspect in an integrated way and for the entire period life.

The scientific results obtained are of particular interest for the study of maximization of the planning protocols of "terotechnological" interventions, providing a contribution to the science of programmed maintenance for the mobility networks and for more complex parts such as bridges and tunnels.

1. Introduction

The maintenance of the public work and above all of network infrastructures has become a conservation and the real science of the collective assets^[1-7], those currently investing the complex sector of the scientific research, called in technical literature with the neolo-

gism of Terotechnology.

From a technical, economic and environmental point of view, this new cultural concept of maintaining design standards and improving the performance of the structure for the entire period life, answers key questions: where, how, when to intervene, with what technological measures

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and at what costs. The need to perform maintenance stems from two primary sources, but not always convergent: the safety and quality of the service offered and the economic efficiency on the other hand.

The latter, however, is not always antithetical compared to the first, in consideration of the fact that a delay in the maintenance intervention always involves costs far more relevant than those due to timely action (even better if taken care of before the situation worsens). This is shown, for example, by the simple analysis of the decaying curves of the com-positional materials of engineering work, as in the following figure, where the representative variables of the "road-paving" and those related to the planned maintenance according to a life-cycle cost analysis criterion. In this sense, terotechnology has an even greater impact on the maintenance of civil structures, landscape assets, and monuments, as well for the "time" and interest required and the effect it will have on the community. In particular, the maintenance of today concludes, in the modern econometric analysis of the management of complex work^[8-12], also in order to maximize the safety and quality of the exercise, the role of a real "conservation strategy" of the public interest, is becoming an increasingly important aspect with the increase and the duration of engineering systems.

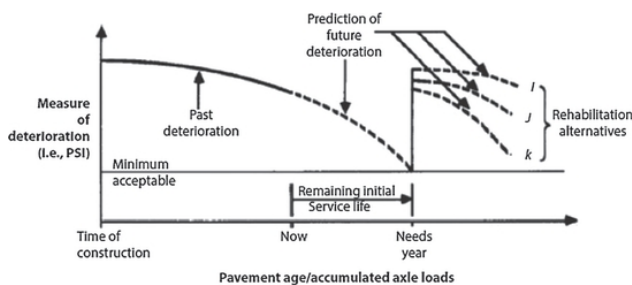


Figure 1. Pavement age/accumulated axle loads

Unfortunately, now we are inundated with news concerning natural disasters, accidents due to non-compliance with regulations, the lack of adequate maintenance programs and interventions to effectively prevent the risk of collapses, errors attributable to inadequate maintenance actions, or the lack of effective monitoring of the complex functioning system considered.

In the recent disaster in Genova, August 14, 2018 due to a serious deficiency of maintenance needed for the Morandi bridge in the Polcevera viaduct (A10 Genoa-Savona motorway), whose concession was given to the "Autostrade per l'Italia" company. The collapse of a bridge only adds a series of errors, design, maintenance and those whom authorized the transit of heavy vehicles, has not provided limitations on traffic and / or speed, narrowing of

the roadway etc. For this strategic work, placed not only on the Liguria mobility network, but also on important transnational corridors, the Società Autostrade had already published a call for tenders for a substantial structural retrofitting operation.

But, on the subject of the "anomalies" of maintenance, other striking events have occurred that have shocked the international public in the past, such as that of June 3, 1998, near Eschede in Germany, when the worst high-speed train accident occurred: 101 people died and another 100 were seriously injured. The first cause of the accident was the breaking of a wheel rim in the first carriage, a part of the wheel on third axle of the convoy. Originally the wheel was cast in one piece but, subsequently, to reduce the vibrations that penalized the passenger's comfort, that was wrongly considered an "improvement" intervention, with the introduction of a special rubber ring between the wheel and rim: this modification was not compatible with the high speed of the train and was the primary cause of the disaster. The consequences of a deficient or inadequate maintenance is always and, in any case, very onerous not only socially but also economically and sometimes generate the loss of many human lives^[13-19]. Sometimes the lack of "reliability" of work done can be fatal; however, the concept of reliability lies on the borderline between design and maintenance, while we now want to focus on the role of maintenance in the conservation of public work, until the maintenance and / or repair or reinforcement (in the case, of a crossing art work, such as the Morandi bridge, a varied configuration of traffic conditions over time and in particular the "flow-velocity" relationship), are not those of the project, requiring an accurate risk analysis, having changed with respect to the original forecasts. It should be noted, in this regard, that in its general meaning, the building process, as defined by the UNI 10838 standard, is the organized sequence of steps that lead from the detection of the needs of the client-user of a building property to their satisfaction through the design, production, construction and management of the asset itself.

2. The Variables Characterizing the "Maintenance-safety" Combination.

Therefore, an appropriate management program for the purposes of optimal conservation of the public health and safety, must include all the operational steps starting from the get go of the building body, are succeeded with the purpose of ensuring its proper functioning, until the end of its functional and economic life cycle^[6,16,30,34]. As seen in Fig. 2 it shows the qualitative trends of the main cost functions and the overall degree of reliability of the engineering work.

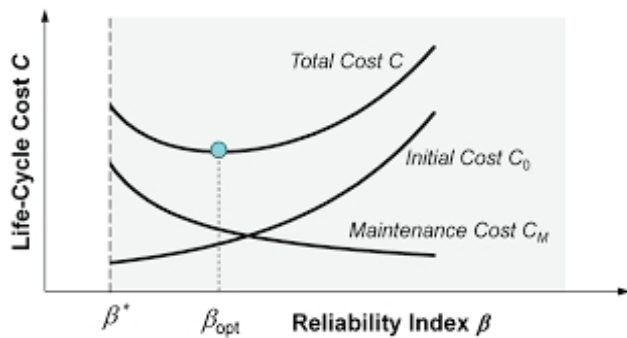


Figure 2. Performance of the main cost functions and the degree of reliability

The most recent definition of maintenance is that in the European standard UNI EN 13306 of 2003, where maintenance is described as the combination of all technical, administrative and management actions, during the life cycle of an entity, designed to keep it in good working order or bring it back to a state where it can perform the required function, in a safe condition.

The central mission of maintenance is therefore that of cooperating throughout the useful life cycle of a public work, from concept to disposal, with the aim to continuously improving its operational availability and maintaining the standard of reliability in operation to protect the public that gave rise to the investment. However, so that the concrete result in favor of the community is consistent with this "mission", the competent subjects must operatively guarantee, together with a steady monitoring of the work, the rigorous implementation of the system of actions defined for scheduled maintenance, in the envisaged thunderstorm.

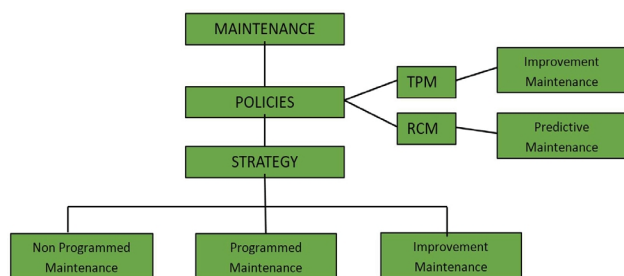


Figure 3. Scheme of the maintenance policy scenarios of a public work

3. A Mathematical Model for the Choice of the Solution that Maximizes the Objectives: the Case of Choice Under Conditions of Uncertainty

The most common methodological approaches to implement the planned maintenance scenarios of complex pub-

lic work are essentially two: Total Productive Maintenance (TPM) and Reliability Centered Maintenance (RCM). The first leads to the Overall Efficiency, i.e. a more efficient use of plants and equipment that introduces a widespread maintenance methodology throughout the organization (Companywide) based on preventive maintenance - predictive (maintenance based on statistical data, as in the case of advanced "Railway terotechnology" implemented by the Italian Railway Network with diagnostic trains also for the AV / AC). In this way it is possible to intervene punctually, effectively and at the lowest operating cost, even before the deterioration occurs.

The RCM maintenance approach is centered on the concept of reliability, born in the aeronautical-military field, with the aim of consolidating the intrinsic reliability of the project. This strategy of optimizing the safety of the work uses, in fact, as a basis the reliability theory, that is a model of analysis of the causes of failure and the risk of the event. These elements allow the constructor responsible for the management and planning of the interventions to define the plans and the operational management methods, putting in place the actions of an integrated type on the complex of the compositional elements at work. In any case, whatever the model of reference, maintenance today requires a complex organization and an effective management system, oriented to the final and above all to the "prevention" of the fault; this implies, respect to the past, also a considerable cultural change of the technical management and of the same maintenance technician (or group of maintenance workers) who must carry out the work, often highly specialized and with the need for special technological equipment^[20-24].

The choice of the best maintenance strategies, and consequently of the "conveniences" and of the opportunities for intervention, are different according to the case in question and, in time, in proportion to the transformation of the structure^[25-28]. Furthermore, the type of choices and the actions required are mainly influenced by the trend of the failure rate $[\lambda(t)]$ of a single component work and their structural interactions, as well as by particular exogenous events that occur (seismic actions, external corrosive agents, other factors of deterioration, etc.).

Unfortunately, in Italy, most of the maintenance interventions, as shown in the graph below, follow a failure strategy; exceptions are that the "predictive maintenance" programs carried out by the Railways, with the train measures that run through the entire network, measuring the characteristic parameters of the infrastructure. These measures are associated with the position: geographic coordinates measured by GPS with differential technology and path space. The position is subsequently linked to the

progressive mileage and to the code of the technical headquarters of the infrastructure data base, which univocally identify the route or location in the company's asset management system.



Figure 4. Morandi Bridge (A10) - visible crack in the stack n. 9 (photo taken 7 minutes before the collapse – Fonte: huffingtonpost).

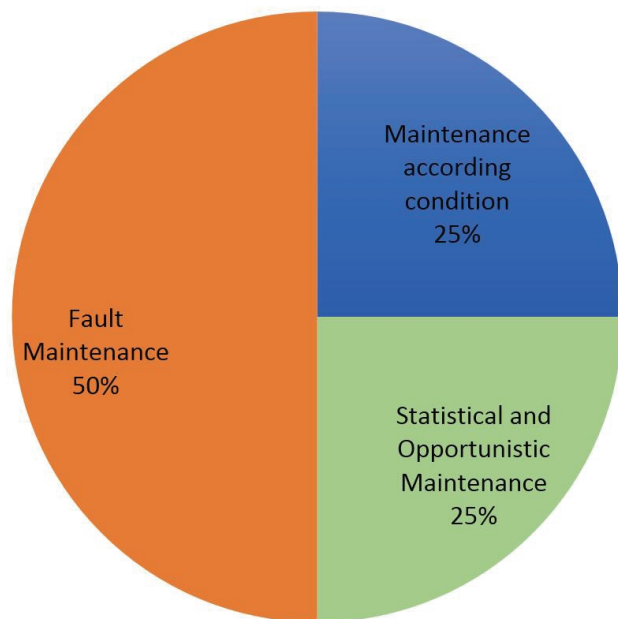


Figure 5. Maintenance culture in Italy

This indicates that the maintenance culture in the general management of public works respect to failure prevention is the tool to lengthen the period of life of the components that are not yet well structured in each sector, to obtain the maximum safety and quality and the minimization of costs over the entire useful life cycle (every predictive intervention, i.e. before the failure to verify, reduces the maintenance charges).

This deficiency emerges above all in the building sector where, in 64% of cases, corrective and non-preventive strategies are used. On the other hand, it is less deficient as

regards the plant engineering fields, where the percentages of preventive measures are much higher than those with a breakdown (with the exception of electrical systems for public works and motorway tunnels). For the road transport sector, without prejudice to the large TEN-T motorway network, it should be noted that maintenance occurs most of the time, including for works of art such as bridges and viaducts, with which the road networks are richly equipped, in "emergency run-up" policy, which can be summarized according to the old "worst-first" culture (heal the worst situation first).

This illogical and uneconomical way of proceeding causes a significant increase in the level of risk, due to the ever-increasing volumes of traffic and therefore to the more critical characteristics of the flow that characterize the network conditions, jeopardizing the safety.

The companies responsible for managing the road patrimony in operation often have budget reductions made to their financial resources dedicated to road maintenance. Limiting even the highly specialized technical resources to comply with a continuous monitoring of the "state of health" of the works. In some cases, there is a lack of proper planning and the "rain" distribution of the overall budget provided on the network under concession, regardless of an accurate and timely assessment of priorities: so, the priority objective to guarantee the essential quality standards of gear and safety, not only to motorized users but to the entire population is nullified (as well as the tragic collapse of the Morandi bridge).

In particular, precisely for the work of crossing the territory, such as bridges, the activity inspection must be technically considered a systematic action that is framed over time for the entire useful life span, related to the continuous data collection of the adequate technological systems.

The analysis work will have to consider the historical series of observed variables, following the evolution of the overall performance and more so the safety level indicators, such as, to characterize the state of the bridge, the Condition Rating mark (CRM)).

Furthermore, in the case of the bridges made with concrete elements, a methodological risk analysis process must be followed, functional to the systematic maintenance management, according to the diagram shown in Fig. 6.

The characteristic CRM indicator represents a numerical evaluation of all possible types of damage that have been detected during the visual inspection of the work and considers their gravity and extent. The condition of a bridge structure is evaluated by using the following general formula:

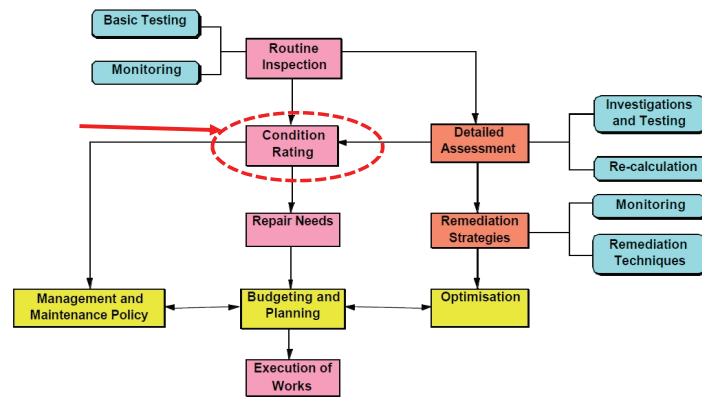


Figure 6. Risk analysis process for a concrete work of art

$$\text{Condition Rating Mark} = \sum G_i \cdot K_{1i} \cdot K_{2i} \cdot K_{3i} \cdot K_{4i}$$

where:

- G_i is the type of damage, $1 \leq G_i \leq 5$;

- K_{1i} is the extent of damage; $1 \leq K_{1i} \leq 1$. It can be described by the words: few or some, frequent or very frequent and big dimensions.

- K_{2i} is the extent of damage; $1 \leq K_{2i} \leq 1$. It can be described by the words: little or insignificant, medium, heavy and very heavy.

- K_{3i} is the importance of the structural element. $1 \leq K_{3i} \leq 1$. Structural components are classified as primary, secondary and other parts.

- K_{4i} is the urgency of intervention $1 \leq K_{4i} \leq 10$ and depends on the type of severity and risk of collapse of the structure or part of it.

-The values that can take Condition Rating Mark are between 0 and 70.

According to this approach, the degree of risk can therefore be roughly characterized by 6 different qualitative scenarios, as shown in the following table:

On the other hand, from a mathematical point of view, the fault alert levels can be identified by specific risk and criticality indicators of the event (detected or potential anomaly), from which the intervention priority can be ob-

tained. Particularly useful for practical applications in the terotechnological sciences, they cover the so-called "risk matrices", as shown below.

Table 1. Degree of risk

Damage class	Definition	Condition Rating value
1	No or very little deterioration	0-3
2	Little deterioration	2-8
3	Medium to severe deterioration	6-13
4	Severe deterioration	10-25
5	Very severe deterioration	20-70
6	Very severe or total deterioration	>50

The latter is attributed on the basis of the variable RPN (Risk priority number) which is a composite risk index and denotes the degree of attention that is required in concrete to address the risk identified for each E_h component of the deterioration event E characterizing in its complex of the public work in the studio (bridge, gallery, entire network, etc.).

The systematic analysis that must be carried out must also include the evaluation of the degree of significance W_h ("weight") of each element E_h characterizing the maintenance problem examined, analyzing all the "concurrent causes" of the degradation.

Table 2. Risk Matrix

		Damage		
		Little	Moderate	Serious
Probability	Very Unlikely	Very Low Risk	Very Low Risk	High Risk
	Unlikely	Very Low Risk	Medium Risk	Very High Risk
	Likely	Low Risk	High Risk	Very High Risk
	Very Likely	Low Risk	Very High Risk	Very High Risk

The "cause-effect" diagrams are the simplest and at the same time the most effective tool for dealing with the problem of the risk analysis of an event. The basis of this tool is to continually use the word "why", that is to constantly question the reason of a certain situation or phenomenon and proceed backwards by asking this question several times.

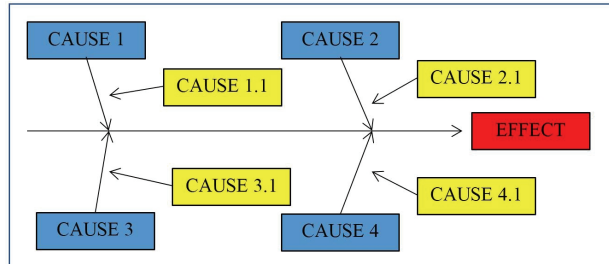


Figure 7. Cause-effect

In this way, it will be possible to make an operative reference to the "Failure Mode and Effect Analysis" criterion, systematically examining all the ways in which it is possible for damage to occur, and for each of them make an estimate of the effects through three indices that define the severity (S), the frequency of occurrence (f) and the detection capacity (C), evaluated according to a numerical scale and combined to define the aforementioned RPN index.

Following this approach, the Risk priority number can be calculated using the mathematical expression:

$$RPN(E) = \sum E_h^{-w_h} (\psi(x_i)) = \sum (S_h \cdot f_h \cdot C_h)^{-w_h} (\psi(x_i)),$$

where $\sum w_h = 1$.

We must determine the values of $x_1, x_2, \dots, x_k$, in order to obtain the optimum solution of the objective function

$$y = \psi(x_1^{-w_1}, \dots, x_1^{-w_1} \dots x_h^{-w_h}),$$

where

$$y = \psi(x_i^{-w_i}),$$

and $\sum w_i = 1$, and expresses the coordinated set of elements of optimization of safety and the quality of the operation of the work at the time "t" in which the verification is carried out, within the interval $[0, \dots, t, \dots, T]$ of the relative useful life. The aim of the aforementioned analysis is to be able to identify in advance all the actions necessary for the full restoration of structural efficiency and performance in operation and to avoid all possible damage related to the risk event detected, ensuring the quality global engineering work and at the same time minimizing management costs, thanks to the timely adoption of the best solutions to the maintenance problems. Depending on the technical framework offered by the complex from the

data collected and in relation to the risk scenario where decisions must be made in conditions of uncertainty (in the operational choices on maintenance the random variables often play a decisive role), a methodology approach in such case, the problem can be summarized as follows^[29]. We consider m random independent events E_i ($i = 1, \dots, m$) which characterize the problem and we suppose that they are complementary, such that if the event E_1 occurs, it excludes any other alternative E_i .

For any other possible events we associate the probability p_i with $\sum_{i=1}^m p_i = 1$. If we denote with A_j ($i = 1, \dots, n$) the different alternative options in order to make the maintenance program, the Project Manager must make his choices by analyzing a complex set I, made up of elements R_{ij} obtained from:

$$A_j = f(E_i).$$

The problem is represented by a data table, where the decision alternatives take on the mathematical connotation of random variables. Considering that the expected value of a discrete random variable (that assumes that is only a finite number or a countable infinity of values) is given by the sum of the possible values of this variable, each multiplied by the probability of being assumed (ie the occurrence of event), we need to calculate the weighted average of the possible results and, therefore, the expected value $V_j(A_j)$ of each variable A_j . The latter is given by the expression:

$$V_j(A_j) = \sum_{i=1}^n R_{ij} \cdot p_i.$$

Therefore, on the basis of the previous reports, it will be possible to reach the "optimal" project solution $S_p(A_k)$, considering all the variables A_k that set in the definition of the decision-making process (including those A_j of random type):

$$S_p(A_k) = \arg \left\{ \max_{k=1, \dots, s} [V_k(A_k)^{-w_k}] \right\},$$

where W_k represents the "weight" of each alternative A_k with $\sum_{i=1}^s w_k = 1$.

In order to evaluate the degree of relevance and, therefore, make the best choice, the specific impact of each risk must be cataloged on the basis of a scale of factors such as performance, timing, costs, quality, the image of the organization, the damage to international relations, the effects to the environment, etc.

Finally, the probability of occurrence must be assigned to each identified risk and the expected monetary value estimated for each consequent impact generated (including the "externalities" due to the effects on the intrinsic safety of the work). This in order to be implement effectively the risk planning and management of better coordinated management of emergencies, providing for a targeted response

strategy: this must ultimately include the definition of all the actions and resources necessary to reduce the impact and / or probability of risk within acceptable levels of safety and quality.

To this end, a logical scheme useful in practice to optimize this important aspect, can be represented by the following matrix (see Fig. 8) that provides a representation of the activities (A, ..., F) and the risk characterization, evaluated according to the criticality of the event and its probability of occurrence^[30-33]

Critic		
IMPACT	B C	D E
	Successful Prerequisites of the project	
Minor	A	F
	Low	High
	PROBABILITY	

Figure 8. Logical scheme of probability

Through this methodology of approach to the problem under study, we come to the choice of the "optimal" solution of the project $S_p(A_k)$, given by the formula:

$$S_p(A_k) = \arg \left\{ \max_{k=1, \dots, s} [V_k(A_k) - w_k] \right\},$$

where A_k is the generic project alternative of intervention, among the "s" compared, in respect to the different technical, economic and environmental constraints, while is the expected value of each variable A_k (many of them aleatory) analyzed in the decision-making process, to which a "weight" w_k has been attributed.

4. Preventive Failure Rate Study to Optimize Maintenance

Consider a sequence $X_1, X_2, \dots$ of independent random variables of the same order, which represent periods of life^[34]. It could either represent time of service before a failure of any material kind occurring at an initial time of $t=0$. Our aim is to obtain information on the common distribution of these periods of life starting from observation data. Putting $X=X_1$, for convenience' sake, we note that $F(x)=(X \leq x)$ is the probability that the length of life is less than or equal to x . It is supposed that F has a probability density $f(x) = \frac{d}{dx} F(x)$ continuous on $(0, \infty)$, which allows us to define the rate of failure as

$$\lambda(x) = \frac{f(x)}{1 - F(x)} = \frac{\text{Number of fail in the period } [x, x + dx]}{dx \times \text{Mean number of observations } x} \quad (1)$$

The most classic model to present these periods of life is the exponential law $F(x) = 1 - \exp(-\lambda x)$ for $x > 0$, corresponding to a λ constant rate of failure. From a sample $X_1, X_2, \dots, X_n$ of data resulting from this exponential law, λ can be calculated without difficulty by the method of the maximum likelihood ratio

$$\hat{\lambda} = \frac{n}{\sum_{i=1}^n X_i}, \quad (2)$$

which is asymptotically normal with $n^{1/2}(\hat{\lambda}/\lambda - 1) \rightarrow N(0,1)$ when $n \rightarrow \infty$. However, this is an ideal situation, and a more complicated distributions of exponential laws that are more frequent. The most classic example is given by the Weibull family of laws which includes the exponential law as a particular case, and for which,

$$F(x) = 1 - \exp(-\lambda x^\alpha),$$

and

$$f(x) = \alpha \lambda x^{\alpha-1} \exp(-\lambda x^\alpha) \quad \text{for } x > 0.$$

The corresponding rate of failure is therefore

$$\lambda(x) = \alpha \lambda x^{\alpha-1} \quad \text{for } x > 0.$$

IFR (increasing failure rate) or DFR (decreasing failure rate) laws are thus obtained by putting $\alpha > 1$ or $0 < \alpha < 1$. Evaluation of λ and α parameters of such a distribution is more complex than the exponential law. This is in part due to the fact that density $f(x)$ can become infinite at $x=0$ for certain values of α . However, it is possible to use the method of the maximum likelihood ratio estimating (λ, α) for $(\hat{\lambda}, \hat{\alpha})$, obtained from the solution of the following equations

$$\hat{\lambda} = \frac{n}{\sum_{i=1}^n X_i^{\hat{\alpha}}} \quad \text{and} \quad \frac{1}{\hat{\alpha}} = \frac{\sum_{i=1}^n X_i^{\hat{\alpha}} \log X_i}{\sum_{i=1}^n X_i^{\hat{\alpha}}} - \frac{\sum_{i=1}^n X_i^{\hat{\alpha}} \log X_i}{n} \quad (3)$$

This is usually obtained by means of recurring algorithms, starting from the initial value $(\hat{\alpha}, \hat{\lambda})$ of (α, λ) , obtained from the moment's method. To obtain this, it can be seen that, for $r > 0$ we have:

$$(X^r) = \Gamma(r/\alpha + 1) \lambda^{-r/\alpha},$$

$$(X) = \Gamma(1/\alpha + 1) \lambda^{-1/\alpha},$$

$$(X) = \Gamma(2/\alpha + 1) \lambda^{-2/\alpha},$$

which gives values $(\hat{\alpha}, \hat{\lambda})$, obtained from the solution of the system

$$\frac{\Gamma(2/\hat{\alpha}+1)}{\Gamma(1/\hat{\alpha}+1)^2} = \frac{\frac{1}{n} \sum_{i=1}^n X_i^2}{\left(\frac{1}{n} \sum_{i=1}^n X_i\right)^2} \quad \text{and} \quad \hat{\lambda} = \left(\frac{\Gamma(1/\hat{\alpha}+1)}{\frac{1}{n} \sum_{i=1}^n X_i} \right)^{\hat{\alpha}} \quad (4)$$

The complex, implicit form the equations (3) and (4) gives us an idea of the practical difficulties which can be encountered in the application of these methods based on non-exponential parametric models. In addition, it may happen that data has to be used which do not have a clear model of parameters. There-fore, different models are compared amongst themselves, for example, based on gamma and lognormal families of laws. More details on this can be found in the work of Kalbfleisch and Prentice^[35].

5. A Mathematical Approach for a Problem of Preventive Maintenance

The problem becomes even trickier when, instead of looking at raw data for a period of life $X_1, X_2, \dots, X_n$, there is censored data^[36-42]. It is supposed that there exists a sequence $Y_1, Y_2, \dots$ of the censored time whereby it is only possible to observe periods of life through the intermediary (Z_i, δ_i) , $(Z_2, \delta_2), \dots$ where, for $i = 1, 2, \dots$,

$$Z_i = \min\{X_i, Y_i\} \quad \text{and} \quad \delta_i = \begin{cases} 1 & \text{when } X_i \leq Y_i \\ 0 & \text{when } X_i > Y_i \end{cases} \quad (5)$$

in other words Z_i is the minimum value of length of life X_i and time of censored Y_i , while δ_i is equal to 1 if the length of life is not censored, otherwise it equals 0.

Actually, this is the most frequent situation. In industrial application situations one does not wait for material to fail (at the end of time X_i) to substitute it, in a preventive maintenance program (carried out at the end of time Y_i). Intervention can take place at the end of time $Z_i = \min\{X_i, Y_i\}$ distinguishing cases $\delta_i = 1$ (intervention after failure) from $\delta_i = 0$ (intervention of preventive maintenance).

In practice, a model can be used where the sequence of lengths of life $\{X_i : i \geq 1\}$ and the successions of censored time $\{Y_i : i \geq 1\}$ are independent, and where each of these sequences are made up of independent and random variables of the same order, with

$$\begin{aligned} F(x) &= (X \leq x), \quad G(x) = (Y \leq x), \\ H(x) &= (Z \leq x) = 1 - (1 - F(x))(1 - G(x)) \\ &\text{for } x > 0, \text{ when } Y = Y_1 \text{ and } Z = Z_1 \end{aligned} \quad (6)$$

The shape of the distribution of the censored data (that is of G) is, in general, totally unknown. What is still worse, is that there is no reason to suppose that this dis-

tribution function G is continuous. For example, in the case of preventive maintenance, censored times are often used, taking a finite value number, which corresponds to discrete laws. Let it be said we are not particularly interested in G , which is introduced as a negative parameter of modern urban life, here we try to eliminate it to recuperate data on F .

In the case of which $F(x) = 1 - \exp(-\lambda x)$ follows an exponential law, evaluation of the rate of failure λ (which here fully determines the distribution of the length of life) is relatively easy, even with censored data. The following reasoning is quite clear. Let us put

$$G_{-}(x) = \lim_{\varepsilon \rightarrow 0} G(x - \varepsilon).$$

It can easily be seen that

$$H(x) = Z \square x = H^{(0)}(x) + H^{(1)}(x),$$

when

$$H^{(0)}(x) = P(Z \leq x \text{ and } \delta = 1) = \int_0^x (1 - G_{-}(t)) dF(t),$$

and

$$H^{(1)}(x) = P(Z \leq x \text{ and } \delta = 0) = \int_0^x (1 - F_{-}(t)) dG(t),$$

$$p = (\delta = 1) = (\delta) = \int_0^{\infty} (1 - G_{-}(t)) dF(t), \quad (7)$$

when $\delta = \delta_1$. From (7) it is implied that

$$p = (\delta) = \lambda \int_0^{\infty} (1 - G_{-}(x)) \exp(-\lambda x) dx = \lambda \int_0^{\infty} (1 - G_{-}(x)) \exp(-\lambda x) dx,$$

while

$$(Z) = \int_0^{\infty} x dH(x) = \int_0^{\infty} (1 - H(x)) dx = \int_0^{\infty} (1 - G(x)) \exp(-\lambda x) dx.$$

the estimator can be deduced

$$\hat{\lambda} = \frac{\sum_{i=1}^n \delta_i}{\sum_{i=1}^n Z_i} = \frac{n^{-1} \sum_{i=1}^n \delta_i}{n^{-1} \sum_{i=1}^n Z_i} = \frac{\bar{\delta}}{\bar{Z}}. \quad (8)$$

It can be seen that (8) takes us back to (2) in the case of non-censored data (since $\delta_i = 1$ for every i). This estimate has optimum properties (estimator of the maximum likelihood ratio). It can be shown without difficulty that

$$(Z^2) = 2B = 2 \int_0^{\infty} x(1 - G(x)) \exp(-\lambda x) dx, \quad (Z) = A = \int_0^{\infty} (1 - G(x)) \exp(-\lambda x) dx,$$

$$(Z\delta) = \lambda B = \lambda \int_0^{\infty} x(1 - G(x)) \exp(-\lambda x) dx \quad (\delta) = \lambda A = \lambda \int_0^{\infty} (1 - G(x)) \exp(-\lambda x) dx,$$

$$\text{Var}(Z) = 2B - A^2, \quad \text{Cov}(Z, \delta) = \lambda(B - A^2) \quad \text{Var}(\delta) = \lambda A(1 - \lambda A)$$

In addition, when $n \rightarrow \infty$,

$$\begin{aligned} n^{1/2} \left(\frac{\hat{\lambda}}{\lambda} - 1 \right) &= n^{1/2} \left(\frac{\bar{\delta}}{XZ} - 1 \right) = n^{1/2} \left(\frac{1 + n^{-1/2} \left\{ n^{1/2} (\bar{\delta} - \lambda A) / \lambda A \right\}}{1 + n^{-1/2} \left\{ n^{1/2} (Z - A) / A \right\}} - 1 \right) \\ &= n^{-1/2} (\bar{\delta} - \lambda A) / \lambda A - n^{1/2} (Z - A) / A = \\ &= N \left(0, \frac{1}{\lambda A} \right) = N \left(0, \frac{1}{\lambda \int_0^1 (1 - G(x)) e^{-\lambda x} dx} \right) \end{aligned} \quad (9)$$

In this case of non-censored data results are found putting $G(x)=1$, and we obtain

$$\lambda \int_0^1 (1 - G(x)) e^{-\lambda x} dx = \lambda \int_0^1 e^{-\lambda x} dx = 1.$$

The convergence (9) allows us to obtain confidence intervals for λ if we consider

$$n^{1/2} \left(\frac{\hat{\lambda}}{\lambda} - 1 \right) \bar{\delta}^{1/2} \xrightarrow{d} N(0, 1) \quad \text{with} \quad \bar{\delta} = \frac{1}{n} \sum_{i=1}^n \delta_i$$

if it is underlined that

$$n \bar{\delta} = \sum_{i=1}^n \delta_i = N$$

is nothing more that the number of observations of the non-censored length of life, the asymptotic confidence interval is obtained

$$\left[\lambda \in \left[\hat{\lambda} \left(1 - \frac{V_{\alpha/2}}{\sqrt{N}} \right), \hat{\lambda} \left(1 + \frac{V_{\alpha/2}}{\sqrt{N}} \right) \right] \right] \approx 1 - \alpha,$$

where $V_{\alpha/2}$ indicates the order quantity $1 - \alpha/2$ of the normal law $N(0, 1)$. The formula above the above formulas are generalised, not without some technical difficulties, for the Weibull, gamma or lognormal family of laws. However, in the absence of precise information on models it is strongly advised to use non-parametric estimators such as the Kaplan-Meier (1958) estimator.

6. Conclusion

The recent and dramatic collapse of the Morandi Bridge on the A10 motorway, in Genova, has opened a lively debate on the investments actually incurring in Italy and in the EU for the maintenance and modernization of both the road and motorway networks, and moreover, on the whole transport system and on major crossing works.

The technical literature of the sector shows how an effective risk prevention tool is already represented by an accurate Bridge Management System (see Fig. 9), through which the managing body can continuously have all the information necessary to program in an optimal manner the maintenance and control of the structures heritage, considering structural, economic and social factors.

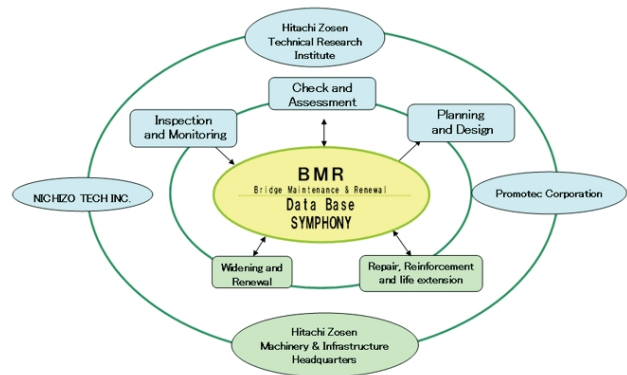


Figure 9. Bridge Management System

The OECD data show that Italy would rank second in Europe for road maintenance spending, with just over € 15,000 spent per km in the years between 2010 and 2015. However, these figures are not strictly indicative, because the Italian orographic context requires proportionately higher expenses than those that might be needed in another flat country of the Union such as, for example, Denmark.



Figure 10. Morandi Bridge collapsed in 14.8.2014 Genova (A10)

In the last decade, the science of maintenance (terotechnology) has had a significant development in the scientific field due to the incidence that it assumes in the economy of a modern country and for the community, representing a fundamental element for the exercise in safety of the complex integrated mobility system, both for passenger and freight traffic.

In the present work, attention has been focused on the assessment and analysis of the degradation status of the road infrastructures and in particular to the major works of art, in order to estimate the degree of risk of each compositional element and to establish the priorities of the interventions. maintenance necessary to ensure appropriate quality and safety standards.

Moreover, original mathematical models have been developed which, through the use of specific variables characterizing the problem under study, allow to achieve the optimization of the results of the planned maintenance action, both in terms of quality and safety and containment. Operating costs in the useful life cycle of the public works (or the set of assets, in the case of a network) under consideration.

The Project optimum solution (considering different aspect) $S_p(A_k)$ is taken from:

$$S_p(A_k) = \arg \left\{ \max_{k=1, \dots, s} [V_k(A_k)^{-w_k}] \right\},$$

where A_k is the k-th alternative project alternative, $V_k(A_k)$ is the aspected value for any variable A_k considered in the decisional process and w_k is the weight.

Finally, the preventive study of the failure rate was optimized to optimize a maintenance process and the mathematical resolution of a preventive maintenance problem was also proposed, in the presence of censored data.

The mathematical model can be effectively used where the sequence of life span and the sequences of the censored times are independent and where each of these sequences composed of independent random variables of the same order.

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REVIEW

A Brief Review for E- Commerce and the Critical Success Factors

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ABSTRACT

Along with the rapid development of information technologies, traditional trade has moved to electronic area. Today, many business activities are performed in electronic environment. Since electronic commerce is rapid and easily reachable, it has begun to attract much more attention by consumers and businesses over time. In this study, a brief review about e-commerce is provided. The main aim is to examine the hot topic of e-commerce with different aspects. The increasing importance of e-commerce is presented by providing statistical support which shows a dramatic increase in total e-commerce sales worldwide. Tools, types, payment methods, and critical success factors of e-commerce are investigated. Eight different tools which can be used in e-commerce are explained. Seven types of e-commerce are classified. In addition, nine payment methods of e-commerce are elaborated. Moreover, three main critical success factors including eight sub-factors are structured in a hierarchical form to aid the companies in e-commerce. Depending on these critical success factors, this study aims to set a well-organized base in order to decide the best e-commerce company in further studies.

1. Introduction

The improvements in communication and computer technology have brought many opportunities to facilitate human life. In recent years, electronic commerce (e-commerce) has come to the forefront as a dynamic economic sector and it has also become one of the attractive ways of starting a business activity. E-commerce has emerged as a result of the emergence and development of information technology which is an innovation that allows for easier trade.

According to Demir^[1] transactions must have certain characteristics in order to be evaluated as e-commerce. First of all, the operations must be done in an electronic environment. Secondly, it must include dealing between

two or more parties. Thirdly; sound, image and all digital products have to be processed and stored. Finally, transactions must be commercially viable or capable of supporting these commercial transactions^[2].

Similarly, World Trade Organization (WTO) defined e-commerce as the production, advertisement, sales and distribution of goods and services through telecommunication networks^[3].

In another study, e-commerce working system is depicted in Figure 1^[4]. Customer orders product or service from the seller via using telecommunication networks. The seller procures the desired unit from its suppliers as in the form of final product or raw material to be processed. Then, the seller transmits the item to its customer by using

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different means of logistics. By the way, banks which are responsible for the payment infrastructure perform the funds transactions between the customer and the seller.

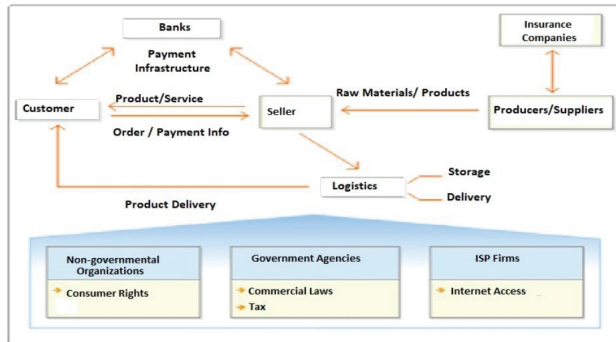


Figure 1. Electronic Commerce Working System ^[4]

In recent years, the usage of e-commerce has increased tremendously due to its advantages both for customers and enterprises. Advantages of e-commerce in terms of customers can be listed as ^[5],

Accessibility: Shopping in the electronic environment allows instant access to every product at any moment.

Less Shopping Time: Customers save time thanks to electronic commerce. Shopping on the Internet is fast and practical.

Comparability: E-commerce has more options to see and choose who offers the best pricing. Product comparison in electronic shopping is easy. Comparisons of products can be made easily.

Comments: The views of other buyers regarding the

products and services can be easily viewed.

Discount Rates: In e-commerce, coupons and opportunities are utilized. Large stores often show their products in online stores with higher discount rates.

Advantages of e-commerce in terms of companies can be listed as ^[5],

Higher Customer Database: E-commerce offers advantages in increasing customer base in businesses. In online shopping, people from all over the world can access their products and return at any moment.

Wider International Markets: It increases sales. An enterprise can have more online sales with higher profit margins. More products can be sold while serving international markets.

Accessibility: Electronic commerce sites are accessible every day and hour of the year. Online shopping or transactions are always open to consumers.

Expandability: It gives the opportunity to expand the business scene. An online business does not have to create a site for every language. With the right marketing, consumers around the world can easily find the business, the products and the information whenever they want.

Easy-Pay Systems: Each business can easily adjust their payment system.

Instant Transactions: You do not need to wait 30 days for e-commerce for approval or for some other payment types.

Although e-commerce contains some similarities with traditional trade, there are some differences ^[6]. The birth of traditional commerce has come when people and societies began trading among themselves. With improved

Table 1. Comparison of Traditional Trade and E-Commerce ^[3]

Purchasing Firm	Traditional Trade	Electronic Commerce
Information Retrieval Methods	Negotiations, magazines, catalogs, advertisements	Web pages
Demand Specification Method	Written form	Electronic mail
Demand Approval	Written form	Electronic mail
Price research	Catalogs, interviews	Web pages
Ordering	Written form, fax	Electronic mail, EDI
Suppliers	Traditional Trade	Electronic Commerce
Stock control	Written form, fax, telephone	Online Database, EDI
Shipping Preparation	Written form, fax, telephone	Online Database, EDI
Delivery note	Written form	Online Database, EDI
Invoice	Written form	Electronic mail, EDI
Ordering Firm	Traditional Trade	Electronic Commerce
Delivery Confirmation	Written form	Electronic mail, EDI
Payment Schedule	Written form	Online Database, EDI
Payment	Bank Transfer, Mail, Collection.	Internet banking, EDI, EFT

living conditions and the development of modern technological innovations, traditional trading has now become a faster and easier way to trade. With the development of information technologies, trade has now begun to take place in the digital environment. The main differences between traditional trade and e-commerce are examined in Table 1 [3].

The table above shows the basic differences between traditional trade and e-commerce. E-commerce is a type of trade that takes place entirely in the digital environment. In traditional trade methods, the methods used to purchase goods and services are usually conducted by face to face interviews with the firm or persons and looking at brochures about the products. But goods or services to be purchased in e-commerce are easily examined on the internet pages of companies [3].

In addition, the statistical inferences from the present e-commerce environment need to be studied to show the importance of the topic. The following first statistic gives information about the total e-commerce sales worldwide from 2014 to 2021 and shown in Figure 2 [7]. In 2017, retail e-commerce sales worldwide amounted to 2.3 trillion US dollars and e-retail revenues are projected to grow to 4.88 trillion US dollars in 2021.

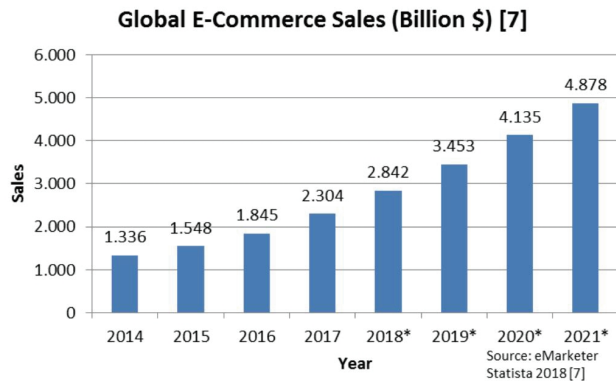


Figure 2. Global e-commerce Sales (\$) from 2014 to 2021. (*represents the expected values) [7]

Depending on the statistical researches, the digital buyer penetration worldwide from 2016 to 2021 can be achieved and shown in Figure 3 [8]. In 2016, 58.3 percent of global internet users had purchased products online. In 2021, this figure is expected to surpass 65 percent of internet users worldwide, the e-commerce industry is set to evolve and expand. Beyond these statistics, the readers can achieve many statistical reports via the literature [8].

Since e-commerce has many advantages and differences from the traditional trade; there is a need for a general brief about e-commerce to appeal. The main contributions of this manuscript are in two-fold. Firstly, general information about e-commerce is explained. Secondly, the

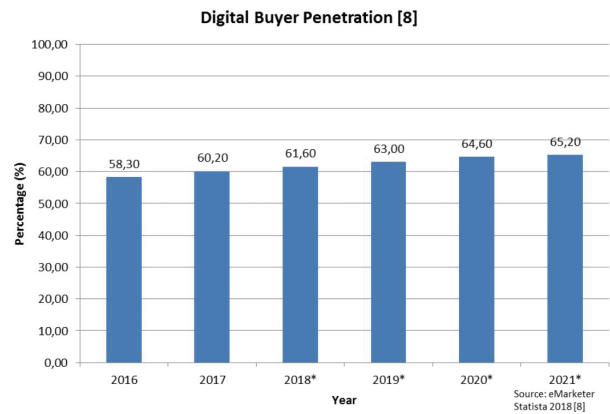


Figure 3. Digital Buyer Penetration Percentages from 2016 to 2021. (*represents the expected values) [8]

factors affecting the customer satisfaction and increasing the success of e-commerce are elaborated. While performing these contributions following objectives are achieved. Firstly the evolution of eight different e-commerce tools is presented. Then, e-commerce types are categorized in seven classes. As the third aim, payment methods used in e-commerce are clustered in nine groups. After that, as the final objective, the critical success factors for e-commerce have been deeply investigated and hierarchically listed in three main and eight sub criteria. In short, the main goal of this study is to present a brief review about e-commerce. This brief is also supported by some statistical data given in Figure 2 and Figure 3.

The mapping of this study is as follows: Section 1 introduces the definition and explains the importance of e-commerce as well as stating the advantages and differences of e-commerce from the traditional trading system. Section 2 mentions about different e-commerce tools. Section 3 classifies e-commerce systems. Section 4 reveals different payment methods in e-commerce. Section 5 explains the importance of customer satisfaction and different techniques to measure the satisfaction. Section 6 specifies the critical success factors in e-commerce and structures them in a hierarchical form. Section 7 concludes the study while enlightening future research directions.

2. E-commerce Tools

In previous years, e-commerce tools such as telephone and fax were used for a long time, but with the advent of the internet, e-commerce tools have begun to change. The following e-commerce tools are listed below.

Telephone: It is the oldest vehicle that has been used in e-commerce for many years. The spread of e-commerce has maintained its importance for many years. Since it provides an interactive and flexible mutual communication, it is generally preferred for communication between

parties. Today, the telephone is still actively used in e-commerce.

Fax: It is a tool developed to reduce the time loss for written communication ^[9]. It has not been preferred by users in recent years in terms of price being expensive and poor quality. Especially with rapid changes in technology, it loses its importance over time.

Television: It is widely used as a one-way communication tool, which makes it difficult to carry out transactions in many ways in e-commerce transactions ^[10]. But with today's technology and smart TVs, people are shopping with a single transaction that they do in front of the television. Although smart TVs are still constraints in terms of e-commerce transactions, they are still an important electronic commerce tool for creating a brand preference in terms of trading sites.

Electronic data interchange (EDI): Electronic Data Exchange is a communication standard that enables sharing of business documents such as information, invoices, bill of lading, and product stock number ^[11].

WAP (Wireless Application Protocol): WAP is a technique used by telephone users to provide convenient access to wireless devices and the Internet. It is fast, convenient and reliable to access the network internally with compatible devices only. Mobile users can perform banking operations; can learn road status, weather or news, thanks to the implementation of this method ^[12].

Electronic payment and money transfer systems: Automated Teller Machines (ATMs) which are widely used today are examples of these systems. However, these machines do not have a wide range of functions in e-commerce due to the limited transaction capacity they perform. In e-commerce, credit cards are the most popular electronic payment and transfer system tools today. Apart from these, smart cards, electronic checks and digital money are examples of other electronic tools in e-commerce ^[13].

Intranet: The intranet and internet are terms that are often compared by most people. But intranet is a method that is established within the company and can work alone without internet connection. This practice is generally used by institutions. The aim is to maintain the communication within the company in a rapid manner. In this way, employees are able to keep track of work remotely, actively use most software, share documents and distribute them ^[13].

Internet: The Internet is an important technology that is heavily used in electronic commerce. Internet is a communication network established among computers, where people communicate with each other and perform many operations ^[10]. As you can see in Figure 4, the time of the discovery of the Internet took place between 1961 and

1974. With the development of computer use after the 70's, the process of institutionalization of the internet has begun. From 1975 to 1995, the use of the internet began to become widespread. In 1995 and after, the internet began to take its place in commercial business. Today it is still an important tool of e-commerce.

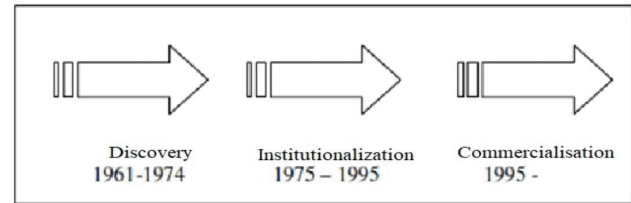


Figure 4. Steps in the Development of the Internet ^[11]

As it is seen, there are eight different tools of e-commerce. However, new tools of e-commerce have been arising progressively. In recent times, mobile phones are being used as a newer tool for e-commerce. Although they use the existing internet technology in the background, m-trading (mobile trading) has become an emerging way of e-commerce. Therefore, the tools of e-commerce can be inferred as evolving continuously in the time.

3. Classification of E-commerce

With the development of e-commerce, the environment of trade, its scope and its sides have begun to expand. We can examine the types of e-commerce in 7 broad categories.

Business to Business (B2B) e-Commerce: It is a type of trade that takes place between two companies. In this trading system, if the products or services are sold from a supplier to other firms and if all these transactions are carried out in an electronic scope, this type of trade can be called B2B ^[14].

Business to Consumer (B2C) e-Commerce: It is a type of trade that is between a business and a consumer. It has become increasingly popular with the development of internet technologies in recent years. Consumers can access all kinds of products and services on-line, obtain necessary information about these products and services and make comparisons with the products of other companies ^[15]. This method of trade allows businesses to build websites to promote their goods and services on-line. Consumers can access these information and services practically via the internet, and at the same time they can communicate directly with consumers through this method ^[16].

As seen in Figure 5, China (with a share of 33.7%) and the United States (with a share of 26.2%) are the leading countries where electronic commerce is most intensively undertaken. In addition, the biggest players in e-commerce, which are Amazon, Alibaba, and E-bay, are located

in these two countries.

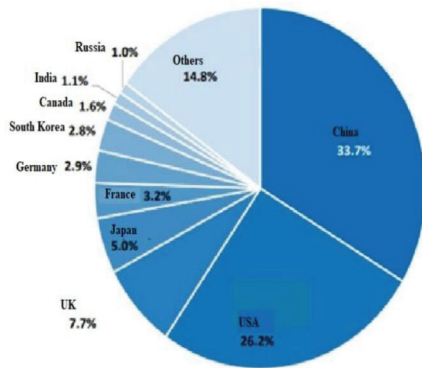


Figure 5. Top 10 Countries in B2C E-commerce Sales ^[17]

Consumer to Consumer (C2C) e-Commerce: It is a trade model in which two people or consumers directly deal with each other. It may be a third party in the process, but the intent of this tool is simply to facilitate the process and create an environment that connects people together. This tool may charge a fee or commission, but is not responsible for product changes. In this trade model, there is an auction where the proposal is made online. In this auction, products are sold online to another consumer. Seller may pay a fee on this platform to sell its products, but the buyer is generally not subject to any fee ^[18].

Consumer to Business (C2B) e-Commerce: This is an e-commerce model in which the consumers offer goods and services to the firm and the companies pay for the consumers. This trade model is a form of trade that is the opposite of the trade model that firms offer goods and services to consumers or offer. Blog sites can be exemplified on the internet. The blog author can direct a person visiting the page to receive a book that he recommends to any popular ecommerce site. As a result, the writer is able to earn member sales revenue from sales made ^[19].

Business to Government (B2G) e-Commerce: In this model, businesses bid on the government projects or products which are needed for their organizations. This can encompass public sector organizations that propose the bids. It is also referred to as public sector marketing. In this model of trade between firms and public administrations, situations such as tenders or specifications governed by these administrations are evaluated within this trade model ^[20].

Government to Government (G2G) e-Commerce: This is defined as the activities of different public departments or organizations in the same public administration on-line ^[10]. It is commonly used in the UK. Two types of trade model are used here. The first is inward-looking e-commerce. In other words, it is in the form of a single government department, centralized or organized trade. An example is the UK health data binding system. The second is e-commerce,

which is done outwardly. In outward-looking e-commerce, more than one government must establish information systems. This is exemplified by the information systems that Schengen countries are using to meet the provisions of the Schengen agreement ^[19].

Consumer to Government (C2G) e-Commerce: It is a type of trade that occurs between the consumer or the citizen and the state authorities. In this trade model, many transactions such as health and passport transactions, tax payment and population transactions take place in the electronic environment. As an example in Turkey, www.turkiye.gov.tr can be nominated.

In our point of view, among these seven e-commerce types; B2C, C2C, and C2B are the most widely used ones. Since the end users (consumers) are a part of these commerce, these e-commerce types can touch to anyone in the society. On the other side, that would be better to compare the market share of each e-commerce type. However, the aim of this study is just to clarify a brief review about e-commerce. In need of deeper analysis, the readers are referred to the literature ^[21].

4. Payment Methods in Electronic Commerce

Electronic payment methods are a condition that must be examined in terms of electronic commerce security. The payment methods in e-commerce are examined below.

Credit Card: Paying by credit card is one of the payment methods heavily used in the virtual environment ^[22]. Credit cards are shown as reasons for preference in terms of the customers because they are easy to use and do not need an additional system. The parties to the credit card are card issuers, service providers, banks and card issuers ^[22].

Credit card usage is also preferred over the internet for customers. In the case of paying over the internet, the counterparty receives the information of the buyer by credit card. However, it is important to take some precautions while performing these operations in the virtual environment. There is a danger that the receiver's credit card information may be stolen by other people ^[22].

Some methods have been developed for securing credit cards. One of them is SET (secure electronic transaction) that works by encrypting card information. SET is a security process developed by credit card companies in 1996 as a result of collaboration with organizations such as Microsoft, IBM and Netscape. It is a method that is used to block the security aspect of payments made by credit card ^[22]. Nowadays, this security process is replaced by a 3D security scheme ^[23].

Payment with Virtual Card: It is issued for online shopping. Virtual cards are being issued to enable consumers to make secure shopping online. The starting limit of the card is zero and works depending on the original card.

The cardholder carries out the shopping within the limits allocated for purchasing goods and services. Since the security code and number of the card are different from the main card, it is not possible to access the mother card information. The person is not physically carrying this card. Card numbers and transactions are processed only online. For this reason, there is no risk to be stolen or lost ^[24].

Payment with smart card (Chip Card): Smart cards, or in other words, chip cards, are much more useful and functional than other card types. These cards are divided into 3 parts in terms of content; cards with only memory, with security features, and with their own processor. If they are physically connected, they are divided into two groups, Contacted and Non-Contacted ^[24]. The details of these types of cards can be found in the literature [24, 25].

Payment with electronic cash: Electronic cash means that storing money in virtual environment for payment ^[26]. In order to benefit from this system, it is necessary for the consumers to install the software specially prepared by the companies that provide electronic money service on their computers and to have the accounts in the banks where the company agrees. After this step, shopping is done in virtual environment with electronic money contracted institutions ^[27]. With the development and widespread use of electronic payment instruments, new electronic currencies such as BitCoin and LiteCoin are emerging. All electronic currencies used today are produced by companies or organizations, regardless of individual or state ^[26].

Payment by electronic check: It is a system that enables businesses operating in e-commerce sites to receive payments as checks. In this system, the payment is made by entering the necessary bank information of the person into the system without the need for a credit card. In other words, the customer is paying this trade site by check withdrawal ^[27].

Payment by electronic wallet: Electronic wallet is a program developed to shop in virtual environment. For the use of the electronic wallet, users are beginning to use the wallet by downloading this program to their computer or smart phones and identifying their personal information once ^[28]. Electronic wallet payment is a convenient method for frequent shoppers in the virtual environment. Many personal data are stored in here such as credit cards, passwords, and financial information ^[29].

Payment with electronic fund transfer (EFT) system: In Electronic Funds Transfer (EFT) system, payment transactions are made in the virtual environment over the currency of the country. The system has been divided into two types of transactions: transfer between customers and transfer between banks. In the inter-client transfer system, it includes payments such as rent payments, payments made by banks to customers, and salaries. In the

inter-bank transfer system, the banks also include the payments they made among themselves ^[30].

Payment with PayPal: PayPal is an e-commerce organization that facilitates payment between parties through money transfers in a virtual environment. This system allows users to create an account linked to credit card on their website. Once the credentials are confirmed, the user can initiate payments from other PayPal accounts. The PayPal system is a system that does not require you to open credit card information or bank account information for creditors or payers. This provides a safe environment for electronic Exchange ^[31].

Cash on delivery: Payment system at the door is to make payment when the consumer who orders in electronic environment gets the product from the relevant cargo company. These payments are mostly made in cash as well as credit cards. The door-to-door payment system plays an important role in eliminating customer safety concerns. In the evaluations made, especially in the developing countries, some consumers do not want to give credit card information in the virtual environment, leading to the payment system at the door ^[32].

As it is seen, there are many different payment methods. The selection of the payment depends on the requirement of the e-commerce business. The subject of this study is not to decide which method is best. However, these methods can be inferred through their security and privacy concerns. Security technology for payments online is an important issue. Moreover, increasing payment customer experience also increases the adoption of electronic payments. Therefore, security and privacy concerns regarding the personal data and customer information can act as a restraining factor in the market. The recent trend prevailing in the market is the rise in mobile biometrics for payments such as fingerprint recognition, voice recognition, iris recognition, and facial recognition.

5. Customer Satisfaction

In addition to the profitability of the companies, the attitude of the customers towards the firm is also important in terms of the future of the company. The companies should perform their best effort in order to acquire new customers, not to lose existing customers, and to regain old customers ^[33]. Therefore, the companies need to keep their customers in the foreground and the satisfaction of the customers should be well defined

Customer satisfaction is generally defined as the satisfaction level of the customer's wishes and needs in the consumption of a particular service or product that affects the purchase request of the next product ^[34]. Satisfied customers are ready to buy products and services that companies will present to the market. On the other side, unsatis-

fied customers can negatively affect the decisions of other customers and lower the companies' sales.

The reasons for unsatisfied customers are discussed below^[35].

Inadequate customer service.

Business employees' disinterestedness and disrespect towards the customer.

Imbalances in prices.

Waiting times and similar disturbing problems.

Inefficiency of complaints management.

The companies should evaluate customer complaints and improve their business to increase customer satisfaction. A successful effort and improvement of businesses in products and services will have a positive impact on customer satisfaction and desire to purchase again. However, an unsuccessful effort to improve the business will have a negative effect on customers because they will create a second frustration. It will destroy the customer's desire to purchase and reduce his commitment to business^[36].

The unsatisfied customers are more important than they are thought to be. Because, there are some conclusions about the spread of customer dissatisfaction. One of these studies shows that 90% of the unsatisfied customers never purchase anything from the company where they become unsatisfied. In addition, they share their negative thoughts for that company with at least 10 people about this dissatisfaction. According to another research, "3-33" system is brought to the stage. According to this system, a satisfied customer talks with 3 people about the good experience, but an unsatisfied customer shares his negative thoughts with 33 people. Therefore, companies must maintain customer complaints management effectively^[37].

In order to manage customer complaints and increase customer satisfaction, there should be a measurement technique. Companies can use a number of different techniques to measure customer satisfaction. Some of the important methods used in the process of measuring customer satisfaction after the academic researches are examined in the headings below.

Focus groups: Focus group interviews are an effective technique in obtaining information except for digital information in customer relations^[38]. In this technique, interviews are conducted in a suitable environment by educated staffs who manage the interview in small groups. The important thing to see is the unexpected consequences reached during these discussions^[38].

Survey management: Surveys conducted in customer relations include quantitative and qualitative measurements. When these measurement programs are in use, the company should make an assessment based on the location in which they are located. During the creation of the

questionnaires, it is necessary to clearly state the objectives of the company in an understandable, achievable and measurable quality^[38].

Benchmarking method: Customers are satisfied with meeting their expectations by companies. The best way to use products and services is to have the best processes^[39]. One of these applications of the benchmarking method is to take into account the best practices in the world for doing a job^[38].

Critical event technique: The critical event technique is a method of examining the behavior of employees or customers against critical events. In general, these behaviors and observations are collected and classified^[38]. In this technique, employees and customers report critical situations that affect or are dissatisfied with themselves in situations they are experiencing^[38].

6. Critical Success Factors in Electronic Commerce

In addition to measuring the customer satisfaction, companies need to be aware of the critical success factors (CSFs) in e-commerce. Hence they can improve their business processes according to these factors. There are many studies in the literature about the factors affecting customer satisfaction in e-commerce.

According to Sung^[40], there have been few studies explicitly examining CSFs for E-commerce. Most studies implicitly advises a set of factors to be considered in E-commerce. Due to literature review, Sung^[40] identified 16 CSFs which were mentioned by at least three studies. Sehora et al.^[41] analyzed the effects of three dimensions of traits, and support systems on the success of e-commerce. These dimensions were nominated as; Founder Factors, E-Service Factors, and External Factors. Under each dimensions they examined different traits and behavioral styles. Due to their results; Achievement Orientation and Locus of Control were found as important aspects of Funder Factors. Reliability and Ease of Use were noted as the significant components of E-Service Factors. Choshin and Gaffari^[42] pointed the fact that, success in e-commerce depends on determining the effective factors. Therefore, they defined two sets of both inside and outside organizational effective factors. Due to their study, customer satisfaction, the amount of costs, infrastructures, and knowledge-information are the effective factors for e-commerce success. Nisar and Prabhakar^[43] also analyzed the customer satisfaction in e-commerce. They determined the factors affecting customer satisfaction. They also noted a relationship between customer satisfaction and consumer spending in e-commerce.

The list of CSFs for ecommerce can be extended. How-

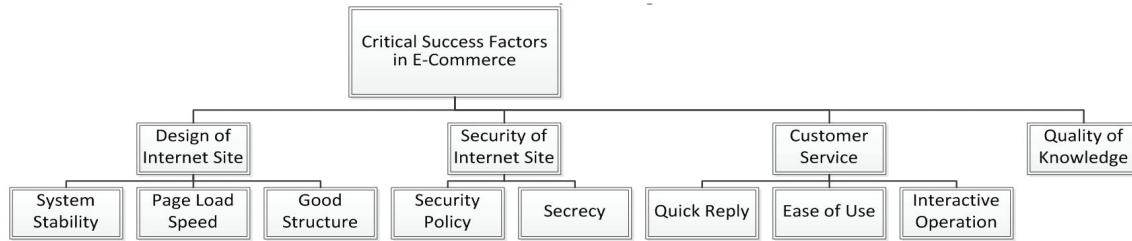


Figure 6. Hierarchical representation of the critical success factors in E-Commerce

ever, depending on the current literature, the major CSFs can be classified under headings and the related sub criteria can be listed as shown in a hierarchical way in Figure 6.

6.1 Design of Internet Site

In electronic commerce, poorly designed internet sites can lead to loss of existing and potential customers. Therefore, the design of these sites is important for enterprises. Design is usually applied to upgrade the quality of a website's system. The variables needed to evaluate an internet site are listed below ^[44].

System Stability: The Internet system contains technological hardware and software such as the system, applicability, availability, reliability and usefulness of the system. The web platform system should be stable and reliable for the customers.

Page Load Speed: Customers do not like the slow downloading of their website pages they shop. Therefore, page loading is an important measure at the point of evaluating internet sites. Very large and complex pages should be divided into several pages. Large footprint elements such as images and video must be compressed before being loaded.

Good Structure: The structure and logical flow of the Internet system is welcomed. Well-crafted product display includes functions such as order and payment, order management. It is also easy to update and maintain.

6.2 Security of Internet Site

Internet sites have two parameters in terms of security. One of them is security policy and the other is secrecy.

The Security Policy: It means that there is a security policy on internet sites.

Secrecy: It means that the website is committed to protecting your personal privacy ^[44].

Both parameters are important factors for customer satisfaction. Clients often prefer to shop on websites with high security features. Therefore, enterprises should pay attention to security policy and privacy factors in internet sites.

6.3 Customer Service

Today, customer service has become an important measuring factor in the success and failure of electronic com-

merce ^[44]. Improved customer service quality is an important factor in achieving high customer satisfaction for businesses operating in e-commerce. Customer service has revealed four important elements. These factors are examined below ^[44].

Quick Reply: After a quick response, the customer's feedback is sent to the website or customer service center, the business should respond to it as soon as possible.

Ease of Use: It is easy to browse on the internet site or look at the catalogs. It means that you can easily access everything you want. What the customer wants on the site is important. For this reason, businesses need to install a user-friendly search engine or system. It is a very important factor in ensuring customer satisfaction.

Interactive Operation: It is one of the most effective methods used to understand the customer. A customer service management that businesses use to inform their customers of low-priced offers. These include e-mail, free phone line, address, online chat and other real-time communications software.

Frequently Asked Questions: Businesses sometimes divide a page on common issues. Many of these questions can be seen by the customers. This causes problems to be solved easily and increases productivity.

6.4 Quality of Knowledge

Information is an important issue in e-commerce. As explained in the research conducted by an e-commerce company called Webbonanza.com, the important thing is that information attracts visitors to the website. The information includes all content related to website and its content ^[45].

Some measurable variables can include whether emails or order confirmation messages are available on the website. It is also important for the information to be understandable and reliable. All these factors contribute to the quality of information. In order for the customer to be satisfied, the business needs to maintain high standards for these information parameters ^[45].

7. Conclusion

This study mainly fulfills the gap in the literature by providing a brief analysis for e-commerce including all of the related components. In addition, the critical success fac-

tors which should be considered are also specified for the companies in e-commerce business.

A brief review about the e-commerce is presented including the definition and importance of e-commerce. The rising importance of e-commerce is also supported by statistical data, which shows the increase in total e-commerce sales worldwide. Also, the advantages and the differences between e-commerce and traditional trading system are elaborated. Eight different tools which can be used in e-commerce are listed. Seven classes of e-commerce types are investigated. Nine payment methods in e-commerce are explained. Importance of customer satisfaction in e-commerce is underlined. As the last, four critical success factors for e-commerce are specified and tabulated in a hierarchical structure including the sub-factors. By elaborating various aspects of e-commerce, the main aim of this study, which is to provide a comprehensive and brief review about e-commerce, is achieved.

Although this is a comprehensive study for this topic, it is open to some further studies in this research area. Firstly, other components of e-commerce can be embedded to this study. For example, the difficulties or problems occurring in the contemporary trading systems can be studied. Secondly, the customer satisfaction ratio of an e-commerce company can be measured as a case study. Thirdly, for a specified country, the best website in e-commerce can be identified with using one of the multi criteria decision making methods. The critical success factors nominated in this study can be used as the criteria to measure the performance of alternative web sites of e-commerce companies.

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REVIEW

Research on Property Rights, Revenue Transparency and Equity Financing Costs

—Based on the Perspective of CEO Overconfidence

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ABSTRACT

This paper takes the Chinese listed company with the equity refinancing qualification from 2012 to 2013 as the research object, and uses the residual revenue model to calculate the equity financing cost. This paper discusses the impact of the overconfidence of executives on the equity financing cost and its impact mechanism. The unique institutional background examines the differences in property rights characteristics. The research found that: (1) executive overconfidence has a negative impact on the cost of equity financing, executives tend to be overconfident, the higher the equity financing cost of the company; (2) the overconfidence of executives to state-owned enterprises compared to private enterprises The negative impact of financing costs is more significant; (3) in addition, this paper also examines the potential impact mechanism of executive overconfidence on the cost of equity financing. The quality of information disclosure and the risk of investor prediction have a mediating effect on the impact of executive overconfidence on equity financing costs.

1. Introduction

The influencing factors of equity financing costs are long-term hot issues in capital market research. As the main basis for enterprise investment and financing decision-making, the accurate measurement of equity financing cost is not only beneficial to guide the flow of funds in the capital market, but also has important practical significance for improving the financial decision-making level and performance value of the company. The research on the factors affecting the cost of equity financing, domestic and foreign scholars mainly from the micro and macro levels: the micro level includes factors such as company characteristics, information disclosure and corporate governance; the macro level considers ex-

ternal governance environmental factors such as investor protection and political relations. A large number of domestic and foreign literatures examine the impact of information disclosure on equity financing costs. Based on the theory of information asymmetry, the existing theoretical research believes that due to the information asymmetry between the management and investors of the enterprise and the existence of the investor's predicted risk, the lower level of corporate information disclosure makes the information between the enterprise and the investor. Asymmetry is further aggravated. Investors will face higher estimated risks when estimating future earnings. Potential investors will inevitably demand higher return on investment, which in turn will lead to an increase in

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corporate financing costs. That is, the lower the level of corporate information disclosure, the higher the cost of equity financing^[1,2,3].

As mentioned above, the academic research on the cost of equity financing is based on the rational human hypothesis of the neoclassical economic theory. The influencing factors are mainly limited to the internal and external aspects of the enterprise, and less attention is paid to the individual psychological characteristics of the executive group. Equity financing cost research has achieved more results, but the rational person hypothesis does not match the management's prevailing tendency of overconfidence. In addition, most of the research on management's overconfidence is limited to the internal financial decision-making level, and less on how executive overconfidence affects the judgment of external stakeholders, including potential investors, on corporate value and risk.

Since Hambrick et al. proposed management's high-level theory, research scholars have begun to pay attention to the impact of managerial characteristics on corporate behavior and external stakeholders. Behavioral finance introduces psychology into the field of corporate finance research, explaining how managerial personality traits influence management's behavioral decisions. Overconfidence is one of the most robust findings in psychology. A large body of research literature shows that people tend to show a tendency to be overconfident in economic activities. Psychology and behavioral finance studies have also confirmed that people's behavior is not completely rational due to the existence of overconfident cognitive bias. Because the manager is at the top of the organizational structure of the enterprise and is in the core decision-making position, he will have more information than the average employee, plus the successful management experience accumulated over the years. Therefore, managers are more likely to show excessive self-confidence in the process of business decision-making. A lot of empirical research has also proved that management does have the characteristics of overconfidence, which is characterized by their easy systemic cognitive bias on the project's benefits and risks, which is reflected in the fact that overconfident executives can easily overestimate the project's benefits. Level or underestimate the risk level of the project, overestimate your ability level and master the accuracy of the information^[4,5]. The above performance must be reflected in the irrationality of corporate decision-making^[3]. The irrational decision-making caused by the overconfidence of executives, many scholars at home and abroad have conducted a lot of research and achieved a series of research results. The research found that executive overconfidence can affect the company's dividend distribution, investment

mergers and acquisitions, earnings forecast, company performance, accounting stability, etc.^[4,5,6,7,8,9]. From recent research, scholars have been paying attention to the economic consequences of irrational decision-making by executive overconfidence companies. The research found that executives' overconfidence led the company to adopt a radical financing strategy by influencing the company's investment behavior, and its economic consequences were the rise in equity financing costs^[10].

Different from the existing research, this paper explores the impact of the overconfidence bias of executives on the cost of equity financing of enterprises based on the perspective of information disclosure. The answer to the above questions helps us to deepen the irrational psychological characteristics of managers. It has theoretical and practical value to influence external stakeholders and their corresponding economic consequences. Therefore, this paper attempts to explain three questions: (1) How does the overconfidence bias of executives affect the cost of equity financing? (2) What is the mechanism of the influence of executive overconfidence on the cost of equity financing? (3) In the enterprises with different property rights, is there any difference in the influence of the overconfidence bias of the executives on the equity financing costs of the enterprises?

The possible contributions of this paper are: firstly, using behavioral finance theory to extend the influence of executive overconfidence on other stakeholders to the level of potential investors, providing empirical data on the relationship between executive overconfidence and equity financing costs. Research has made up for the shortcomings of the existing literature; secondly, based on the transmission mechanism of information disclosure affecting the cost of equity financing, this paper helps to understand the decisive factors of the pricing of equity financing market and provide the deep motivation for the overconfidence of executives to affect the cost of equity financing. Moreover, the existing research on the cost of equity financing is mainly localized in the internal characteristics of the company and the external environment, and the internal characteristics of the company are closely related to the executives. This paper extends the research to the individual characteristics of management and may further deepen the research results in this field.

2. Theoretical Analysis and Research Hypothesis

Many domestic and foreign literatures examine the impact of information disclosure on equity financing costs from both theoretical and empirical perspectives.

The theoretical research level agrees that the princi-

ple of information disclosure affecting the cost of equity financing can be described as two types of mechanisms: First, the perspective of information disclosure. The hypothesis believes that information disclosure can reduce information asymmetry between management and investors, reduce the transaction cost of stocks, enhance stock liquidity, and thus reduce the cost of equity financing; second, the perspective of investor risk prediction. When information disclosure is low, investors will bear the risk of predicting future utility. If this risk is not diversified, investors will demand a higher return on the information risk, that is, information disclosure will reduce the cost of equity financing by reducing the estimated risk of stock returns.

The empirical research level measures information disclosure from the aspects of quantity and quality of information disclosure, and empirically tests the relationship between information disclosure and equity financing costs. Botosan et al., Wei Wang and Gaofeng Jiang are scholars who have carried out related research earlier at home and abroad. They choose the amount of information disclosure as a surrogate indicator of information disclosure. The empirical results show that there is a negative correlation between information disclosure and the cost of equity financing^[11,12,13]. In the recent research literature, the quality indicators of earnings disclosure quality have begun to be adopted by research scholars. Bhattacharya and other scholars try to use income smoothness to measure the transparency of earnings, and examine the impact of information disclosure quality on the cost of equity capital from the national level. Their research found that the more opaque the country, the higher the cost of equity capital^[14]. Domestic scholars have used the data of listed companies in China to conduct empirical tests. The conclusions of Bhattacharya and other scholars have reached the same conclusion. The quality of information disclosure of listed companies in China is significantly positively correlated with the cost of equity financing^[15,16].

Based on the foregoing analysis, there are two types of mechanisms for the influence of managerial overconfidence on the cost of equity financing: First, the information disclosure mechanism. Executives with overconfidence are more likely to adopt aggressive earnings management. Hriber and Yang's research found that when executives are overconfident, companies tend to release optimistic earnings forecasts and adopt more aggressive business strategies. When actual earnings fail to reach predictive targets, they are forced by capital market pressures. It is forced to report earnings through aggressive positive earnings management^[17], which will inevitably reduce the quality of information disclosure and worsen the

information asymmetry between enterprises and investors, and enterprises will face higher equity financing costs. Second, in order to whitewash the report, overconfident executives may have a motive for smooth performance for earnings management. The reason is that overconfident managers tend to overestimate their own ability level or the accuracy of the information they have, thus over-optimistic expectations of corporate earnings, overestimating the probability of revenue growth, and underestimating the probability of a decline in earnings. Therefore, when the company's performance is not good (such as below the refinancing conditions), overconfident managers tend to report more surplus by accelerating the recognition of income, delaying the reporting fee and other accruals management methods, and the company's performance is better (such as exceeding refinancing conditions, overconfident managers will understate more surplus as a future profit reserve. Therefore, compared with other companies, overconfident managers adopt more income smoothing methods to cover the real fluctuations of income, the income of the enterprises is smoother, and the information asymmetry between enterprises and investors is more serious. Enterprises must face higher equity financing costs.

Secondly, from the perspective of investors' predictive risk mechanism, overconfident executives believe that their ability is higher than the industry average, tend to overestimate the expected cash flow and return on investment of the company's projects, and underestimate the risk level of project investment. At this point the company's risk is increasing. Investors are bound to face higher estimated risks when estimating future earnings. Potential investors will inevitably demand higher return on investment, which in turn will represent an increase in corporate financing costs. Guangguo Sun and other researchers found that managers' overconfidence is negatively correlated with the level of corporate accounting stability. Especially when the company is in financial distress, the overconfident management is more likely to adopt unreliable accounting methods such as recognizing income in advance and delaying the confirmation of losses. Increase the risk that investors estimate future earnings, and thus increase the return on investment requirements of potential investors^[18].

Based on the above analysis, the overconfident management has a more aggressive incentive for earnings control, and investors estimate that the risk increases, leading investors to demand a higher return on investment for managers with overconfidence, so we propose hypothesis H1:

H1: There is a significant negative correlation between executive overconfidence and equity capital costs.

Because the situation of corporate governance supervision and restriction faced by state-owned enterprises and non-state-owned enterprises is very different, the degree of overconfidence of executives with different property rights has different effects on the cost of equity financing. The high concentration of equity in state-owned listed companies and the absence of owners are likely to lead to internal control, and managers have great rights. Compared with private enterprises, executives are more likely to form "one-word situation" (deciding everything by one man's words) when making decisions. Moreover, executives of state-owned listed companies enjoy administrative levels and are more prone to overconfidence. As a result, the degree of executive overconfidence is more pronounced in state-owned enterprises. The following is an analysis from the information mechanism and on the one hand, from the perspective of the information mechanism. Due to the imperfect corporate governance structure and internal and external regulatory mechanisms of state-owned enterprises, it is easy to aggravate the degree of overconfidence of state-owned enterprise executives. As a result, the overconfidence of state-owned enterprise executives has a greater impact on corporate behavior decisions, and there is more room for earnings manipulation. When the management of state-owned enterprises faces greater financing motives and political pressures, in order to cover up the real income situation of enterprises, they will adopt more aggressive earnings control methods, thus aggravating the information asymmetry between state-owned enterprises and investors. Further reducing the quality of accounting information of state-owned enterprises will eventually lead to higher equity financing costs for state-owned enterprises. On the other hand, Garmaise et al. found that when ineffective corporate governance is combined with management opportunistic behavior, the company's systemic risk will rise and the cost of equity financing will increase.^[19] Huang's research findings further confirm that higher levels of management encroachment will result in higher equity financing costs, as the investment itself will bear additional agency risks and higher monitoring costs^[20]. Therefore, from the perspective of risk mechanism, compared with other enterprises, because the degree of overconfidence of executives is more prominent in state-owned enterprises, state-owned enterprise executives have greater jurisdiction over corporate decision-making, leading to greater risks for state-owned enterprises. Estimating the risk of future earnings is higher, which in turn will increase the return on investment requirements of potential investors^[21].

Based on the above analysis, we further propose hypothesis H2:

H2: Other conditions remain unchanged. Compared with private enterprises, the overconfidence of senior executives of state-owned listed companies has a more significant impact on the cost of equity financing.

3. Research Samples and Research Variables

3.1 Research Samples

This paper selects non-financial A-share listed companies with refinancing qualifications in 2012 and 2013 as research samples, and excludes the following companies: (1) Companies with CEO changed during the research year; (2) Companies with missing financial data, abnormal financial indicators, and have been specially treated; (3) The companies in the financial and insurance industry; (4) Companies that issue B shares and H shares at the same time; (5) Listed companies but listed for less than 3 years. After the above elimination, there are 553 in 2014 and 612 in 2015, a total of 1,165 observations. Among them, 53 CEOs were overconfident in 2014 and 69 in 2015, with a total of 122 observations.

3.2 Research Variables

3.2.1 Managers with Overconfidence

Senior managers with overconfidence: How to accurately measure managerial overconfidence is a problem in academia^[4,5]. From the macro environment to the micro-enterprise level, domestic and foreign scholars use many alternative indicators to measure manager's overconfidence. The most representative surrogate indicators include CEO holding status; company earnings forecast deviation; media evaluation of CEO; business climate indicator; CEO's relative compensation, etc. But whether these alternative indicators are reasonable is still debatable. Considering that investment opportunities have a key impact on the growth of the company, this paper draws on the methods of Malmendier and Tate^[4] and Ying Hao^[6] to select investment opportunities to represent the growth opportunities of enterprises. Considering the unobservable investment opportunities, this paper draws on the methods of domestic and foreign scholars to use the market value book to measure the growth opportunities of enterprises than the MBA. The MBA for each sample company for each research year is adjusted to the industry median.

Therefore, the criterion for judging the overconfidence of executives in this paper is that if the growth of the current period is lower than that of the previous period, and the number of CEOs' growth increases or remains unchanged, the stock trading behavior reflects the CEO's growth of the company. Excessively optimistic estimates can be used to judge executives' overconfidence, and vice

versa to judge that executives are not overconfident.

3.2.2 Information Disclosure Quality Indicators and Control Variables

Referring to relevant research, this paper uses the income smoothness to measure the quality of information disclosure of listed companies. Since the accrual items do not match the cash flow (that is, the correlation coefficient between the two is close to zero) is a common phenomenon in listed companies. If the directions of the two changes are inconsistent and the absolute values of the correlation coefficients are large, It may be that the listed company is using the difference between the two to smooth the income return smoothness, so the degree of correlation between the earnings and cash flow of the listed company in a certain period of time can be used to measure the degree of smoothness of the income. This paper draws on the ideas of Leuz et al.^[22] and Myers et al.^[23] to measure the smoothness of returns by using the correlation coefficient between quarterly accruals and quarterly cash flow changes.

In the research model below, we also control other factors that may affect the interpreted variables. Previous studies have shown that company characteristics such as company size and solvency are important factors influencing earnings management. In addition, we also control corporate characteristic variables such as profitability, growth, operating efficiency, and fixed asset ratio. Many studies have shown that the quality of earnings information is closely related to the corporate governance mechanism. The ownership structure, board structure and executive shareholding affect the level of motivation for management to implement earnings management. Therefore, we use equity concentration, the proportion of independent directors and the proportion of CEOs. These factors are controlled.

3.2.3 Equity Financing Costs and Control Variables

Referring to the existing estimation method of equity financing cost, this paper uses the residual income model of Gebhardt et al.^[24], and uses the method of Kangtao Ye et al.^[25] to estimate the cost of equity financing. In order to make the empirical research more accurate, this paper also controls the two important variables of β coefficient and book market value ratio BM which may affect the cost of equity financing.

4. Research Methods and Empirical Results

4.1 Descriptive Statistics

Descriptive statistics for the study variables showed that the average cost of equity financing was 6.5%, with a me-

dian of 5.4%, a maximum of 11.5%, and a minimum of 1.2%. The sample company's average return smoothness is 0.850, and the median is 0.930, which indicates that the sample company's refinancing qualification is smoother, which is consistent with the research results of Ying Zeng and Zhengfei Lu^[17].

4.2 Univariate Grouping Test

In order to test hypothesis H1, we divide the sample companies into over-confident enterprise groups and non-overconfident enterprise groups according to whether the CEO is overconfident. The difference between the two groups was significant, and the smoothness of the overconfident group was greater than that of the non-overconfident group. Further, the T-test and Wilcoxon test results of the mean and median differences between the two groups showed that the yield smoothness of the two groups was significantly different at the 1% significance level. This result shows that the profit smoothness of overconfident enterprises is significantly greater than that of non-overconfident enterprises, so that our hypothesis H1 is initially supported by the univariate test. As a result of the difference between the group financing costs, the mean and median of the equity financing costs of the two groups passed the T test and the Wilcoxon significance test, which shows that the CEO's overconfidence of corporate equity financing costs is also significantly greater than CEO non-overconfident enterprises. Since no control variables were added, the results of the univariate test may be overestimated. To make the study more meaningful, we further performed a multivariate regression analysis of the multivariate test.

4.3 Analysis of CEO with Overconfidence Related to Earning Smoothness

4.3.1 Analysis of the Impact of CEO Overconfidence on Earning Smoothness

To test hypothesis H1, we establish the following model to test the impact of CEO overconfidence on Earning Smoothness:

$$ES_i = \alpha_0 + \alpha_1 Con_i + \alpha_2 Size_i + \alpha_3 Lev_i + \alpha_4 Turn_i + \alpha_5 Roa_i + \alpha_6 Grow_i + \alpha_7 Tan_i + \alpha_8 Board_i + \alpha_9 Hold_i + \alpha_{10} Control_i + \alpha_{11} Herf_i + \varepsilon_i \quad (1)$$

Among them, the interpreted variable ES is the income smoothness indicator defined above, and the explanatory variable Con is the CEO overconfidence dummy variable. To make the inspection more accurate, we control other factors that may affect the smoothness of the earnings of listed companies. The multi-collinearity test results of the

regression model show that the variance expansion factor of the regression model is less than 2, Therefore, there is no multi-collinearity problem in the setting of the regression model.

In order to ensure the robustness of the test results, we introduce control variables step by step for regression. With the introduction of control variables, the significance of the coefficients is significantly enhanced. When the income smoothness ES is the explanatory variable, the coefficient is always positive and significant at the 1% level, which shows that the more CEOs tend to be overconfident, the smoother the earnings of listed companies and the lower the transparency of earnings. So our hypothesis 1 passes the test.

4.3.2 Analysis of the Impact of CEO Overconfidence on the Correlation between Earning Smoothness and Equity Financing Cost

After analyzing the impact of CEO overconfidence on the smoothness of listed companies' earnings, we join the CEO overconfidence variable and establish the following joint multiple regression models to further examine whether CEO overconfidence will increase (or weaken) the positive correlation between earnings smoothness and equity financing costs:

$$r_i = \alpha_0 + \alpha_1 ES_i + \alpha_2 Con_i \times ES_i + \alpha_3 \beta_i + \alpha_4 Size_i + \alpha_5 BM_i + \alpha_6 Lev_i + \alpha_7 Turn_i + \alpha_8 Roa_i + \alpha_9 Grow_i + \varepsilon_i \quad (2)$$

Among them, the dependent variable r is the equity financing cost, the income transparency ES is the income smoothness indicator defined above, and Con is the CEO overconfidence dummy variable. To test the hypothesis proposed, we establish an interaction term between the income smoothness ES and the CEO overconfidence dummy variable Con. If the coefficient of the interaction term is significantly positive, then our hypothesis H2 holds. In order to make the inspection more accurate, we also control other factors that may affect the cost of equity financing of listed companies. The multi-collinearity test results of the regression model show that the variance expansion factors of each variable in the regression model are less than 2; therefore, there is no multicollinearity problem in the setting of the regression model.

The empirical results show that the size of the firm, the book value of the market value and the cost of equity financing are significant at the level of 1%, but the relationship between the beta coefficient and the cost of equity financing is not significant, which is consistent with the empirical results of Ying Zeng and Zhengfei Lu.^[17] Finan-

cial leverage is significantly positively correlated with equity financing costs, indicating that the risk of bankruptcy failure increases with the increase of financial leverage, and investors must demand higher risk compensation, resulting in an increase in equity financing costs^[26]. The asset turnover rate is significantly negatively correlated with the equity financing cost, and the symbol is also in line with theoretical expectations. Because the lower the asset turnover rates, the worse the business efficiency of the company, the more serious the agency problem, the higher the investment risk of investors, and therefore the higher risk return^[27]. The return on assets and the growth rate of operating income are significantly related to the cost of equity financing. The symbol is consistent with the existing research^[17,28], indicating that the profitability and growth of the enterprise are important factors affecting investors' investment decisions.

To test hypothesis H2, we adopt a joint multivariate analysis method to test whether CEO overconfidence increases the impact of earnings smoothness on equity financing costs. The empirical results show that the income smoothness is significantly positively correlated with the equity financing cost at 5%, indicating that the smoother the return and the higher the cost of equity financing, which is consistent with the expected research conclusion.^[8,11] More importantly, the coefficient of CEO overconfidence dummy variable Con and income smoothness ES interaction term Con*ES is significantly positive at 5% level, which shows that CEO overconfidence enhances the positive correlation between earnings smoothness and equity financing costs, and Hypothesis H2 is verified.

4.3.3 Analysis of the Impact of CEO Overconfidence on the Correlation between Earning Smoothness and Equity Financing Costs

In order to further test whether the hypothesis H3 is established, on the basis of the above regression analysis, the sample companies are classified into state-owned enterprises and non-state-owned enterprises in groups according to the characteristics of ownership. The results show that the coefficient of the interaction term Con*ES in the state-owned enterprise group is significantly positive at the level of 1%, and in the group of private enterprises, the coefficient is only significant at the level of 10%; the full sample empirical results show that CEO overconfidence enhances the impact of earnings smoothness on equity financing costs. Further analysis of ownership analysis shows that compared with private enterprises, the influence of CEO overconfidence is significantly reflected in state-owned listed companies. This empirical analysis supports hypothesis H3.

4.4 Robustness Test

In order to enhance the robustness of the research results, the paper conducted the following tests: (1) According to the existing research and data availability, the CEO's evaluation and CEO relative salary are used to measure CEO overconfidence, and the empirical results are still valid; (2) Using the annual accrual item and cash flow correlation coefficient to measure the return smoothness indicator^[10], the empirical results are still valid; (3) all variables in the regression model are tailed out, eliminating 1% of the abnormal value before and after, the empirical results Still true, the model fit has improved. The above tests show that the empirical results of this paper have good robustness.

4.5 Further Analysis: the Potential Mechanism of Senior Managers with Overconfidence Affecting the Cost of Equity Financing

From the previous theoretical analysis, the underlying mechanisms of executive overconfidence affecting the cost of equity financing are: On the one hand, from the perspective of information disclosure, overconfident executives have more intense aggressive earnings management and income smoothing motives, leading to the company. The decline in the quality of accounting information has aggravated the information asymmetry between managers and investors, making enterprises face higher equity financing costs^[28].

On the other hand, from the perspective of investors' predictive risk, overconfident executives believe that their ability is higher than the industry average, tend to overestimate the expected cash flow and return on investment of the company's projects, and underestimate the risk level of project investment. The risk increases. Investors are bound to face higher estimated risks when estimating future earnings. Potential investors will inevitably demand higher return on investment, which in turn will represent an increase in corporate financing costs.

4.5.1 Analysis of Information Disclosure Machine: Executive Overconfidence and Quality of Information Disclosure

From the regression results, the influence of executive overconfidence on the quality of information disclosure is significantly positive at the 10% significance level; the over-confidence of executives and the quality of information disclosure are simultaneously added to the regression analysis of the cost of equity financing, executive over-extension Confidence in the cost of equity financing is significant at the 10% level, and the quality of information disclosure is significant at the level of 5% equity

financing. After the quality of information disclosure, the influence of over-confidence of executives on the cost of equity financing is still significant, and the quality of information disclosure on the cost of equity financing and over-confidence of executives is significant for information disclosure. Combined with the above regression results, the quality of information disclosure is The influence of executive overconfidence on the cost of equity financing has a partial mediating effect.

4.5.2 Investor Forecasting Risk Perspective Analysis: Executive Overconfidence and Corporate Risk

From the above analysis, investors predict that risk is another potential mechanism for executives' overconfidence to affect the cost of equity financing. When executives are overconfident, they will overestimate the expected cash flow and return on investment of the company's projects, and underestimate the risk of project investment. Levels lead to increased company risk. When investors predict that the company's risk will increase, potential investors will inevitably demand a higher return on investment, which in turn will increase the cost of corporate finance, so it can be expected that the risk of executives with overconfidence will increase. The empirical results show that the level of surplus volatility is used to represent the company's risk. The influence of executive overconfidence on earnings volatility is significantly positively correlated at the 10% level, indicating that the executive's overconfidence tends to increase the level of surplus volatility and increase the company's Corporate risk; joining the company's risk factors, executive overconfidence is significantly positive for equity financing costs at 5%, while corporate risk is significant at 5% for equity financing costs, in summary the investor's forecast risk is also high The influence of overconfidence on the cost of equity financing has a partial mediating effect.

5. Conclusion

This paper takes the Chinese listed company with the equity refinancing qualification from 2012 to 2013 as the research object, and uses the residual income model to calculate the equity financing cost, drawing on the research ideas of Bhattacharya et al.^[11] This paper uses the income smoothness index to measure the transparency of listed companies' earnings, and examines the impact of CEO overconfidence on the quality of listed companies' information disclosure and the economic consequences.

Notes: Since the research sample selected in this paper is an already listed company, the first financing has been completed. Therefore, unless otherwise stated, the equity financing cost in this article refers to the cost (or potential financing cost) of the listed company's equity refinancing.

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