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Measuring Efficiency of the Mobile Industry in the Middle East Using Data Envelopment Analysis

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Approval Certificate

MEASURING EFFICIENCY OF THE MOBILE INDUSTRY IN THE MIDDLE EAST USING DATA ENVELOPMENT ANALYSIS

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DECLARATION

I hereby declare that this Thesis is entirely my own work and that it has not been submitted as an exercise for a degree at any other University.

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ABSTRACT

Purpose – Telecommunications, today, is considered an essential catalyst for economic growth. It has entered a new age of development and increased competition with established players. The purpose of this study is to use a sophisticated model to measure the efficiency and productivity of 16 mobile operators in the Middle East market during 2011.

Design/methodology/approach – To measure relative efficiency, the study applies the partial factor productivity (PFP) and three data envelopment analysis (DEA) models, the CCR, BCC, and A&P models. The efficiency scores obtained from the PFP and the DEA are then compared with four financial indicators of the mobile operators under study.

Findings – The inconclusive results of the PFP affirmed the need to apply the DEA methodology to obtain one single efficiency ratio for each mobile operator. The DEA results showed that 7 of the mobile operators under study were fully efficient and 9 were operating inefficiently during 2011 mainly due to scale inefficiency. The comparison revealed that there was no relation between the levels of efficiency of the mobile operators and their four financial ratios.

Research limitations/implications – The limitations of this study are the drawback of the DEA technique and the difficulty in obtaining mobile operators' data in the Middle East region.

Practical implications – Considering the challenges mobile operators in the Middle East and globally are facing, it is becoming crucial for them to operate in the most efficient manner to generate the highest revenue possible. Since, as shown in this study, the mobile operators' financial ratios do not reflect efficiency, the operators' managements and regulators should apply a model, similar to the proposed DEA model in this study, for efficiency measurement.

Originality/value – This study is the first academic work to measure the performance of mobile operators in terms of productivity and efficiency in the Middle East.

Keywords: Mobile operator, Middle East, Efficiency, Data envelopment analysis, Partial factor productivity

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CONTENTS

Chapter 1- Introduction

1.1 General Background of the Global Mobile Industry

From an agricultural economy to an industrial one, the world today has moved into an information economy. An economy based on the continuous availability of information, where information has become the main resource for competition. The flow of information in today's economy is guaranteed by the telecommunications infrastructure which acts as the backbone for such an economy. The development of the Information and Communication Technology (ICT) has allowed the transmission of information and knowledge to all aspects of the human activities and thus has resulted in a societal and economical change.

It is well established that telecommunications is an essential catalyst for economic growth. The International Telecommunications Union (ITU)[1] considers the relationship between economic development and telecommunications self-evident. Highlighting a study performed by the ITU, The Missing Link, concluded that telecommunications play a vital role in stimulating economic growth and enhancing the quality of life.

Telecommunications systems are not only essential for economic growth but are also important in conducting, organizing and managing processes in various sectors of the economy. A significant amount of cross-border information flow, a reduction in transaction and transport costs, a stimulation in consumer demand for world-class brands, services and products are all benefits of the integration of telecommunications in today's economy (Leff, 1984).

Moving forward, the face of telecommunications has changed with the introduction of the mobile phones in the last part of the twentieth century. Since then, the evolvement of the telecommunications sector has been associated with a continuous growth in the mobile sector.

[1] ITU (International Telecommunication Union) is the United Nations specialized agency for information and communication technologies (ICTs)

When mobile communication was first introduced in the early 1990's, it faced many technical constraints, very limited competition and expensive handsets prices. It was mainly targeted towards businesses and was perceived by many as a luxurious service for the wealthy. This perception may have been true back then, but mobile has now entered a mass market phase. The increase in competition, the subsidization of handsets and the decrease in tariffs have made the mobile communications abundant for the average citizen to use. It has also become the only mean of communication in countries with low fixed-line penetration.

Studying the milestones passed by mobile communications shows that in 1996 the number of new mobile subscribers was greater than the number of new fixed-line subscribers, and in 1998 the number of new mobile users was twice that of fixed ones. The turning point in the mobile industry's history was in 2002 when the number of mobile subscribers has surpassed the number of fixed-line subscribers worldwide (Gruber & Koutroumpis, 2010).

From a geographical perspective, mobile technology first emerged in North America. Nevertheless with the efforts of Ericsson and Nokia, the telecommunications equipment providers, North Europe became the leader in the fast growing telecommunications industry. Then the mobile technology expanded through entire Europe and the rest of the world reaching the Middle East area.

1.2 The Need for Measuring Efficiency of the Mobile Industry in the Middle East

As seen earlier, one of the primary economic benefits of enhanced mobile telecommunications is the improved efficiency in various sectors of the economy. The question is how efficient the mobile operators offering this service are.

The mobile industry in the Middle East has witnessed fast growth, considerable technological developments and fierce competition due to the issuance of multiple mobile licenses in the region. Competitive pressures have led the mobile operators to work on improving their services and products, cutting their costs and still managing to maintain their profits. This is hard to achieve when the mobile operator is not operating at optimal level of efficiency and productivity. This makes of the mobile operators in the Middle East interesting candidates to examine their efficiency.

Productivity and efficiency are essential for mobile operators especially when operating in a gradually saturated market such as the Middle Eastern one. Benchmarking is a common method for evaluating performance. Moreover, when comparing the efficiencies of different mobile operators with their national and international counterparts, it would be possible to determine the stronger and the weaker players and to identify their strengths and weaknesses. By doing so, the mobile operators will be able to amend their managerial strategies to work on increasing their efficiency and productivity levels and thus attaining higher profits.

Measuring productivity and efficiency has been a field of interest for numerous researchers. One model for efficiency measurement is the partial factor productivity (PFP). However, it has been a challenge to find a model for measuring efficiency that, unlike the PFP, does not only take a single input and a single output but takes into account multiple input and multiple output factors. The data envelopment analysis (DEA) is one of those models and which has proved to be effective especially when the relationship between the factors of production, the inputs and outputs, is not clear or is unknown.

No academic work measuring and comparing the performance of mobile operators in terms of productivity and efficiency has been previously done in the Middle East. This study will be the first attempt to do so using the PFP and DEA models, despite the difficulty in getting data for mobile operators in such a region where only few of them are publicly listed.

1.3 The Purpose of the Study

The purpose of this study is to use a sophisticated model to measure the efficiency and productivity of mobile operators in the Middle East market. The study will use the partial factor productivity (PFP) and the data envelopment analysis (DEA) methods to measure and compare the efficiency and productivity of 16 mobile operators in 9 different countries in the Middle East during the year 2011.

The mobile operators under study are:

1. Orange Jordan
2. Mobily Kingdom of Saudi Arabia
3. STC Kingdom of Saudi Arabia
4. Viva Kuwait
5. Wataniya Kuwait
6. Nawras Oman
7. Omantel Oman
8. Jawwal Palestine
9. Wataniya Palestine
10. Vodafone Qatar
11. Avea Turkey
12. Turkcell Turkey
13. Etisalat UAE
14. Du UAE
15. Cellcom Israel
16. Orange Israel

After the efficiency scores of the mobile operators under study are obtained, they will be compared with four financial indicators:

a. EBITDA Margin
b. Return on Asset (ROA)
c. Total Asset Turnover
d. Profit Margin Ratio

Furthermore, the results will show if the mobile operators with the best financial performance in 2011 were the most efficient and productive ones during that same year.

1.4 Overview of All Chapters

The structure of the study is organized as follows. Chapter two presents an overview of the global telecommunications and mobile market and then focuses on the mobile market in the Middle East and in the 9 different countries under study including Lebanon.

Chapter three explores the literature of efficiency measurement and the two models used in the study, the partial factor productivity (PFP) and the data envelopment analysis (DEA). The chapter then reviews the literature of previous studies of productivity and performance measurement in the mobile industry.

Chapter four describes the data and the selection of the appropriate input and output factors for the study. It is then devoted to the application of the above mentioned two models and to the calculation of the needed financial ratios for the 16 mobile operators under study.

Chapter five reports the results of the PFP and DEA models and compares them to the financial performance of the mobile operators with an interpretation of the findings.

Chapter six concludes the study and provides suggestions for future research.

Chapter 2- Mobile Market Analysis

2.1 Introduction

This study concentrates on measuring the efficiency and productivity of mobile operators in the Middle East. For this purpose, an overview on the global and Middle Eastern mobile industry will be first presented, and then an analysis on the countries and the mobile operators under study will be performed.

Although Lebanon is not included in the study, the Lebanese mobile industry is analyzed along with the rest of the countries under study to see how the Lebanese mobile operators compare with their peers in the region.

2.2 Global Mobile Industry

Telecommunications systems are able to boost economic growth through their integration in every sector of the economy; agriculture, infrastructure, education, health, business, as well as the governmental sector. It succeeded in removing several obstacles from the everyday economical processes. It shortens geographical distances, allows for a faster flow of information and is a main driver for cost reduction.

Nowadays, telecommunications has become a must for participating in the competitive world markets and for attracting investments. The mobile sector is one of the major corner-stones of the telecommunications systems.

It has taken the mobile sector a little more than 20 years to achieve what the fixed networks have struggled to achieve in almost 130 years. If it weren't for the mobile revenue, the telecommunication sector would be shrinking rather than expanding. The revenue from the fixed networks has been decreasing globally since 1996.

The use of mobile lines instead of fixed ones is referred to as fixed-mobile substitution (FMS). An ITU report on mobile cellular, World Telecommunication Development Report 1999, has explored the reasons why mobile communication is preferred and can be more attractive than the fixed one. The report states the below reasons:

1. Mobile networks can be built faster than fixed line networks and can reach geographically distinct locations.
2. Mobile networks are cheaper to install than fixed networks.
3. The providers of mobile networks are mainly private companies which tend to capitalize on the financial resources and the technical expertise of their strategic foreign partners.
4. The features of mobile networks similarly attract users in developed and developing countries.
5. Mobile networks solve through the prepaid models the issue faced by disqualified users due to lack of creditworthiness.

The introduction of prepaid models has helped a lot in boosting the growth of the mobile sector, especially in developing countries, allowing mobile operators to reach new segments of the population. Such models are appealing to the mobile operators since they allow them to reduce the credit risk and earn the revenue upfront. As for the cost of acquiring a new prepaid subscriber, it is lower compared to that of acquiring a postpaid one.

On the other hand, prepaid models are good for the users who are not eligible for a postpaid line, and for those who would like to maintain anonymity or wish to control their mobile costs. Prepaid lines are now even bundled with handsets and are being sold at shops and kiosks like any other commodity.

The number of mobile connections at the end of 2012 was 6,523,212,148 [2] and is forecasted to become 7,012,555,057[3] at the end of 2013. However the number of unique subscribers at the end of 2012 is 3,195,590,895[4]. The number of unique subscribers differs from connections such that a unique subscriber can have multiple connections.

[2] The figure is a calculation of the sum of total connections in the market.
Source: GSM Association (GSMA) - Founded in 1987, The GSM Association (GSMA) is a global trade association representing more than 700 GSM mobile phone operators across 217 territories and countries of the world. In addition, more than 180 manufacturers and suppliers support the Association's initiatives as associate members.

[3] The figure is a forecast. Source: Wireless Intelligence. Wireless Intelligence is part of GSM Media LLC. It provides coverage and data of all 1,140 mobile operators, 3,505 networks and 236 countries from 1979–present with five-year forecasts and analysis on the mobile ecosystem. https://wirelessintelligence.com/

[4] The figure is a calculation of the total number of subscribers in the market. Source: Wireless Intelligence

This indicates that 45% of the world population holds at least one mobile line. Figure 1 shows the total number of mobile connections globally on a yearly basis.

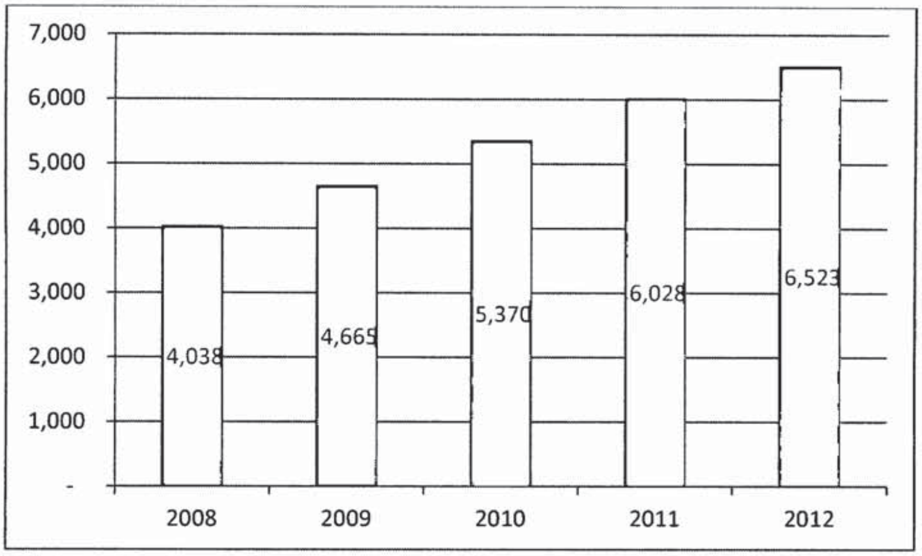

Figure 1: Global mobile connections (billion)
(Source: GSMA- Wireless Intelligence, Global and Regional Mobile Revenue Trends Report https://wirelessintelligence.com/analysis/2013/01/global-and-regional-mobile-revenue-trends/367/)

The increase shown in the above figure, is namely for the fact that mobile operators, unlike fixed networks, deliver a wide range of services such as Voice and Video telephony, Short Message Service (SMS), Mobile Payment Gateways, Mobile Banking and access to Broadband and High Speed internet. This has made of the mobile service a general purpose technology[5].

The higher the adoption of this general purpose technology, the higher is the revenue generated from it. The revenue generated from the mobile sector is representing a significant percentage of the gross domestic product (GDP) especially in developing countries. According to the World Bank, a 10% increase in the *mobile penetration rate*, which is the total number of mobile lines in a country divided by the population, causes a 0.6% increase in the GDP of a developed country and a 0.81% increase in the GDP of a developing country. The economic indicators prove that the mobile industry is a

[5] Technologies that can affect the entire economy and have the potential to reshape the society and boost productivity across all sectors and industries

success story and is causing considerable externalities on the different economic activities. Figure 2 shows the total mobile revenue from the global industry per year.

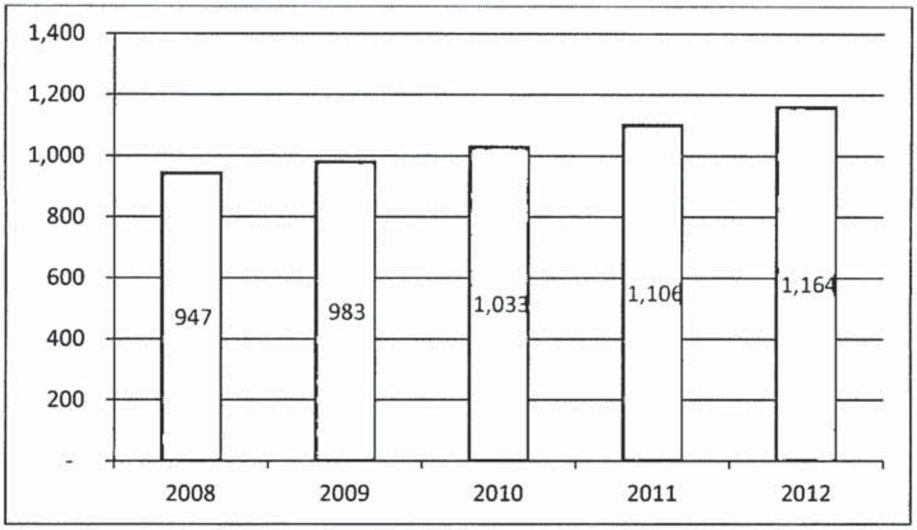

Figure 2: Total global mobile revenue ($, billion)
(Source: GSMA- Wireless Intelligence, Global and Regional Mobile Revenue Trends Report)

Looking at the global revenue trends in the recent years, developing economies are gaining an advancing share of the global mobile revenues, as shown in figure 3, when compared with developed economies.

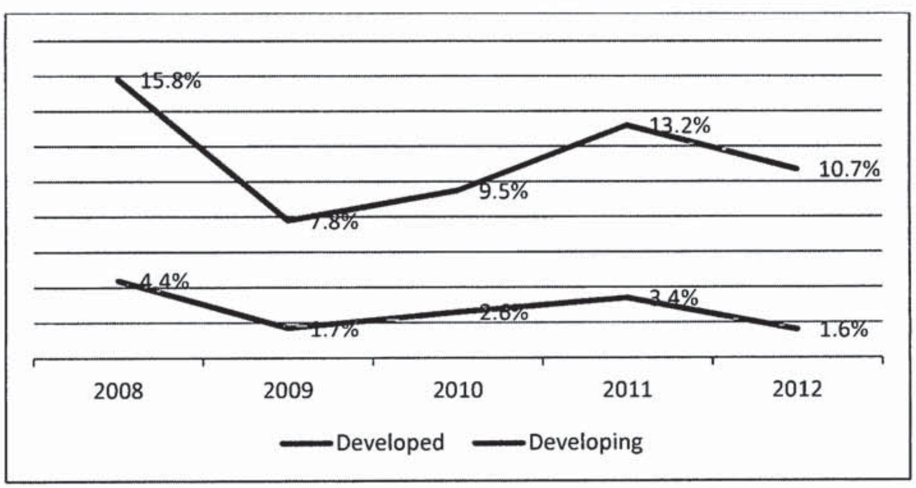

Figure 3: Total revenue growth rates, developed and developing countries
(Source: GSMA- Wireless Intelligence, Global and Regional Mobile Revenue Trends Report)

As for the regional share of the total mobile revenue, the Asian markets have been the main driver behind global growth. As illustrated in figure 4, the Asian region as a whole increased its share of revenue from 36.5% in 2008 to 42.1% in 2012, and is showing little sign of slowing down. In contrary, Europe's share is falling, whereas Africa and America have recorded minor increases in their market shares.

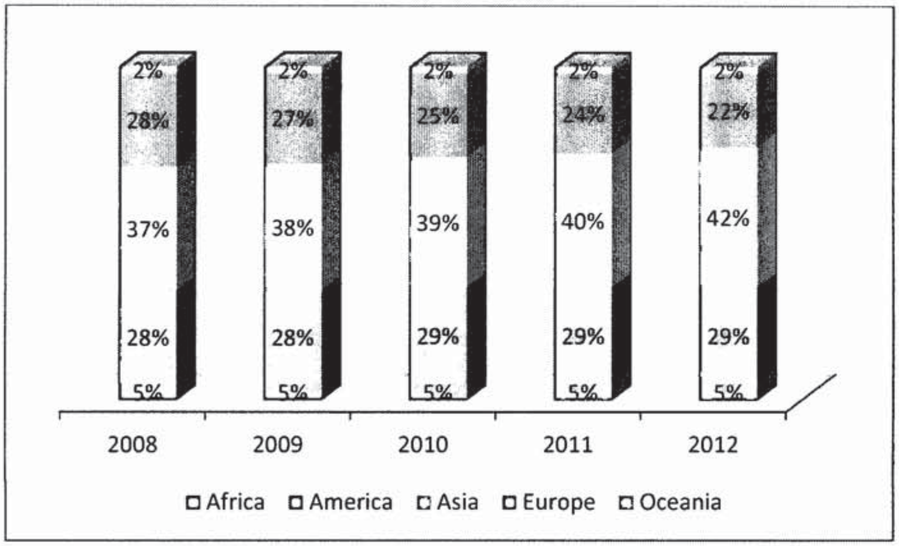

Figure 4: Regional share of global total revenue
(Source: GSMA- Wireless Intelligence, Global and Regional Mobile Revenue Trends Report)

2.3 Mobile Industry in the Middle East

The Middle East region is part of the fast growing Asian market and includes both developing and developed economies. It constitutes of the following 14 countries:

Bahrain	Kuwait	Qatar	UAE
Iraq	Lebanon	Saudi Arabia	Yemen
Israel	Oman	Syria	
Jordan	Palestinian Territories	Turkey	

Table 1: Middle East Countries

With 39 operators offering the service today, usage of mobile phones has dramatically increased in the Middle East in recent years reaching more than 240 million connections by the end of 2012. The mobile market penetration rate has significantly increased from 1% in 1997 to 110%[6] in 2012. Figure 5 shows the distribution of the mobile subscribers over the 14 Middle Eastern countries.

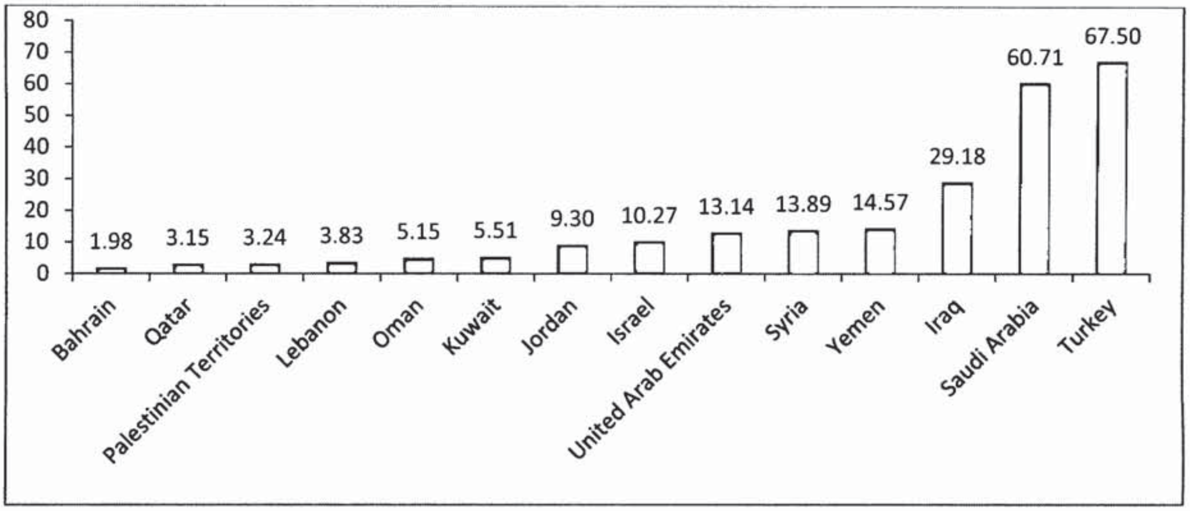

Figure 5: Total Middle East mobile connections per country in 2012 (billion)
(Source: GSMA- Wireless Intelligence https://wirelessintelligence.com)

2.3.1 Countries under Study

An overview of the 9 countries under study and Lebanon with figures from the year 2011 is represented in Table 2. Lebanon was excluded from the study due to the impossibility of obtaining the accurate financial figures of its two state-owned mobile operators.

[6] It is important to note that the mobile penetration rate is the total connections at the end of the period, expressed as a percentage share of the total market population. It might not take into consideration the expats residing in the country.

Country	GDP	GDP/Capita	Population	Mobile Penetration Rate	Total Number of Mobile Operators	Number of Mobile Operators under study	Hirfindahl-Hirschman Index
Lebanon	$ 42,185,230,768	$ 9,904	4,275,562	80.31%	2	0	5025
Jordan	$ 28,840,197,019	$ 4,666	6,393,714	121.54%	3	1	3336
Saudi Arabia	$ 576,824,000,000	$ 20,540	28,393,837	199.78%	3	2	3922
Kuwait	$ 176,590,075,215	$ 62,664	2,854,797	178.95%	3	2	3584
Oman	$ 71,781,535,039	$ 25,221	2,875,091	165.31%	2	2	5174
Palestinian Territories	$ 6,257,900,000(est)	$ 1,594(est)	4,211,580	68.62%	2	2	7300
Qatar	$ 172,981,588,421	$ 92,501	1,904,397	150.52%	2	1	5986
Turkey	$ 773,091,360,340	$ 10,498	74,074,183	88.14%	3	2	3936
UAE	$ 360,245,074,960	$ 45,653	7,998,398	162.73%	2	2	5197
Israel	$ 242,928,731,135	$ 31,282	7,628,432	128.68%	5	2	3073

Table 2: Overview of countries under study (2011)
(Source: UN http://esa.un.org/wpp/unpp/panel_population.htm
World Bank http://data.worldbank.org/
GSMA- Wireless Intelligence
Palestinian Central Bureau of Statistics http://www.pcbs.gov.ps)

The mobile penetration rate is an indicator of how widely the mobile technology is adopted within the country.

As sorted in Figure 6 below, extracted from the above table, Saudi Arabia has the highest mobile penetration rate of 199.78% and Palestine has the lowest rate of 68.62%. This implies that the integration of the mobile technology into the Saudi economy is relatively high, while the Palestinian market is not as saturated yet.

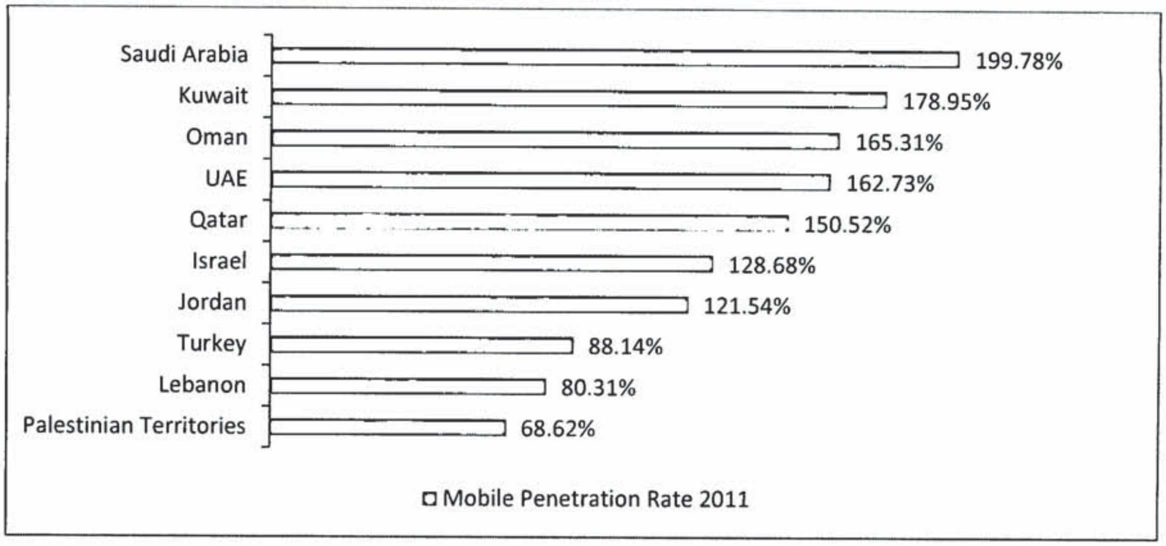

Figure 6: Mobile penetration rate in countries under study (2011)
(Source: GSMA- Wireless Intelligence)

Presented in table 2, the Herfindahl-Hirschman[7] index is a commonly accepted measure of market concentration. It is named after economists Orris C. Herfindahl and Albert O. Hirschman. It measures the size of firms in relation to the industry and indicates the amount of competition among them. It is represented on a scale from 0 to 10,000 (0 indicating an evenly distributed competition and 10,000 indicating an absence of competition, a monopolistic market).

Figure 7 shows the Herfindahl-Hirschman index in the countries under study. The highest competition level is present in Jordan and Israel, followed by Kuwait and Saudi Arabia, while the lowest competitive market is the Palestinian one.

[7] Calculated by squaring the market share of each firm competing in a market, and then summing the resulting numbers. The HHI number can range from close to zero to 10,000. The HHI is expressed as: HHI = s1^2 + s2^2 + s3^2 + ... + sn^2 (where sn is the market share of the nth firm).

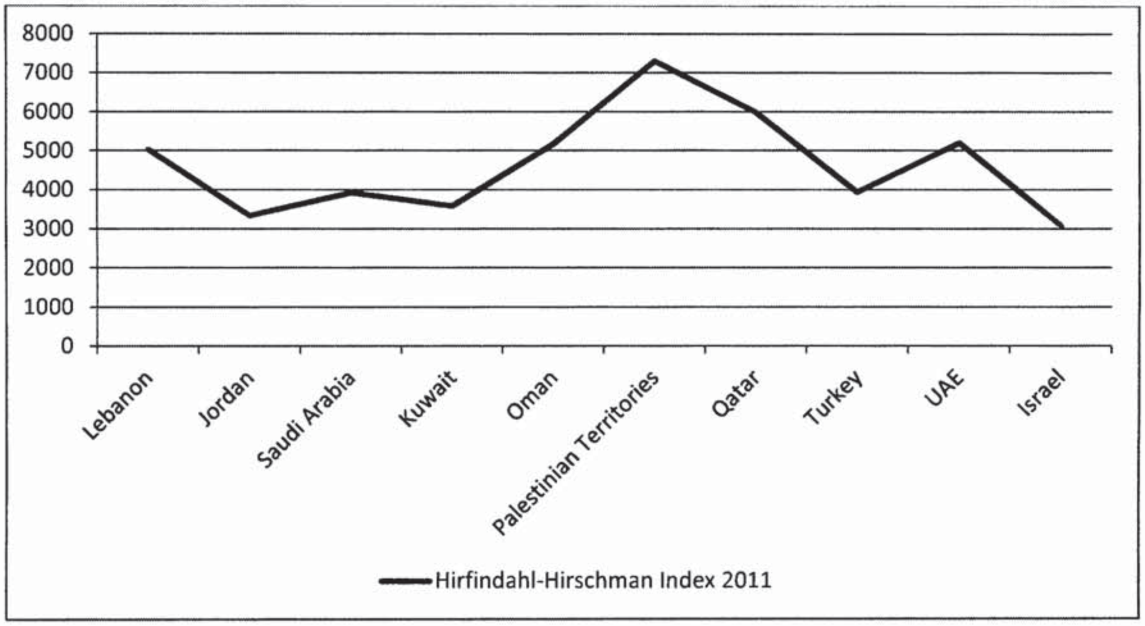

Figure 7: Herfindahl-Hirschman indexes in countries under study (2011)
(Source: GSMA- Wireless Intelligence)

2.3.2 Mobile Operators under Study

The below table compares the 16 operators under study in terms of the total number of mobile subscribers and the number of 3G[8] subscribers. Turkcell Turkey and STC Saudi Arabia have the highest number of mobile subscribers, while Wataniya Palestinian Territories and Vodafone Qatar have the lowest number of subscribers. This is mainly due to the fact that both Wataniya and Vodafone are new entrants into their respective markets.

It is important to note that 3G technology was introduced into the Lebanese mobile market in the fourth quarter of 2011explaining the low number of 3G subscribers for alfa and Touch relative to the total number of subscribers. On the other hand, the 3G technology has not been introduced yet in the Palestinian market which is an indication of an under developed mobile market. This is mainly attributed to the political instability the country is witnessing.

[8] Third generation of mobile telecommunications technology. 3G allows mobile operators to offer high speed internet service.

Country	Operator	Total number of mobile subscribers	Number of 3G subscribers
Turkey	Turkcell	34,500,000	18,500,000
Saudi Arabia	STC	25,969,406	10,203,292
Saudi Arabia	Mobily	23,032,657	11,057,603
Turkey	AVEA	12,800,000	3,725,000
UAE	Etisalat	7,800,000	3,779,417
UAE	du	5,216,000	2,122,179
Israel	Cellcom	3,349,000	3,349,000
Israel	Orange	3,176,000	1,826,909
Oman	Omantel	2,819,858	605,178
Jordan	Orange	2,694,000	900,000
Palestinian Territories	Jawwal	2,425,000	0
Kuwait	Wataniya	1,957,713	1,026,758
Oman	Nawras	1,933,061	255,393
Lebanon	Touch	1,839,000	18,390
Lebanon	alfa	1,594,888	15,949
Kuwait	Viva	1,047,000	627,054
Qatar	Vodafone	797,000	302,468
Palestinian Territories	Wataniya	464,964	0

Table 3: A comparison between the mobile operators' subscribers number
(Source: GSMA- Wireless Intelligence)

However, the number of mobile subscribers alone is not an accurate indicator of how dominant the mobile operator is in its country of operation. Since the size of the population varies, a more precise indicator is the market share that each mobile operator owns.

Table 4 shows that all of Jawwal, Etisalat, Omantel and Turkcell are major players in their markets holding more than half of the market share.

Country	Operator	Market Share
Palestinian Territories	Jawwal	84%
UAE	Etisalat	60%
Oman	Omantel	59%
Lebanon	Touch	53%
Turkey	Turkcell	53%
Lebanon	alfa	47%
Saudi Arabia	STC	46%
Oman	Nawras	41%
Saudi Arabia	Mobily	41%
UAE	du	40%
Kuwait	Wataniya	38%
Jordan	Orange	35%
Israel	Cellcom	34%
Israel	Orange	32%
Qatar	Vodafone	28%
Kuwait	Viva	20%
Turkey	AVEA	20%
Palestinian Territories	Wataniya	16%

Table 4: Mobile operators' market share
(Source: GSMA- Wireless Intelligence)

On the other hand, and as the Herfindahl-Hirschman index previously showed, the situation is different in Jordan, Saudi Arabia, Kuwait and Israel. Looking at the market share of all the mobile operators in each of these countries (even the ones not under study), we notice that the market share is more evenly distributed between them.

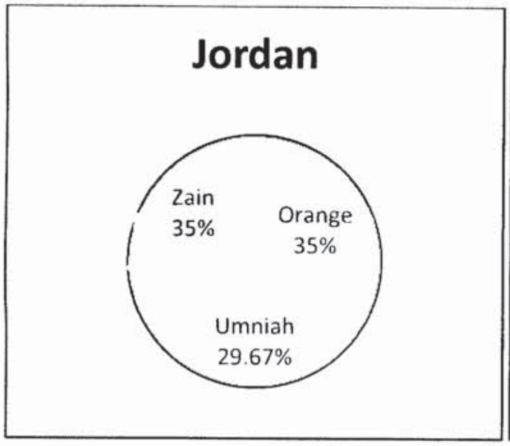

Figure 8: Market share in Jordan
Source: GSMA- Wireless Intelligence)

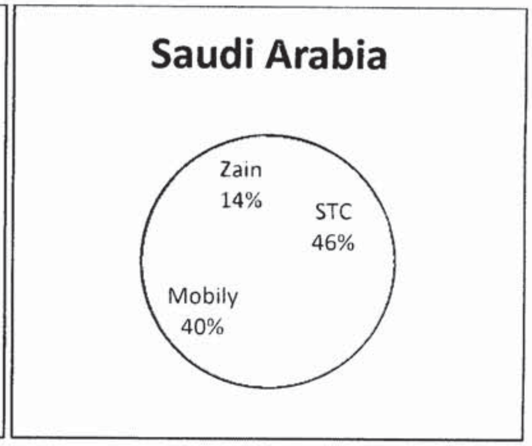

Figure 9: Market share in Saudi Arabia
(Source: GSMA- Wireless Intelligence)

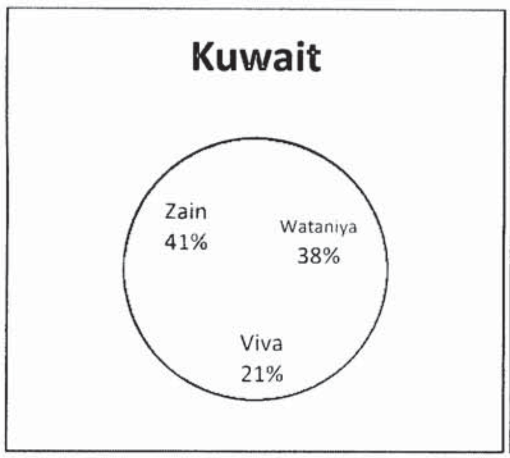

Figure 10: Market share in Kuwait
(Source: GSMA- Wireless Intelligence)

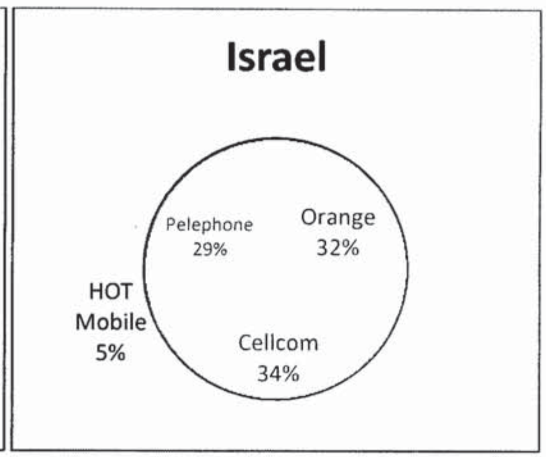

Figure 11: Market share in Israel
(Source: GSMA- Wireless Intelligence)

Even though the Herfindahl-Hirschman index does not show that the mobile market in Lebanon is a competitive one, the market share is somehow equally divided between the two operators. This is mainly because before 2004 the mobile sector in Lebanon was not fully state-owned yet. Two companies were granted 10 years Build- Operator- Transfer (BOT)[9] contracts on a revenue sharing basis, where the government receives 20% of the revenue the companies generate from the sector. The two companies were able to gain a

[9] BOT contract: A type of arrangement in which the private sector builds an infrastructure project, operates it and eventually transfers ownership of the project to the government.

high subscriber base which today the two current state-owned operators, alfa and touch, still own due to the lack of significant competition between them.

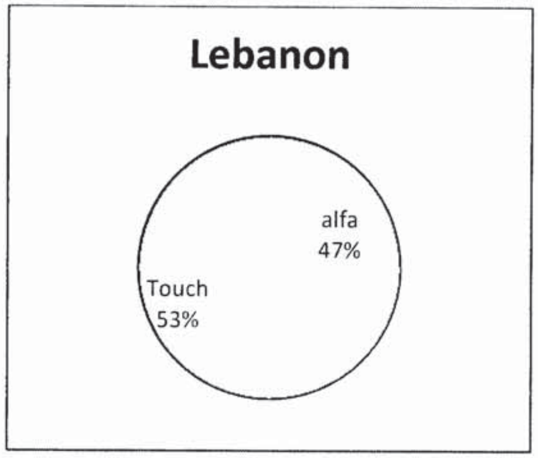

Figure 12: Market share in Lebanon
Source: GSMA-Wireless Intelligence)

Now looking at the customer base distribution between postpaid and prepaid users, as figure 13 shows, all the operators under study have a significantly greater percentage of prepaid users except for Cellcom and Orange Israel.

Globally, the prepaid customer base for mobile operators is usually much greater than the postpaid one. In contrast, it is always better for an operator to have more postpaid users with predictable usage patterns and less prepaid users who are often hesitant to make calls and prefer to receive them. Cellcom and Orange Israel have a big advantage when it comes to the customer base distribution when compared with the rest of the operators because the postpaid users constitute more than 70% of their respective customer bases.

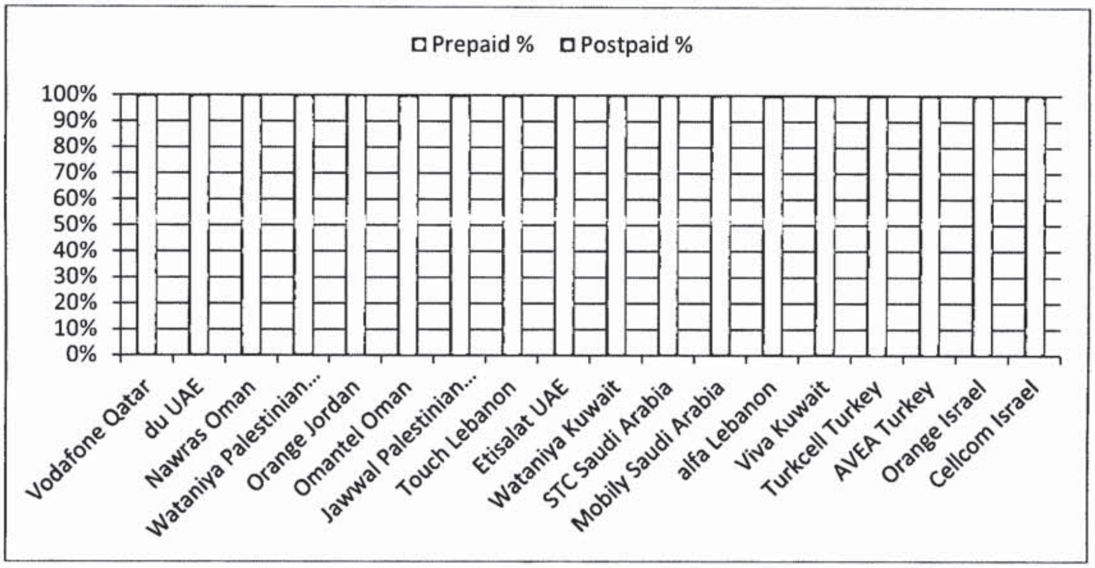

Figure 13: Prepaid v/s Postpaid customer base distribution
(Source: GSMA- Wireless Intelligence)

2.4 Conclusion

The analysis of the mobile sector in the Middle East shows that the circumstances and conditions differ between the countries. Over the past years, the region has undergone a wave of market liberalization. Several operators have been privatized and the issuance of new licenses has given way to new entrants. However, the degrees of liberalization vary between the markets. Some are currently witnessing fierce competition such as in Jordan, Kuwait, Saudi Arabia and Israel. While the competition level remains low in countries like Palestine, Qatar, and UAE.

Subject to the different regional economic and political situations and the global mobile trends, the mobile operators in the Middle East are forced to operate at full efficiency to maintain and possibly increase their profits and markets shares. Means to measure the efficiency and productivity of mobile operators are presented in the next chapter.

Chapter 3- Literature Review

3.1 Introduction

The literature review chapter is composed of two sections. In the initial section, the efficiency and productivity measurement methods will be reviewed. It will also present an explanation of the partial factor productivity (PFP) and the data envelopment analysis (DEA) methods.

The second section will be dedicated to review the studies previously performed to measure efficiency in the mobile sector.

3.2 Efficiency

There is an increasing concern among organizations, such as business branches, government agencies, hospitals, educational institutions and especially mobile operators to study the level of efficiency with which they operate relative to their competitors. This study will focus on measuring the efficiency of the mobile industry in the Middle East.

Efficiency is an important aspect to measure because all the resources used by organizations are scarce. Inputs such as labor, raw materials, time and energy are not very abundant anymore. This is why organizations should try to conserve and use them in the best possible manners. Efficiency is concerned with the optimal use of these scarce resources to produce outputs of a given quality.

Efficiency can be assessed in terms of technical efficiency, allocative efficiency, productive efficiency, dynamic efficiency, cost efficiency, social efficiency and distributive efficiency. This study mainly focuses on the technical efficiency concept. The most common concept of efficiency is the technical efficiency. A unit is said to be technically efficient if it is producing the maximum amount of output while using the minimum amount of inputs.

Moreover, efficiency is an important factor in the determination of productivity. Productivity is usually expressed in the form of partial factor productivity or total factor productivity.

3.2.1 Partial Factor Productivity

Partial factor productivity (PFP) is the ratio of single output to single input factor. It shows how much output has increased over time relative to inputs. An increase in productivity occurs when output increases for a level of input or when the amount of input decreases for a constant level of output. It is useful as a relative measure of actual output of production compared to the actual input of resources, measured across time or against common entities. Therefore, a productivity measure describes how well the resources of an organization are being used to produce output.

Managers tend to use the partial productivity measure because the data needed is readily available and it is easy to understand. Partial factor productivity plainly indicates the results of output from single input and thus it is easier to relate it to specific processes within the organization.

However, partial factor productivity is subject to the weakness that it fails to measure the total productivity with multiple inputs and outputs.

Moving from partial factor productivity to total factor productivity by combining all inputs and all outputs helps to avoid accrediting gains of production to one input that should be attributable to another input. For example, when a single output to input ratio is used, an increase in the amount of goods produced from an increase in capital can be mistakenly accredited to labor although the performance of labor deteriorated during the period under study. Nonetheless, moving to total factor productivity faces several difficulties such as choosing the inputs and outputs to be considered and assigning weights for each of them to reach a single output to single input ratio.

3.2.2 Data Envelopment Analysis (DEA)

A model that does not require a common set of weights and prior assumption of the production function is the data envelopment analysis (DEA). DEA is a non-parametric linear-programming (LP) based technique that converts multiple input and output measures into a single comprehensive measure of relative efficiency.

Additionally, DEA is a methodology directed to frontiers and not to central tendencies. It uncovers the relationships between the inputs and outputs. It does not keep them hidden like other methodologies such as statistical regression where a regression plane is fit through the center of the data.

In DEA, the organization under study is called a decision making unit (DMU). The definition of DMU has been intentionally left unrestricted to allow the use of DEA over a wide range of applications. A DMU is considered any entity responsible for converting inputs into outputs and whose performance is to be measured.

DEA is concerned in measuring relative efficiency, whereby, a DMU is to be rated as 100% or fully efficient if and only if the performances of other DMUs do not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs (William W Cooper, 2011). This definition of relative efficiency avoids the necessity of assuming weights for the factors of production or specifying the relations that are supposed to exist between them.

3.2.2.1 CCR Model

DEA was first introduced by Charnes, Cooper and Rhodes in 1978. It came in response to the thesis efforts of Edwardo Rhodes under the supervision of W. W. Cooper. The thesis was directed to evaluate the educational programs for disadvantaged students, mainly black and Hispanic, in a series of large scales studies undertaken in U.S. public schools with support from the Federal government. Their approach applied the efficiency concept outlined by Farrell in 1957.

In his 1957 article, The Measurement of Productive Efficiency, Farrell used activity analysis[10] concepts to develop better methods and models to evaluate productivity. However, Farrell faced difficulties in computing the model he established because he did not take advantage of the fact that activity analysis models can be transformed into

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[10] Identification and description of activities in an organization, and evaluation of their impact on its operations.

linear programming models to be able to solve them. Here came the development of the first DEA model by Charnes, Cooper and Rhodes called the CCR model.

To better understand the concepts behind the DEA method and the CCR model, below are a series of examples starting from a simple one input- one output example. Then a one input-two output example is presented, moving to a multiple input- multiple output case illustrating the transformation from a nonlinear problem to a linear programming model and concluding with the original CCR model form.

3.2.2.1.1 Example 1- One Input-One Output

Consider there are 4 branches for a firm that produces mobile handsets. For each branch there are one single output measure which is the number of handsets produced and one single input which is the number of employees.

Branch	**Number of Employees**	**Number of Handsets ('000s)**
A	18	125
B	16	44
C	17	80
D	11	23

Table 5: Data (example 1)

For example, branch B in one year has produced 44,000 handsets and 16 employees were employed.

Using the data we have to compare and measure the performance of these branches, we start with the efficiency equation:

$$Efficiency\ (E) = \frac{Output}{Input} \tag{3.1}$$

$$in\ this\ case\ E = \frac{\text{Number of handsets}}{\text{Number of employees}}$$

Branch	Efficiency (handsets/employee)
A	6.94
B	2.75
C	4.71
D	2.09

Table 6: Efficiency Ratios (example 1)

Here we see that branch A has the highest efficiency ratio whereas branch D has the lowest one.

To calculate the relative efficiency of the branches, we take branch A since it has the highest ratio and compare all the other branches to it.

$$Relative\ Efficiency = \frac{\text{Efficiency Ratio x}}{\text{Efficiency Ratio A}}\ X\ 100 \qquad (3.2)$$

where x= A, B, C, D

Branch	Relative Efficiency
A	100%
B	40%
C	68%
D	30%

Table 7: Relative Efficiency (example 1)

From the results in Table 7, we notice that the other branches do not compare well to branch A and are relatively less efficient at using their input (employees) to produce output (handsets).

3.2.2.1.2 Example 2- One Input-Two Outputs

To extend the above example, we now consider that the branches are still using one input, employees, and are now producing two outputs, handsets and laptops.

Branch	Number of employees	Number of Handsets (000's)	Number of Laptops (000's)
A	18	125	50
B	16	44	20
C	17	80	55
D	11	23	12

Table 8: Data (example 2)

For example, branch B has produced 44, 000 handsets and 20,000 laptops using 16 employees during the year under evaluation.

To measure the performance of the branches, we will use the ratios method as in example 1. One of the output measures will be divided by one of the input measures. Since we have only one input and two outputs, we will have two ratios

$$\frac{\text{Number of handsets}}{\text{Number of employees}} \quad \& \quad \frac{\text{Number of laptops}}{\text{Number of employees}}$$

Branch	**Handset/employee**	**Laptop/employee**
A	6.94	2.78
B	2.75	1.25
C	4.71	3.24
D	2.09	1.09

Table 9: Efficiency Ratios (example 2)

We notice from the results that branch A has the highest handset per employee ratio, and branch C has the highest laptop per employee ratio. Whereas, branches B and D do not compare very well with A and C and are, hence, relatively less efficient.

The problem that arose from this simple example when introducing more than one output variable is that comparison via ratios can give a different picture and makes it difficult to obtain a single numeric judgment.

However, one way to solve this problem is to draw a graphical illustration of the results.

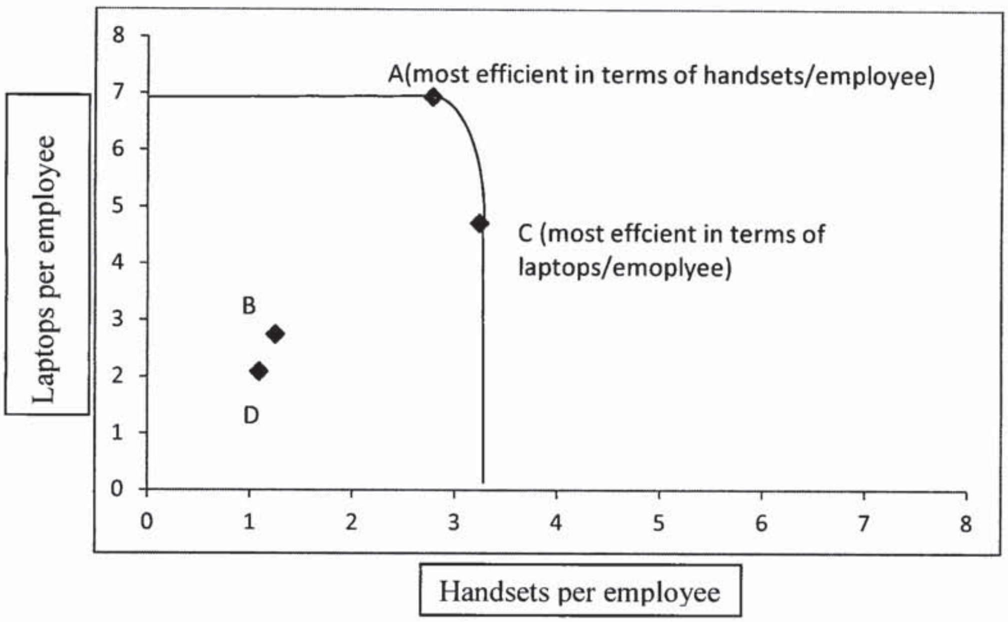

Figure 14: Efficiency Frontier (example 2)

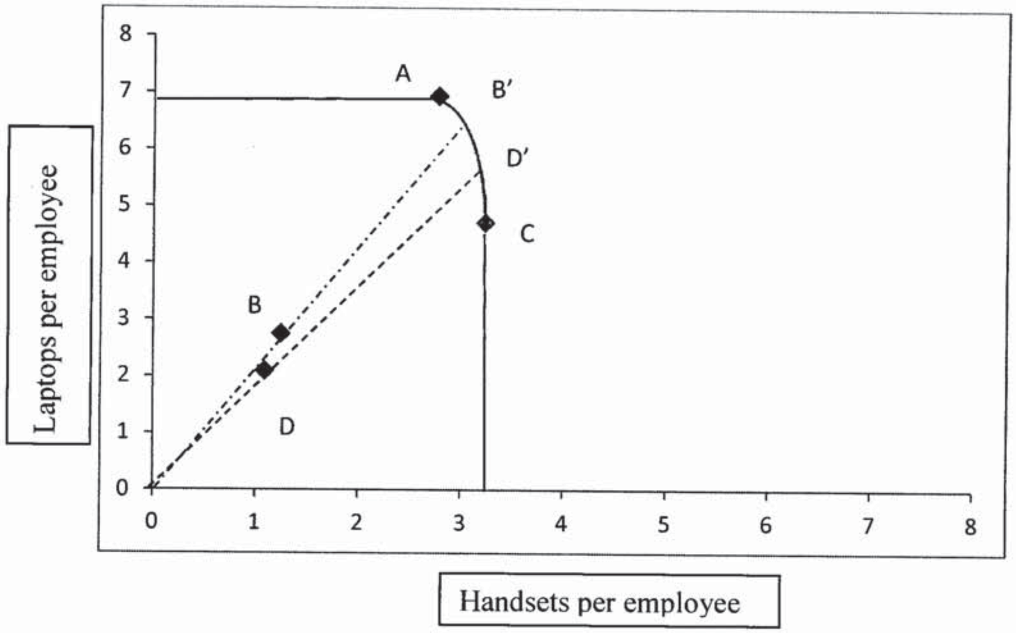

Figure 15: Best Possible Performance (example 2)

The line joining the y-axis, point A, point C and the x-axis in figure 14 is called the efficiency frontier. All the branches on the efficiency frontier are said to be 100% efficient. It represents a standard of performance that the branches below it could try to achieve.

For branches B and D to become fully efficient they have to improve and become, as seen in figure 15, B' and D'. Points B' and D' are the best possible performance that branches B and D respectively can achieve.

However, branches B and D can reach the efficiency frontier through:

1. Reducing their input while keeping the same level of output → input oriented
2. Increasing both outputs while keeping the same number of input → output oriented
3. Doing a combination of the above

This efficiency frontier envelopes all the data, and this is how the name data envelopment analysis arises.

3.2.2.1.3 Multiple Input-Multiple Output

In the above example, we had one input with two outputs which was ideal for graphical illustration. But when the number of input and output variables increases, it becomes impossible to illustrate them graphically. Nevertheless, it would still be possible to calculate the efficiencies by using mathematics rather than graphs.

3.2.2.1.3.1 Nonlinear Problem

Using the data in example 2, to calculate the efficiency of branch B, for instance, from an input oriented method, we would be aiming at maximizing efficiency of B.

Maximize E_B

subject to:

- $E_A = (125W_{hand} + 50W_{lap}) / (18W_{emp})$
  $E_B = (44W_{hand} + 20W_{lap}) / (16W_{emp})$
  $E_C = (80W_{hand} + 55W_{lap}) / (17W_{emp})$
  $E_D = (23W_{hand} + 12W_{lap}) / (11W_{emp})$
- $0 \leq E_A \leq 1$
  $0 \leq E_B \leq 1$
  $0 \leq E_C \leq 1$
  $0 \leq E_D \leq 1$
- $W_{hand} \geq 0$
  $W_{lap} \geq 0$
  $W_{emp} \geq 0$

where:

- E_A is the efficiency of branch A (expressed as a fraction)
- E_B is the efficiency of branch B (expressed as a fraction)
- E_C is the efficiency of branch C (expressed as a fraction)
- E_D is the efficiency of branch D (expressed as a fraction)
- W_{hand} is the weight attached to handsets
- W_{lap} is the weight attached to laptops
- W_{emp} is the weight attached to employees

3.2.2.1.3.2 Linear Programming (LP) Problem

The above model is a nonlinear problem and difficult to solve numerically. To be able to solve it, it should be converted into a liner program. Linear programming (LP) is a mathematical optimization technique which attempts to maximize or minimize a linear function of decision variables. A linear model consists of the following components:

- An objective function
- A set of decision variables
- A set of constraints (which are linear equations of linear inequalities)

The LP form of the above non linear problem is as follows:

maximize E_B = maximize $(44W_{hand} + 20W_{lap}) / (16W_{emp})$

However, the above ratio form yields an infinite number of solutions. For this reason, when converting to linear programming, a representative solution is selected. The selected solution in DEA is where the sum of weighted inputs is equal to 1.

Therefore, to solve the above ratio the denominator is set equal to 1 ➔ $(16W_{emp}) = 1$

subject to the same conditions as the non linear problem

- $0 \leq E_A \leq 1 \rightarrow 0 \leq (125W_{hand} + 50W_{lap}) / (18W_{emp}) \leq 1$
  $0 \leq E_B \leq 1 \rightarrow 0 \leq (44W_{hand} + 20W_{lap}) / (16W_{emp}) \leq 1$
  $0 \leq E_C \leq 1 \rightarrow 0 \leq (80W_{hand} + 55W_{lap}) / (17W_{emp}) \leq 1$
  $0 \leq E_D \leq 1 \rightarrow 0 \leq (23W_{hand} + 12W_{lap}) / (11W_{emp}) \leq 1$

- $W_{hand} \geq 0$
  $W_{la\ p} \geq 0$
  $W_{emp} \geq 0$

After substituting $(16W_{emp}) = 1$, it becomes

maximize $(44W_{hand} + 20W_{lap})$

subject to:

- $(125W_{hand} + 50W_{lap}) - (18W_{emp}) \leq 0$
  $(44W_{hand} + 20W_{lap}) - (16W_{emp}) \leq 0$
  $(80W_{hand} + 55W_{lap}) - (17W_{emp}) \leq 0$
  $(23W_{hand} + 12W_{lap}) - (11W_{emp}) \leq 0$
- $W_{hand} \geq 0$
  $W_{lap} \geq 0$
  $W_{emp} \geq 0$

Through this LP the efficiency of branch B can be calculated and to calculate the efficiency of the other branches, what is maximized is changed, for example, maximize E_A instead of E_B and so on.

When solving the LP the results are:

- E_A is 100% efficient
- E_B is 43% efficient
- E_C is 100% efficient
- E_D is 36% efficient

To generalize the above example, when the efficiency of a DMU needs to be calculated:

$$\text{maximize } E_{DMUx} = \text{maximize(weighted output)}_{DMUx} \qquad (3.3)$$

subject to:

- $(\text{weighted input})_{DMUx} = 1$
- $(\text{weighted output} - \text{weighted input})_{DMUn} \leq 0$
- $\text{Weight } z \geq 0$
- $0 \leq E_{DMUn} \leq 1$

  where :

  - x is the DMU who's efficiency is being calculated
  - n is the set of DMUs
  - z is the input and output variable

3.2.2.1.4 Basic CCR Model

Starting from the input orientation, the CCR model assumes:

- There are *n* DMUs under evaluation
- Each DMU uses varying amounts of *m* different inputs to produce *s* different outputs

$$\text{Max } h_o(u,v) = \sum_{r=1}^{s} u_r y_{rjo} / \sum_{i=1}^{m} v_i x_{ijo} \qquad (3.4)$$

subject to

- $\sum_{r=1}^{s} u_r y_{rj} / \sum_{i=1}^{m} v_i x_{ij} \leq 1$
- $u_r, v_i \geq \varepsilon \geq 0$

where

- h_o is the efficiency of DMU_o
- x_{ij} is the amount consumed of input i
- y_{rj} is the amount produced of output r
- v is the weight of the input i
- u is the weight of the output r
- ε is a non-Archimedean element smaller than any positive real number

Turning it into a LP model the equation becomes

$$\text{Max } h_o(u,v) = \sum_{r=1}^{s} u_r y_{rjo} \qquad (3.5)$$

subject to

- $\sum_{i=1}^{m} v_i x_{ij} = 1$
- $\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \; j = 1, 2, \ldots, n$
- $u_r, v_i \geq \varepsilon \geq 0$

Alternatively and as mentioned earlier, the efficiency of a DMU can be improved either through an input oriented model or an output oriented one. The CCR output oriented model would reorient the objective from maximization to minimization to obtain:

$$\text{Min} \sum_{i=1}^{m} v_i x_{ijo} / \sum_{r=1}^{s} u_r y_{rjo} \qquad (3.6)$$

Subject to

- $\sum_{i=1}^{m} v_i x_{ij} / \sum_{r=1}^{s} u_r y_{rj} \leq 1$
- $u_r, v_i \geq \varepsilon \geq 0$

The LP would become

$$\text{Min} \sum_{i=1}^{m} v_i x_{ijo}$$

Subject to

- $\sum_{r=1}^{s} u_r y_{rj} = 1$
- $\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \geq 0$
- $u_r, v_i \geq \varepsilon \geq 0$

3.2.2.2 BCC Model

The CCR model assumes constant returns to scale (CRS). Nevertheless, returns to scale are not always constant and can vary between increasing and decreasing returns to scale.

1. Constant Returns to Scale (CRS) occurs when inputs are increased by amount m and output increases by the same amount m.
2. Increasing Returns to Scale (IRS) occurs when inputs are increased by amount m and output increases by an amount greater than m.
3. Decreasing Returns to Scale (DRS) occurs when inputs are increased by amount m and output increases by an amount less than m.

Assuming CRS is appropriate when all DMUs are operating at an optimal scale. However, factors such as imperfect competition, constraints on finance, and several other factors, sometimes prevent a DMU from operating at an optimal scale.

In 1984, Banker, Charnes and Cooper proposed an extension on the CCR (CRS) model to account for variable returns to scale (VRS). The model they proposed is called the BCC model.

The multiplier form of the BCC model differs from the one in the CCR model by the introduction of one extra constraint. Equation (3.5) becomes as follows:

$$\text{Max } h_o(u,v) = \sum_{r=1}^{s} u_r y_{rjo} - u_o \tag{3.7}$$

subject to

- $\sum_{i=1}^{m} v_i x_{ij} = 1$
- $\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \; j = 1, 2, \ldots, n$
- $u_r, v_i \geq \varepsilon \geq 0$
- u_o free in sign

where

- u_o is an indicator of returns to scale
  - $u_o > 0$ IRS
  - $u_o < 0$ DRS
  - $u_o = 0$ CRS

3.2.2.3 Scale Efficiency

The technical efficiency score obtained by the CCR model is called Overall Technical Efficiency (OTE). OTE can be decomposed into Pure Technical Efficiency (PTE) and Scale Efficiency (SE).

1. PTE measures how a DMU utilizes the resources under exogenous environments. A low PTE implies that the DMU inefficiently manages its resources.
2. SE measures whether a DMU is operating at the optimal size. A DMU is said to be scale efficient when its size of operations is optimal so that any modifications on its size will render the unit less efficient.

PTE can be obtained from the BCC model.

After applying both the CCR and the BCC models in this study, it will be possible to obtain the SE of each DMU by substituting the values of OTE and PTE in the below formula:

$$SE = OTE/PTE \tag{3.8}$$

3.2.2.4 Modified DEA Model (MDEA)

Ever since the CCR model has been introduced, several extensions have been made to it and a number of different models have appeared. One of the models is called the modified DEA model (MDEA).

As seen earlier the basic DEA models evaluate the relative efficiency of DMUs and assign an efficiency score less than one for the inefficient DMUs and an efficiency score equals to one for the efficient DMUs. Ranking of the efficient DMUs is not allowed in the basic models.

The MDEA model used in this study is the one proposed by Andersen and Petersen in 1993 also known as the A&P efficiency measure. Their model is identical to the BCC model, except that the unit under evaluation is not included in the reference set. Subsequently, the efficient DMUs will have in the A&P efficiency measure model an efficiency score equal to one or greater than one.

It is essential to provide a full ranking of all the DMUs to be able to know the position of each DMU and compare it to its peers. Additionally, it is critical for knowing which factors significantly influence the efficiency of each DMU under study.

3.2.3 Conclusion

More than 2000 articles have been published since the initial study of DEA by Charnes, Cooper and Rhodes. The rapid growth and extensive acceptance of the DEA methodology is evidence to its strength and applicability. Below are few of the characteristics that made of the DEA such a powerful measurement tool:

- DEA can handle multiple input and multiple output models with each being stated in different measurement units.
- It doesn't require an assumption of a functional form relating inputs to outputs.
- There is no restriction on the functional form of the production relationship.
- DEA only requires information on input and output quantities to calculate efficiency and does not need information about prices.
- DMUs are directly compared against a peer or combination of peers.
- DEA can produce specific estimates for desired changes in inputs and/or outputs for projecting DMUs below the efficient frontier onto the efficient frontier.

Due to the above characteristics, DEA has been used in a number of studies involving efficient frontier estimation in the non-profit sector, in the regulated sector and in the private sector. In the next section, studies on the application of DEA in the mobile sector will be reviewed.

3.3 Review of Previous Studies

Many studies have been performed to measure the productivity and efficiency of companies in various industries of the economy. Researchers have been attracted to measure efficiency in the mobile industry using several methods. The methods used included partial productivity, data envelopment analysis (DEA), Tobit regression, sensitivity analysis, Malmquist index approach, total factor productivity, and other measurements.

Eleven empirical studies of productivity and efficiency measurement in the mobile sector will be reviewed. The purpose, methodology and objective of each will be described.

A study on 39 of Forbes[11] 2000 ranked leading global telecom operators was performed (Hsiang-Chih Tsai, 2006). The purpose of that study was to measure the productivity efficiency ratings of those operators and to check if the top ranked Forbes operators have the top ranked efficiency measures. The study applied the Data Envelopment Analysis (DEA) to measure the efficiency using three methods:

a. The traditional radial method, also known as the CCR model, developed by Charnes, Cooper and Rhodes in 1978
b. The A&P model developed by Anderson and Peterson in 1993
c. The efficiency achievement measure that was proposed by Chiang and Tzeng in 2000

The 39 companies under study were telecommunications groups and mobile operators from America, Asia- Pacific, Europe and Africa. They were as well of both types, state-owned and privatized.

The DEA efficiency scores showed that eight companies out of the 39 were operating at full efficiency: NTT Docomo, Swisscom, KDDI, Telstra Corp., NTT Corp., Carso Global Telecom, Telecom Indonesia and China Mobile.

The DEA efficiency scores obtained of the 39 companies were then compared with their relative EBITDA margin, Return on Assets (ROA), Total Asset Turnover, and Profitability and their Forbes 2000 ranking. The results showed that the DEA ranking, the Forbes ranking and the four quantitative financial performance indicators ranking are significantly different. The DEA ranking showed a higher correlation with the total asset turnover ranking. And the EBITDA margin ranking, the ROA ranking and the profitability ranking revealed a higher correlation with each other. Whereas the Forbes

[11] Forbes is an American media and publishing company headed by former Republican candidate Steve Forbes, best known for *Forbes Magazine*. Forbes provides daily news coverage on business, technology, financial markets, personal finance, sports and a wide array of other topics. Forbes is also widely known for its lists of billionaires, world's richest people, world's leading companies and the richest celebrities, among others. Forbes was founded in 1917.

ranking showed a lower correlation with the ROA ranking, the profitability ranking and the DEA ranking.

Another study was performed to explore the impact of industrial policy on the efficiency and productivity of 24 major Asia-Pacific telecom firms under the circumstance of competition and privatization (Jin-Li Hu, 2008).

The time period under study was from year 1999 until year 2004. Three methodologies were used. In the first stage the researchers applied the data envelopment analysis to measure the efficiency scores of the units under study focusing on technical efficiency, pure technical efficiency and scale efficiency, taking into consideration the returns to scale status. In the second stage, the inefficiency scores obtained from the DEA were regressed using the Tobit regression method against four environmental factors: market concentration, public ownership, fixed assets ratio and fixed line revenue ratio. The results were:

1. Competition has a negative effect on the technical efficiency scores.
2. No evidence was found that privatization has a positive effect on the technical efficiency of improvement of Asia Pacific firms.
3. A higher fixed-line revenue[12] ratio has a significantly negative impact on the technical efficiency of Asia-Pacific telecom firms.
4. A larger firm size has a significantly positive influence on the technical efficiency improvement of Asia-Pacific telecom firms.
5. There is no significant improvement in the productivity in Asia-Pacific telecom firms during 1999 to 2004.

In the third stage, the Malqumist productivity index was used to evaluate the longitudinal total factor productivity (TFP). The results showed that 12 out of the 24 firms improved their productivity while 11 firms declined. The growth in productivity was due to technical growth rather than to efficiency change. The study concluded that firms wishing to increase their efficiency and productivity should rely on technological improvements.

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[12] Revenue generated from fixed-line services provided by the operator

Comparing Operational Efficiency among Mobile Operators in Brazil, Russia, India and China (Chun-Hsiung Liao, 2009) is a study that compared the operational efficiency among 10 mobile operators in the BRIC[13] region between the years 2002 and 2006. The efficiency measure was done through the partial factor productivity (PFP) and the data envelopment analysis decomposed into pure technical efficiency and scale efficiency. Four mobile operators from Brazil and two mobile operators from each of Russia, India and China were analyzed.

A sensitivity analysis was then applied which showed how the DEA efficiency scores of the ten operators varied when deleting one of the three inputs each at a time.

The study has showed similar results for both methods the PFP and DEA. The Brazilian operators which had the highest average productivity factors had as well the highest efficiency scores. And the two Indian operators which had the least efficiency scores had the lowest average productivity ratios.

Furthermore, data envelopment analysis was used to measure the operational efficiency of six mobile operators in Japan and Korea between years 2002 and 2006 (Chun-Hsiung Liao H.-Y. L., 2011). In addition to the DEA, the study applied the partial factor productivity. The analysis was taken further through the Tobit regression to be able to determine the factors that are influencing the overall technical efficiency of the mobile operators under study. The results demonstrated that the Japanese operators are more efficient than the Korean ones. This was mainly due to the higher usage of data services in Japan than in Korea and the unsuccessful implementation of the WCMDA (Wideband Code Division Multiple Access) in the early stage in Korea.

Moreover, the results of the Tobit regression showed that the geographical area, the quality of service, the degree of competition, the 3G network type, the ratio of 3G subscribers, and the ratio of data service revenues all had a significant effect on the efficiency of operators. An extra conclusion that was reached from the study was that the fully efficient mobile operators are not necessarily the ones that have the highest revenues.

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[13] Brazil, Russia, India and China

A study was performed on the Indian mobile telecom operators using DEA and sensitivity analysis (Vineeta Nigam, 2012). To evaluate the comparative efficiency of 126 operators both DEA models the CCR and the BCC were applied. The results showed that the older operators lie on the efficiency frontier and this act as benchmarks for the younger ones. The overall performance in the Indian mobile industry is good but there remains possibility for further improvements in efficiency. A sensitivity analysis was then performed. It showed that the private operators are more efficient than the state-owned ones. Many operators proved to be distinctly inefficient and require improvements to increase their efficiency.

A different form of DEA was applied on the Malaysian telecoms sector to compare its performance before and after privatization. The study was applied only on one operator in Malaysia, Telekom Malaysia, through two dimensions, its fixed line business and its overall business. The period under study was from 1968 until 2007. The period before 1990 represented the pre-privatization era and that after 1990 represented the post-privatization one. Since only the performance of one operator was being analyzed and the purpose was to compare its performance over time, the time series DEA analysis was applied. The time series DEA approach treats each year's data as a different decision making unit and compares them to each other. The results showed that the performance after the company has been privatized was better than the performance before privatization.

A similar study was performed on one single operator, Korea Telecom, but to measure the impact of competition on its efficiency as a public enterprise and one of the biggest telecommunications service providers in Korea (Young-Yong Lee, 2000). Besides the time series DEA, partial factor productivity was used. The period under study was from year 1982 until year 1996. The period from 1982 until 1990 was considered as the period before competition, and that between 1991 until 1996 as the after competition one. The PFP showed mixed results and did not help the researchers to draw the needed conclusion for their study.

The DEA results showed an improvement in overall efficiency due to an improvement in allocative efficiency and not due to an improvement in technical efficiency. This implied that when monopolistic firms face external competition they tend to respond by reducing input cost and excessive capital but need time to improve their technical efficiency.

Banker, Cao, Menon, and Natarjan (2010) studied the productivity growth of the U.S. mobile telecom industry. 16 out of the top 25 U.S. mobile operators were put under study from the year 2000 until 2002. DEA was used to measure the productivity. The results of the study showed that there was significant growth in productivity of the telecom industry in the U.S and that technological advancement almost exclusively contributed to this growth. Moreover, the operators that were early movers had better productivity improvement and technological progress and the same applied for the national operators in comparison with the regional ones. The growth in productivity and the technological progress was greater between the period of 2001-2002 than that between the period 2000-2001.

In an attempt to measure the effect of partial privatization on the productivity of a mobile operator, Sueyoshi (1998) employed DEA on one operator in Japan, NTT, from 1953 until 1994. The inputs used were total assets, access lines and number of employees. And the output used was total revenue. The result was that NTT's partial privatization enhanced its productivity due to the reduction in number or personnel. On the other hand, NTT didn't manage to improve its cost management due to the government's political control and its interference in price determination.
Giokas and Pentzaropoulos (2000) measured the efficiency of 36 telecommunications centers of Hellenic Telecommunications Organization in Greece. The inputs selected were number of technical personnel, administrative, operations, accounting and finance personnel, general duties, special status and temporary personnel and installed network capacity. The outputs selected were tariff units for automatic local, trunk, and international telephony and number of new connections and transfer of telephone lines. Out of the 36 telecommunications centers, 15 were operating efficiently and 21 were

not. The study recommended that the 21 inefficient telecommunications center can adopt the managerial strategies of the 15 efficient ones to improve their performance.
The same researchers in 2002 applied DEA on 19 European public telecom operators using access lines, mobile subscribers and number of employees as inputs and total revenue as the single output. They found out that an operator with high profitability is not necessarily operating at full efficiency.

To summarize the above productivity and efficiency measurement studies in the mobile sector, the below two tables were created.
Table 10 provides a summary according to objective, methodology and results.
And table 11 summarizes the selection of the data used in each study.

Title	Objective(s)	Methodology(ies)	Results
The comparative productivity efficiency for global telecoms	To measure the productivity efficiency ratings of 39 of Forbes 2000 ranked leading global telecom operators and to check if the top ranked Forbes operators have the top ranked efficiency measures.	1. DEA a. CCR model b. A&P model c. Efficiency achievement measure	A. 8 mobile operators out of the 39 were operating at full efficiency. B. The DEA ranking, the Forbes ranking and the four quantitative financial performance indicators ranking are significantly different
Efficiency and Productivity of Major Asia-Pacific Telecom Firms	To measure the effect of competition and privatization on the efficiency of Asia-Pacific mobile operators	1. DEA 2. Tobit regression 3. Malqumist Productivity Index	A. 2 out of the 24 operators were operating at full efficiency during the whole period of the study. B. No significant improvement in the productivity in Asia-Pacific telecom firms during the period under study. C. Firms wishing to increase their efficiency and productivity should rely on technological improvements
Comparing Operational Efficiency among Mobile Operators in Brazil, Russia, India and China	To measure and compare the operational efficiency of 10 mobile operators in the BRIC region	1. PFP 2. DEA 3. Sensitivity Analysis	Similar results for both methods the PFP and DEA were obtained: A. 2 Brazilian operators, Vivo and TIM, were both scale efficient and technically efficient. B. 2 Indian operators, Bharti Airtel and Vodafone Essar, were the least efficient.
Measuring operational efficiency of mobile operators in Japan and Korea	To measure the operational efficiency of six mobile operators in Japan and Korea	1. PFP 2. DEA 3. Tobit regression	A. Japanese operators were more efficient than the Korean operators. B. The geographical area, the quality of service, the degree of competition, the 3G network type, the ratio of 3G subscribers, and the ratio of data service revenues all had a significant effect on the efficiency of operators. C. The fully efficient mobile operators are not necessarily the ones that have the highest revenues.

Table 10: Summary of Productivity and Efficiency Studies in Telecommunications

Title	Objective(s)	Methodology(ies)	Results
Malaysia's Telecommunications Sector: An Efficiency and Productivity Analysis	To compare the Malaysian's telecom sector performance before and after privatization	DEA (time series model)	The performance after the company has been privatized was better than the performance before privatization.
The impact of competition on the efficiency of public enterprise: The case of Korea Telecom	To measure the impact of competition on the efficiency of Korea Telecom as a public enterprise and one of the biggest telecommunications service providers in Korea	1. PFP 2. DEA (time series model)	A. Mixed results were obtained from PFP did not help the researchers to draw the needed conclusion for their study. B. The DEA results showed an improvement in overall efficiency after the introduction of new mobile licenses in Korea.
Privatization of Nippon Telegraph and Telephone: was it a good decision	To measure the effect of partial privatization on the productivity of the Japanese mobile operator, NTT	DEA	A. NTT's partial privatization enhanced its productivity due to the reduction in number or personnel. B. NTT didn't manage to improve its cost management due to the government's political control and its interference in price determination.
Evaluation productivity efficiency in telecommunications: Evidence from Greece	To measure the efficiency of 36 telecommunications centers of Hellenic Telecommunications Organization in Greece.	DEA	A. 15 out of the 36 operators under study were operating efficiently and 21 were not. B. It is recommended that the 21 inefficient telecommunications center can adopt the managerial strategies of the 15 efficient ones to improve their performance.
Comparing the operational efficiency of the main European telecommunications organizations: A quantitative analysis	To measure the efficiency of 19 European public telecom operators.	DEA	The operator with high profitability is not necessarily operating at full efficiency.

Table 10: Summary of Productivity and Efficiency Studies in Telecommunications (continued)

Title	Period	Number of Operators	Variables	
			Input(s)	Output(s)
The comparative productivity efficiency for global telecoms	2000	39	1. Total Assets 2. CAPEX 3. Number of employees	1. Total Revenue 2. EBITDA 3. EBIT
Efficiency and Productivity of Major Asia-Pacific Telecom Firms	1994-2004	24	1. Fixed Assets 2. Number of employees	1. Revenue from fixed line services 2. Revenue from non-fixed line services
Comparing Operational Efficiency among Mobile Operators in Brazil, Russia, India and China	2002-2006	10	1. Total Assets 2. CAPEX 3. Number of employees	1. Total Revenue
Measuring operational efficiency of mobile operators in Japan and Korea	2002-2006	6	1. Total Assets 2. CAPEX 3. Number of employees	1. Revenues from voice (2G) services 2. Revenues from data (3G) services
Benchmarking of Indian mobile telecom operators using DEA with sensitivity analysis	2010	126	1. Expenditure 2. Call success rate 3. Call drop rate 4. Voice quality	1. Service access delay 2. Complaints 3. Number of subscribers 4. Total revenue
Malaysia's Telecommunications Sector: An Efficiency and Productivity Analysis	1968-2007	1	1. Total number of employees 2. Total access lines 3. Total assets	1. Total Revenue
Technological progress and productivity growth in the U.S. mobile telecommunications industry	2000-2002	25	1. Cost of service 2. Cost of equipment 3. Selling, general and administrative expenses 4. Depreciation and amortization	1. Equipment revenue 2. Service revenue
The impact of competition on the efficiency of public enterprise: The case of Korea Telecom	1982-1996	1	1. Total Assets 2. Number of Lines 3. Number of employees	1. Total Revenue 2. Number of Calls
Privatization of Nippon Telegraph and Telephone: was it a good decision	1953-1994	1	1. Total Assets 2. Number of Access Lines 3. Number of employees	1. Total Revenue
Evaluation productivity efficiency in telecommunications: Evidence from Greece	1971-1993	36	1. Number of employees 2. Installed network capacity	1. Tariff units for automatic local, trunk, and international telephony 2. Number of new connections and transfer of telephone lines
Comparing the operational efficiency of the main European telecommunications organizations: A quantitative analysis	2002	19	1. Number of access lines 2. Number of mobile subscribers 3. Number of employees	1. Total Revenue

Table 11: Summary of Data Selection in Telecommunications Productivity and Efficiency Studies

The inputs and outputs selected for the measurement of efficiency and productivity using data envelopment analysis varied from one study to another. This variety is mainly due to the difference in the purpose of the study and to the fact that generally mobile operators are unwilling to publicly communicate their operational and financial data due to the fierce competition in the sector.

3.4 Conclusion

This chapter has demonstrated that the DEA is an effective measure of efficiency represented by the ratio of outputs to inputs. The development and growth in DEA is evidence to its acceptance as a valuable model for measuring efficiency in the mobile sector. This study will first apply the PFP method and then measure the efficiency of the mobile operators in the Middle East using the DEA model.

Chapter 4- Methodology

4.1 Introduction

This chapter illustrates the methodology that will be applied on the 16 mobile operators to meet the objective of the study. The complete process constitutes of 6 steps:

1. Choose input and output factors
2. Collect the needed data
3. Perform the PFP method on the data obtained
4. Construct and run the DEA model
5. Obtain the financial ratios
6. Analyze the results

Steps one and two are interrelated, because if the input and output factors are not collectable, it would not be possible to use them in the model even if they are meaningful.

4.2 Input and Output Factors Selection and Data Collection

The previous studies reviewed in chapter three adduces that no common set of factors of production has been used when measuring efficiency in the mobile sector. Nevertheless, when choosing them one should keep in mind that the inputs and outputs must relate to the objectives of the decision making units (DMUs), which are the mobile operators in this study, be consistent across DMUs and be quantifiable.

Choosing the input and output factors and collecting them is the most important and difficult step when measuring the efficiency of mobile operators in the Middle East. Few of the operators are publicly listed and thus to obtain their financial and operational data is not an easy task.

4.2.1 Selected Variables

After all the possible data resources have been researched, the study will use 3 input factors and 2 output factors.

Input	Output
Total number of employees (Emp) Total Assets (TA) CAPEX	Total Revenue (TR) EBITDA

Table 12: Input and output factors selected

The input factors chosen in this study are the total number of employees, total assets and capital expenditures. Since labor is an essential input in the production function of any mobile operator, the number of employees was chosen. The capacity a mobile operator has is represented by its total assets. Total assets are all assets owned by the operator, including current assets, fixed assets, intangible assets and deferred tax assets. The mobile communication industry is capital intensive, and the operator's capital expenditures (CAPEX) are necessary for the construction of its network. The CAPEX invested affects call quality, coverage, transmission speed and network capacity. This is why CAPEX was chosen as an input factor in this study. It represents the total expenditures for the purchase of property, equipment and other assets.

As for the output factors, one can use the amount of service produced by the operators which is measured in terms of number of voice minutes, number of SMS and the data volume produced from GPRS and 3G. But those figures are not obtainable for most of the operators studied. Alternatively, one can use the revenue and earnings made by the operators as output factors. In this study, total revenue, and earnings before interest, taxes, depreciation and amortization (EBITDA) were selected.

Operating profit (EBIT) and net income were excluded as output variables because their relevant 2011 values are negative for Viva Kuwait, Wataniya Palestine, Vodafone Qatar and Avea Turkey.

4.2.2 Restrictions in the Variables Selection

Besides the need for the input and output values to be positive, there are two more restrictions to abide with for selecting the variables when constructing a DEA model.

4.2.2.1 The number of DMUs

One of the restrictions when constructing a DEA model is the total number of DMUs, and the number of inputs and outputs to be selected. The basic requirement in DEA is that the number of DMUs exceeds three times the number of input plus output variables.

$$n > 3\ (m+s)$$

where: n is the number of DMUs

m is the number of inputs

s is the number of outputs

The 16 DMUs selected for this study with 3 input and 2 output factors meet the above condition {16 > 3(3+2)}.

4.2.2.2 Isotonicity Test

Another restriction is the isotonicity principle which the input and output factors have to comply with. Increasing an input should result in an increase in the value of an output and not cause a decrease.

To determine this isotonicity property a correlation analysis should be applied on the input and output variables selected. This study uses the Pearson correlation coefficient. Table 13 describes the correlation coefficients obtained and shows that all the coefficients are greater than 0.5, r >0.5, indicating a positive high correlation between the input and output variables. Only the correlation coefficient between EBITDA and CAPEX is 0.46, slightly below 0.5, but still indicating a positive correlation between them.

r	**TR**	**EBITDA**
TA	0.96	0.79
CAPEX	0.67	*0.46
Number of Employees	0.86	0.70

Table 13: Pearson correlation coefficient between inputs and outputs

4.2.2 Data Collection

The data for the above input and output factors were collected from the mobile operators' published financial statements and the 2011 end of year reports. The major challenge was with obtaining the number of employees. Interviews were held with the operators whose number of employees is not publicly stated. Those operators are Wataniya Kuwait, Wataniya Palestine, Vodafone Qatar, STC Saudi Arabia and Etisalat UAE.

All the financial figures collected where converted from the operators' reported currencies to US dollar as per the exchange rate of 16 February, 2013.

Table 14 shows the statistical analysis of the data collected. For the number of employees, the median was used instead of the mean because one company among the 16, STC Saudi Arabia, has a huge number of employees relative to the others (21000 employees).

	n	**Mean**	**Median**	**Minimum**	**Maximum**	**Standard Deviation**
Employees *(person)*	16	4,333	2,726	405	21,000	5,405
TA *($, million)*	16	5,491.70	1,808.64	283.24	29,699.71	8,317.17
CAPEX *($, million)*	16	495.91	254.59	44.36	2,063.67	592.82
TR *($, million)*	16	2,369.38	1,240.02	73.08	9,991.93	2,840.03
EBITDA *($, million)*	16	805.13	352.85	1.77	3,623.22	1,025.29

Table 14: Statistical analysis of input and output variables

To overcome the outlier's issue in the number of employees, table 15 shows the statistical analysis of the 15 operators' data excluding STC Saudi Arabia.

	n	Mean	Median	Minimum	Maximum	Standard Deviation
Employees *(person)*	15	3222	2700	405	11150	3183
TA *($, million)*	15	3,877.83	1,696.70	283.24	17,186.70	5,428.31
CAPEX *($, million)*	15	391.39	157.63	44.36	1,576.68	435.05
TR *($, million)*	15	1,861.21	862.99	73.08	6,545.55	2,053.04
EBITDA *($, million)*	15	707.94	312.15	1.77	3,623.22	982.03

Table 15: Statistical analysis of input and output variables (excluding STC Saudi Arabia)

4.3 Partial Factor Productivity (PFP)

After selecting the variables and collecting the needed data, the first step to measure the productivity of the mobile operators will be through the partial factor productivity (PFP) method. As explained in chapter three, the PFP is a single input to single output productivity measure. Even though it fails to measure total productivity, it plainly indicates the results making them easy to understand. This study calculated and compared six indicators:

1. Revenue per employee (RPE): the ratio of total revenue to the number of employees.
2. Revenue per total asset (RPA): the ratio of total revenue to the total assets.
3. Revenue per capital expenditure (RPC): the ratio of total revenue to the capital expenditure.
4. EBITDA per employee (EPE): the ratio of EBITDA to the number of employees.
5. EBITDA per total asset (EPA): the ratio of EBITDA to the total assets.
6. EBITDA per capital expenditure (EPC): the ratio of EBITDA to the capital expenditure.

Output/Input	**TR**	**EBITDA**
Number of Employees	RPE	EPE
TA	RPA	EPA
CAPEX	RPC	EPC

Table 16: PFP ratios

4.4 Data Envelopment Analysis (DEA)

Following the application of the PFP to measure the productivity, three DEA models will be applied to measure the relative technical efficiency of the 16 mobile operators under study:

1. The basic CCR model
2. The BCC model
3. The A&P or the Modified DEA model

When applying all of the above three DEA models, the input orientation is selected. The input-oriented model measures how much less inputs a mobile operator can employ to produce the same amount of output.

The input-oriented model is chosen because, generally, a mobile operator has better control over its inputs. The outputs in the mobile sector may be driven by factors beyond the control of the mobile operator such as market factors and competition.

4.4.1 The Basic CCR Model

As seen previously, efficiency is measured as a ratio of weighted sum of outputs to weighted sum of inputs. In this study the efficiency formula is translated into the following:

$$Efficiency\ (E) = \frac{u1(TR) + u2(EBITDA)}{v1(Emp) + v2(TA) + v3(CAPEX)} \qquad (4.1)$$

Where:

- *TR* is the total revenue generated by the mobile operator
- *EBITDA* is the mobile operator's earnings before income, tax, depreciation and amortization
- *Emp* is the number of employees employed by the mobile operator
- *TA* is the mobile operator's total assets
- *CAPEX* is the mobile operator's capital expenditure
- u_1 is the weight given to the total revenue output
- u_2 is the weight given to the EBITDA output

- v_1 is the weight given to the number of employees input
- v_2 is the weight given to the total assets input
- v_3 is the weight given to the capital expenditure input

Without knowing the values of u_1, u_2, v_1, v_2, v_3, equation 4.1 is solved by rewriting it in the form of linear programming as done by Chares, Cooper and Rhodes. One of the main advantages of DEA is that it does not require prior assumptions of the production function or the weights of the factors of production, as previously pointed out in chapter three.

$$\text{Maximize } E_1 = u_1\,(\text{TR}) + u_2\,(\text{EBITDA}) \qquad \textit{for mobile operator 1} \qquad (4.2)$$

Subject to:

- $v_1\,(\text{Emp}) + v_2\,(\text{TA}) + v_3\,(\text{CAPEX}) = 1$ *for mobile operator 1*
- $\sum u_1\,(\text{TR}) + u_2\,(\text{EBITDA}) - \sum v_1\,(\text{Emp}) + v_2\,(\text{TA}) + v_3\,(\text{CAPEX}) \leq 0$ *for all mobile operators*
- $u_1, u_2, v_1, v_2, v_3 \geq \varepsilon \geq 0$

4.4.2 The BCC Model

The CCR model shown in equation 4.2 only takes into account constant returns to scale (CRS). Nonetheless, mobile operators are not always operating at optimal scale and are subject to variable returns to scale (VRS). To overcome the constraint of the CCR model, the study will then apply the BCC model which introduces an extra variable, u_o, representing the variable returns to scale.

The linear programming formula in the BCC model becomes as follows:

$$\text{Maximize } E_1 = u_1\,(\text{TR}) + u_2\,(\text{EBITDA}) - u_o \qquad \textit{for mobile operator 1} \qquad (4.3)$$

Subject to:

- v_1 (Emp) + v_2 (TA) + v_3 (CAPEX) = 1 *for mobile operator 1*
- $\sum u_1$ (TR) + u_2 (EBITDA) -$\sum v_1$ (Emp) + v_2 (TA) + v_3 (CAPEX) - $u_o \leq 0$ *for all mobile operators*
- $u_1, u_2, v_1, v_2, v_3 \geq \varepsilon \geq 0$
- u_o free in sign (its sign will indicate how the returns to scale are varying)

The results of both the CCR and the BCC models will then be compared. If the results are similar, this means there is no scale efficiency. But if the results of the BCC model are different from the ones obtained from the CCR model, this indicates the existence of scale efficiency.

4.4.3 Scale Efficiency

Scale Efficiency is expressed as the ratio of Overall Technical Efficiency divided by Pure Technical Efficiency.

$$SE=\frac{OTE}{PTE} \quad (4.4)$$

Once the CCR and the BCC results are obtained, the Scale Efficiency of the 16 mobile operators will be calculated.

Knowing that the CCR model provides the OTE value and the BCC model provides the PTE value, the Scale Efficiency of each mobile operator is obtained from the following formula:

$$SE=\frac{CCR}{BCC} \quad (4.5)$$

4.4.4 The Modified DEA Model

The CCR and BCC models evaluate the relative efficiencies of the mobile operators and allow for the calculation of the scale efficiency, but do not rank the efficient DMUs.

To overcome this weakness in the CCR and BCC models, the study will then apply the A&P modified DEA model proposed by Anderson and Peterson, the A&P model, to be able to differentiate between the efficient DMUs.

The purpose of the application of the three different DEA models is to capture the entirety of the mobile operators' performances.

4.4.5 Software

4.4.5.1 Searching for a Suitable Software

Choosing a software for performing the DEA analysis is a fundamental step in the methodology because it will decide on how accurate and reliable the results will be. Several general-purpose mathematical optimization software can be adjusted to solve DEA problems. However, DEA specific programs offer a wider variety of features allowing for more flexibility in the analysis. Few of the most commonly used ones are:

- Banxia Frontier Analyst *version 4*- by Banxia Software Ltd. Glasgow, Scotland. http://www.banxia.com/frontier/
- DEAP *version 2.1* – by the Centre for Efficiency and Productivity Analysis (CEPA), University of New England, NSW, Australia. http://www.uq.edu.au/economics/cepa/deap.php
- DEA-Solver Professional *version 2.0*- by Saitech Inc. New Jersey, U.S.A. http://www.saitech-inc.com/Products/Prod-DSP.asp
- Efficiency measurement system (EMS) *version 1.3*- by H. Scheel. University of Dortmund, Germany. http://www.holger-scheel.de/ems/

To be able to download Banxia Frontier Analyst and DEA-Solver Professional a license has to be bought, while both DEAP and EMS can be downloaded free of charge. However, DEAP does not offer a Windows version whereas the EMS does.

4.4.5.2 Selecting the Software

Looking at the key features of the different software packages available, the software selected to perform this study was the Efficiency Measurement System (EMS) software. It is a non-commercial software and developed for academic use.

The EMS is a standalone Windows application and uses the LP Solver DLL BPMPD 2.11 by Csaba M´esz´aros for the computation of the scores. Theoretically, there are no limitations on the number of DMUs, inputs and outputs. Problems with over 5000 DMUs and about 40 inputs and outputs have successfully been solved using the EMS. It accepts data in MS Excel or in text format. A step-by-step pdf manual is provided upon download which facilitates its usage.

EMS is a solid, straight-forward DEA solution tool. It has a good selection of available models and a strong feature set. EMS allows for the possibility of choosing between an input and output orientation. It offers the option to solve DEA problems through the CCR and the BCC models. It also has the A&P model option which very few DEA software offer making it suitable to use in this study.

4.5 Financial Ratios

After the efficiency scores of all the DMUs are measured, the values of four financial ratios for each of the 16 mobile operators will be calculated. Financial ratios are mainly used to compare the strengths and weaknesses of companies. Financial ratios are of several types. This study used three profitability ratios and one efficiency ratio to compare the 16 mobile operators.

The ratios used were the following:

1. EBITDA Margin: This ratio is a measure of a mobile operator's operating profitability. It measures to what extent cash operating expenses use up revenue. Investors usually look at it to get a view of the operator's core profitability. The higher the EBITDA ratio, the more profitable the operator is. Basically, an EBITDA margin greater than 40% implies that the operator is in a healthy financial condition. The EBITDA margin formula is:

$$EBITDA\ Margin = \frac{\text{EBITDA}}{\text{Total Revenue}} \tag{4.6}$$

2. Return on Assets (ROA): This ratio is an indicator of how profitable a mobile operator is relative to its total assets. It shows what earnings were generated from invested capital (assets). It gives an idea at how wise the management is at allocating its resources and how efficiently it is using its assets to generate earnings. It also shows investors how efficient the mobile operator is at converting the money it has into net income. The ROA is highly dependent on the industry. The higher the ROA the more earnings the mobile operator is making with less investment. The ROA formula is:

$$ROA = \frac{\text{Net Income}}{\text{Total Assets}} \tag{4.7}$$

3. Profit Margin: This ratio is a measure of how much of its revenue a mobile operator is keeping as earnings or profits after all expenses have been deducted. It is usually used to compare companies within the same industry. A higher profit margin indicates that the mobile operator is more profitable and has better control over its costs compared to its competitors. The formula for the profit margin is:

$$Profit\ Margin = \frac{\text{Net Income}}{\text{Revenue}} \tag{4.8}$$

4. Total Assets Turnover: While the three above ratios are profitability ratios, the total assets turnover is a ratio of efficiency. It measures the mobile operator's efficiency at using its assets to generate revenue. It shows how much revenue was generated from every dollar worth of assets. The higher the ratio the more intensively the mobile operator is using its assets. The formula for the total assets turnover is:

$$Total\ Asset\ Turnover = \frac{\text{Revenue}}{\text{Total Assets}} \tag{4.9}$$

4.6 Conclusion

This chapter illustrated the methodology that will be used in the study to obtain the productivity and efficiency scores of the mobile operators through the PFP and the three different DEA models. It also presented and explained the significance of the financial ratios that will be used in the study.

After collecting all the data and applying the methodology, the efficiency scores of the mobile operators will be compared with the financial ratios values. The results will be reported and analyzed in the next chapter.

Chapter 5- Findings

5.1 Introduction

The main objective of this study is to measure the efficiency and productivity of mobile operators in the Middle East during 2011.

This chapter presents and analyses the results of the application of the PFP and DEA models on the mobile operators as depicted in chapter four. The application of the DEA will identify which mobile operators are efficient and which are not. The results are then compared with the operators' financial ratios to determine the degree of correlation between technical efficiency and performance indicators, such as financial ratios, in the Middle Eastern mobile industry during 2011.

5.2 Partial Factor Productivity (PFP) Results

Partial factor productivity was first applied to measure the partial productivity of the mobile operators in the Middle East. The results of the six indicators adopted in this study are described in table 17.

As predicted, the results of the PFP failed to provide a single numeric judgment for the productivity of the 16 mobile operators under study. The results did not show that one single operator has the highest ratios and thus is the most productive. On the contrary, each operator shows a different level of productivity depending on the indicator measured.

Operators	RPE (\$,thousand/person)	RPA	RPC	EPE (\$,thousand/person)	EPA	EPC
Orange Jordan	263.68	0.622	11.282	104.43	0.247	4.468
Mobily Saudi Arabia	1,297.24	0.535	5.183	482.24	0.199	1.927
STC Saudi Arabia	475.81	0.336	4.842	107.76	0.076	1.097
Viva Kuwait	702.42	0.742	3.250	3.75	0.004	0.017
Wataniya Kuwait	865.58	1.179	0.547	394.73	0.538	0.250
Nawras Oman	502.19	0.658	0.724	263.77	0.345	0.380
Omantel Oman	259.57	0.421	12.544	113.43	0.184	5.482
Jawwal Palestine	425.00	0.477	8.718	191.52	0.215	3.929
Wataniya Palestine	178.25	0.258	0.464	8.64	0.013	0.022
Vodafone Qatar	806.46	0.141	3.667	71.84	0.013	0.327
Avea Turkey	645.65	1.840	3.856	79.61	0.227	0.476
Turkcell Turkey	1,564.81	0.280	9.587	490.97	0.088	3.008
Etisalat UAE	587.04	0.451	13.596	324.95	0.250	7.526
du UAE	808.02	0.735	6.859	266.09	0.242	2.259
Cellcom Israel	229.08	0.717	11.770	77.86	0.244	4.000
Orange Israel	204.92	0.842	12.750	65.11	0.268	4.051

*Note: RPE- Revenue Per Employee. RPA- Revenue Per Total Asset. RPC- Revenue Per CAPEX
EPE- EBITDA Per Employee. EPA- EBITDA Per Total Asset. EPC- EBITDA Per CAPEX

Table 17: Partial factor productivity results

Turkcell Turkey has the highest revenue per employee (RPE) and EBITDA per employee (EPE). This is mainly because Turkcell makes sure to recruit competent employees and focuses on the quality of recruitment. It is also due to the fact that at the end of 2011, Turkcell was able to provide 88% 3G coverage and offered its customers a variety of data plans which resulted in a 20.1% increase in mobile internet revenue when compared with 2010. Turkcell's EBITDA has increased as well in 2011 due to lower general and administrative expenses and lower sales and marketing expenses.

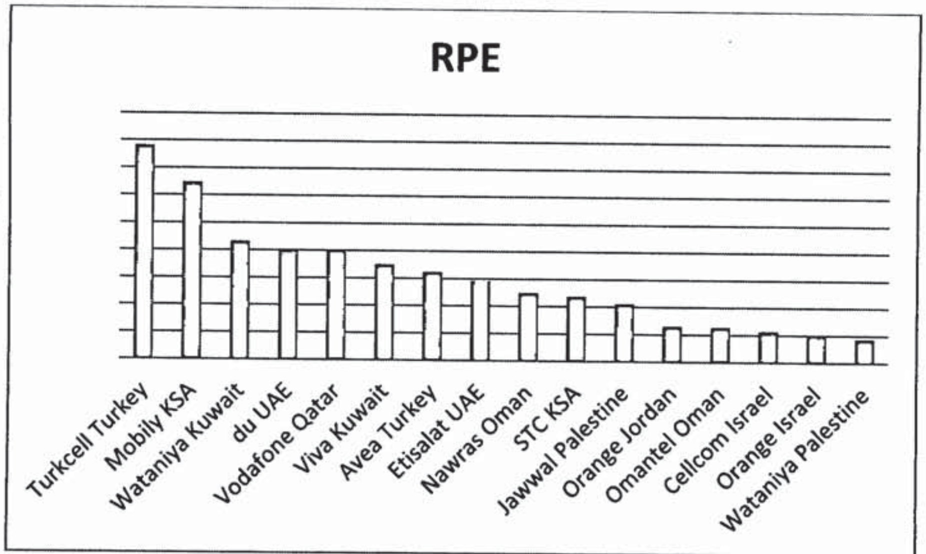

Figure 16: Revenue per employee (RPE) ratios results

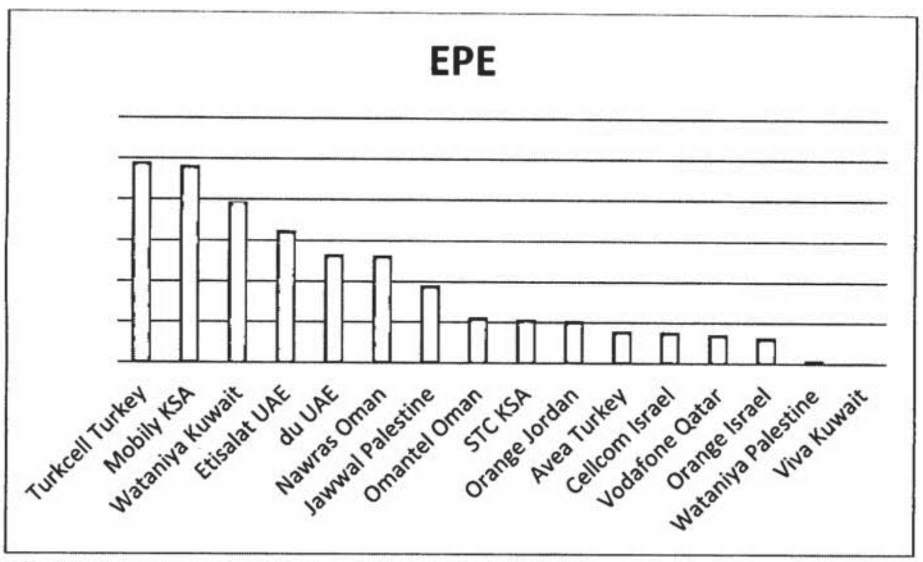

Figure 17: EBITDA per employee (EPE) ratios results

As for the revenue per CAPEX (RPC) and EBITDA per CAPEX (EPC), Etisalat UAE has the highest ratios because its CAPEX in 2011 was at a slower phase and has decreased by 27% compared to 2010, mainly due to the significant network expansion Etisalat made in 2010.

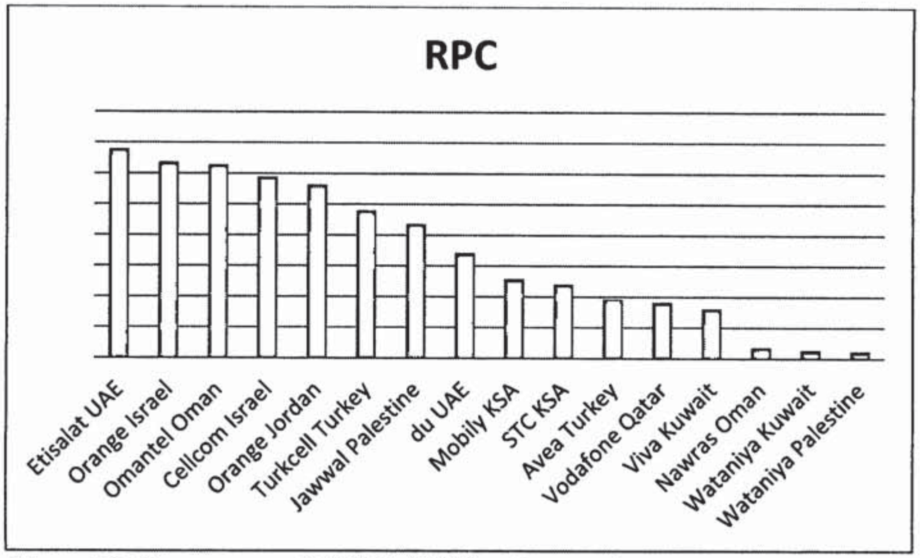

Figure 18: Revenue per CAPEX (RPC) ratios results

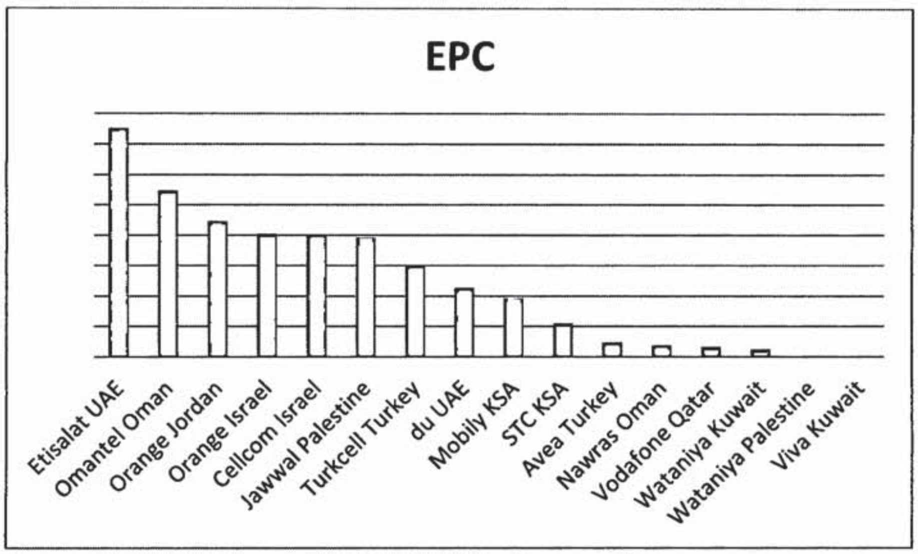

Figure 19: EBITDA per CAPEX (EPC) ratios results

Avea Turkey has the highest revenue per total asset (RPA) because the size of its revenue increase was larger than the increase in its total assets in 2011. While, Wataniya Kuwait has the second highest RPA and the highest EBITDA per total asset (EPA) due to the 10% increase in its revenue and 12.3% increase in its EBITDA during 2011 and the lower percentage increase in its assets.

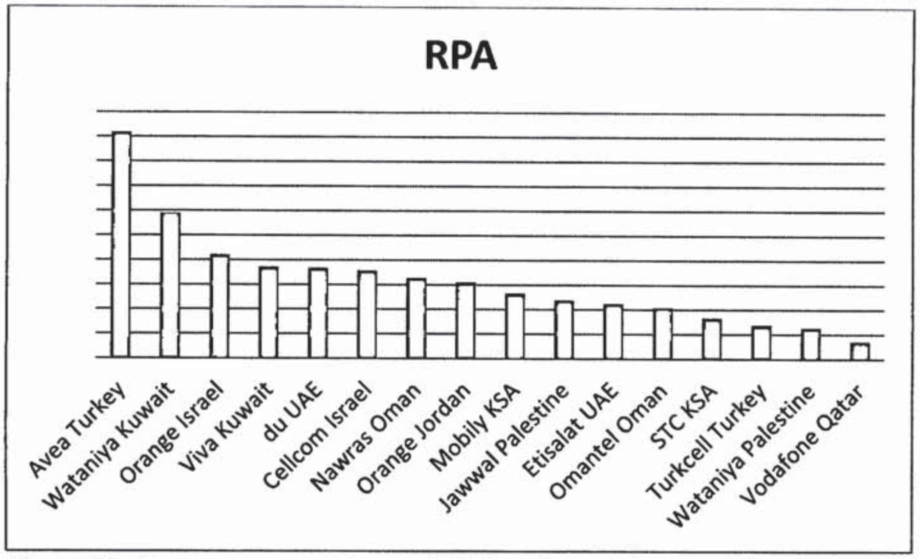

Figure 20: Revenue per total asset (RPA) ratios results

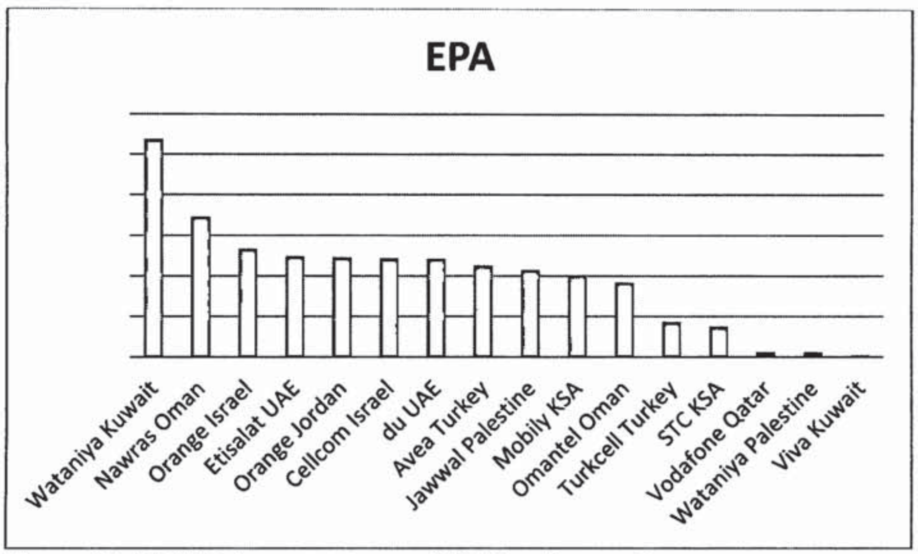

Figure 21: EBITDA per total asset (EPA) ratios results

On the other hand, Wataniya Palestine has the lowest RPE and RPA, Vodafone Qatar has the lowest RPA, and Viva Kuwait has the lowest EPE, EPA and EPC. Those three operators are relatively new ones and had not started generating profits from their operations yet. Viva Kuwait was established during the fourth quarter of 2008. Whereas, Vodafone Qatar and Wataniya Palestine were established during the third and fourth quarters of 2009, respectively. This justifies why they have the lowest revenue and EBITDA ratios.

From the above PFP results, it can be anticipated that Turkcell Turkey, Etisalat UAE, Avea Turkey and Wataniya Kuwait will be evaluated as fully efficient in the DEA analysis since they achieved at least one highest single-output-single-input ratio score. Nevertheless, there is a high probability that other mobile operators will be fully efficient as well when evaluating the efficiency using a multiple input and multiple output ratio.

5.3 Data Envelopment Analysis (DEA) Results

The data envelopment analysis results will show which mobile operators among the 16 are fully efficient and which are relatively less efficient taking into consideration multiple factors of production. The DEA results were generated using the Efficiency Measurement System, EMS 1.3, software.

5.3.1 Loading Data and Running DEA Models in the EMS 1.3 Software

To be able to evaluate the mobile operators' efficiency scores using DEA, the data was first prepared in an excel file to be loaded into the EMS 1.3 software.

The data had to be in the following format, where the string "{I}" identifies the input factors and the string "{O}" identifies the output factors.

Operator	Employees {I}	TA {I}	CAPEX{I}	TR {O}	EBITDA {O}

Table 18: Data format in EMS 1.3

Once the data has been loaded into the software, the three different DEA models, the CCR, the BCC and the A&P, have been run according to the conditions illustrated in figure 22.

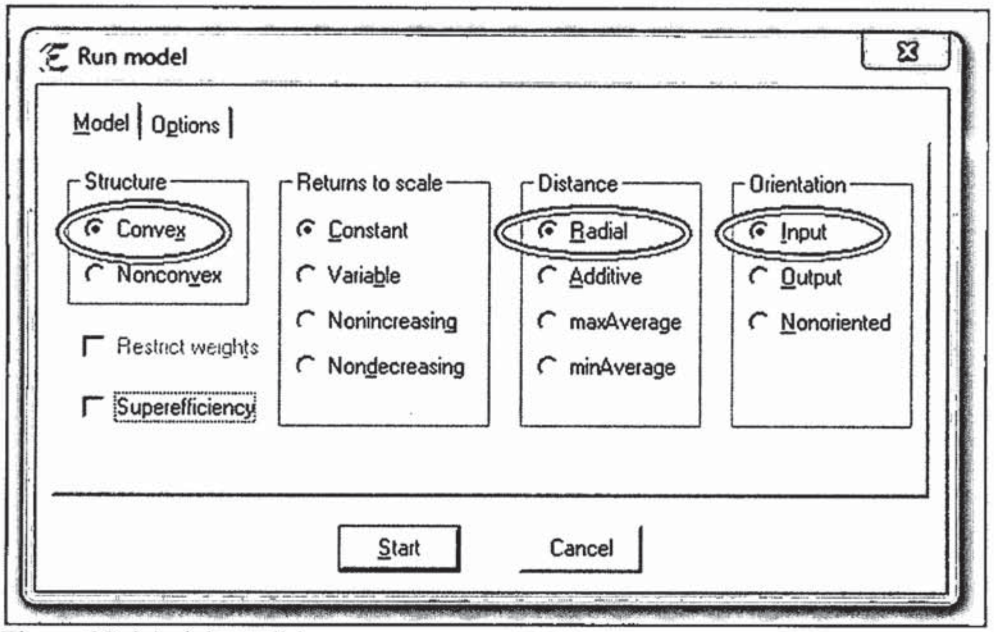

Figure 22: Model conditions

The *input* orientation was selected for the three models, as justified in chapter four. Since all three models assume convexity, the *convex* structure is selected along with the *radial* distance. The radial distance measures the DMU's efficiency score depending on its proportional distance from the efficiency frontier.

First, the CCR model was run, then the BCC model, and finally the A&P model based on constant returns to scale (CRS), as shown in the below figures.

5.3.2 CCR Model Results

The CCR model was ran using the EMS1.3 software as illustrated in the below figure.

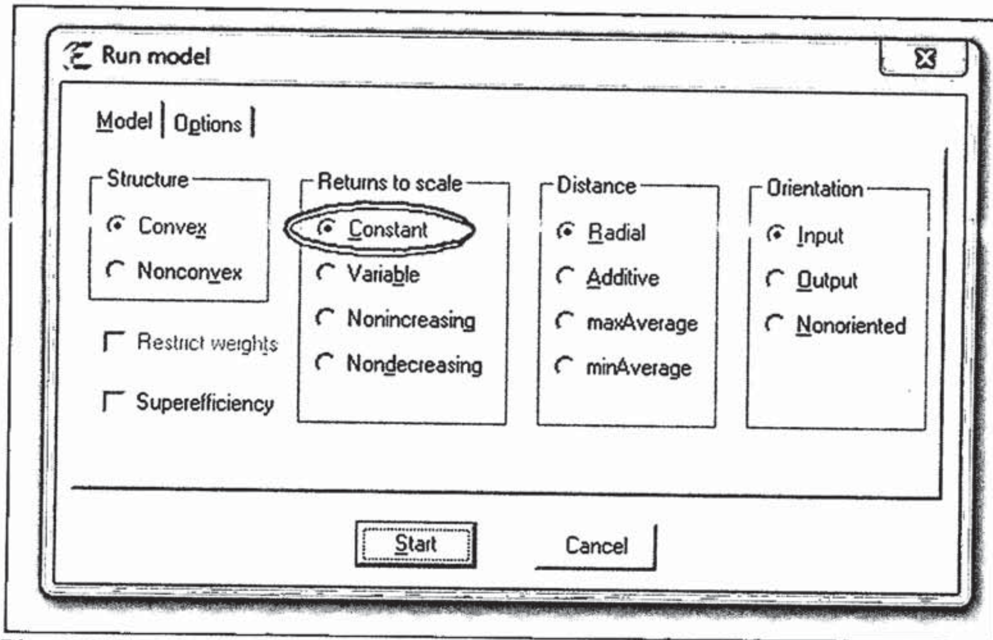

Figure 23: CCR Model

Based on the assumption of constant returns to scale, the DEA scores showed that 7 mobile operators are fully efficient and had a CCR score equal to 1, as displayed in table 19.

As predicted from the PFP results, Turkcell Turkey, Etisalat UAE, Avea Turkey and Wataniya Kuwait are fully efficient, in addition to, Mobily Saudi Arabia, du UAE and Orange Israel.

On the contrary, 9 operators, Cellcom Israel, Orange Jordan, Nawras Oman, Omantel Oman, Jawwal Palestine, Viva Kuwait, STC Saudi Arabia, Vodafone Qatar and Wataniya Palestine, are operating on a relatively less efficient level. Their CCR efficiency scores varied between 0.964 and 0.232.

Operator	*CCR*	Benchmarks
Mobily Saudi Arabia	1.000	2
Wataniya Kuwait	1.000	5
Avea Turkey	1.000	2
Turkcell Turkey	1.000	2
Etisalat UAE	1.000	6
du UAE	1.000	4
Orange Israel	1.000	5
Cellcom Israel	0.964	Orange Israel, Etisalat UAE, du UAE
Orange Jordan	0.955	Orange Israel, Etisalat UAE, du UAE, Wataniya Kuwait
Nawras Oman	0.934	Orange Israel, Etisalat UAE, Wataniya Kuwait
Omantel Oman	0.924	Orange Israel, Etisalat UAE
Jawwal Palestine	0.861	Orange Israel, Etisalat UAE, du UAE, Wataniya Kuwait
Viva Kuwait	0.842	Mobily Saudi Arabia, Wataniya Kuwait, Avea Turkey
STC Saudi Arabia	0.606	Turkcell Turkey, Etisalat UAE, du UAE
Vodafone Qatar	0.515	Turkcell Turkey
Wataniya Palestine	0.232	Mobily Saudi Arabia, Wataniya Kuwait, Avea Turkey

Table 19: CCR model efficiency results

5.3.3 BCC Model Results

To take variable returns to scale into consideration, the BCC model was ran in the EMS1.3 software in the following manner:

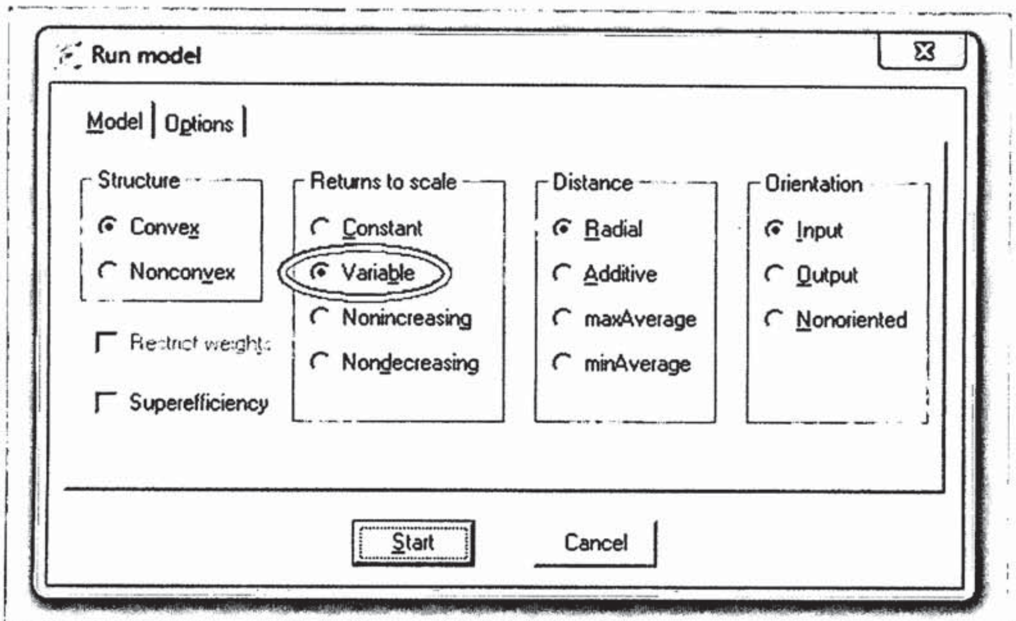

Figure 24: BCC Model

Under variable returns to scale, the results changed dramatically and the majority of the DMUs were evaluated as fully efficient. The only two inefficient operators under the BCC model were Cellcom Israel and Nawras Oman.

Operator	BCC	Benchmarks
Mobily Saudi Arabia	1.000	0
Wataniya Kuwait	1.000	1
Avea Turkey	1.000	0
Turkcell Turkey	1.000	0
Etisalat UAE	1.000	1
du UAE	1.000	1
Orange Israel	1.000	1
Orange Jordan	1.000	2
Omantel Oman	1.000	0
Jawwal Palestine	1.000	1
Viva Kuwait	1.000	0
STC Saudi Arabia	1.000	0
Vodafone Qatar	1.000	0
Wataniya Palestine	1.000	1
Nawras Oman	0.996	Orange Jordan, Wataniya Kuwait, Jawwal Palestine, Wataniya Palestine
Cellcom Israel	0.966	Orange Israel, Etisalat UAE, du UAE, Orange Jordan

Table 20: BCC model efficiency results

5.3.4 Scale Efficiency Results

The results from the BCC model differed from the CCR results indicating the existence of scale efficiency. The results of the CCR and the BCC models provided the mobile operators' scores of Overall Technical Efficiency and Pure Technical Efficiency from which the Scale Efficiency scores are obtained.

Operator	OTE *(CCR)*	PTE *(BCC)*	SE
Mobily Saudi Arabia	1.000	1.000	1.000
Wataniya Kuwait	1.000	1.000	1.000
Avea Turkey	1.000	1.000	1.000
Turkcell Turkey	1.000	1.000	1.000
Etisalat UAE	1.000	1.000	1.000
du UAE	1.000	1.000	1.000
Orange Israel	1.000	1.000	1.000
Cellcom Israel	0.964	0.966	0.997
Orange Jordan	0.955	1.000	0.955
Nawras Oman	0.934	0.996	0.938
Omantel Oman	0.924	1.000	0.924
Jawwal Palestine	0.861	1.000	0.861
Viva Kuwait	0.842	1.000	0.842
STC Saudi Arabia	0.606	1.000	0.606
Vodafone Qatar	0.515	1.000	0.515
Wataniya Palestine	0.232	1.000	0.232
Mean	0.865	0.998	0.867

**SE=OTE/PTE*

Table 21: OTE, PTE and SE results

Interpreting the results in table 21, it becomes evident that the relative inefficiency the mobile operators showed under the CCR model is due to scale inefficiency rather than pure technical inefficiency. PTE purely reflects the mobile operator's managerial performance to organize its inputs in the production process. Whereas, SE indicates the management's ability to choose the optimum size and scale of production that will attain the needed level of production.

The scale inefficiency the inefficient mobile operators showed is because the size of the operator is either too large and is not taking full advantage of scale or too small for its scale of operations.

Only Nawras Oman and Cellcom Israel have a PTE<1 indicating an inefficiency in their managements' performance and their inability to utilize resources in an optimal manner.

5.3.5 A&P Results

The results of the CCR model identified the 7 DMUs with full relative overall technical efficiency and gave each of them a score equal to 1 without differentiating between them.

To be able to rank the efficient DMUs, the A&P model was ran using the EMS1.3 software as shown in figure 25 below.

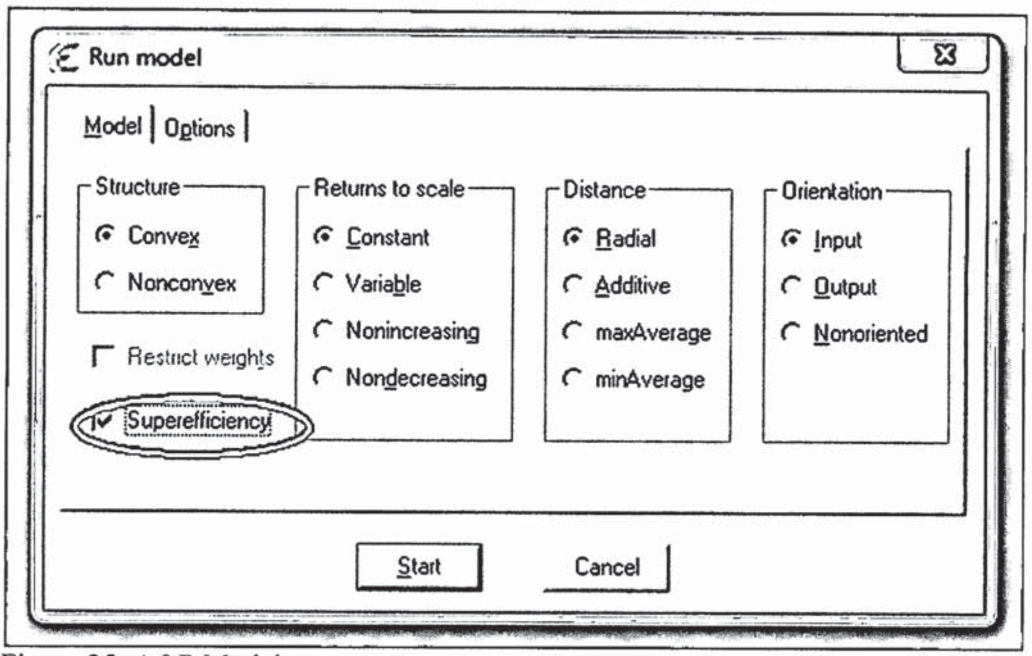

Figure 25: A&P Model

The results of the application of the A&P model are presented in table 22. The most efficient mobile operator among the 16 appeared to be Avea Turkey, followed by Etsialat UAE, Wataniya Kuwait, Turkcell Turkey, Mobily Saudi Arabia, Orange Israel and finally du UAE.

Ranking	Operator	Score
1	Avea Turkey	2.086
2	Etisalat UAE	1.846
3	Wataniya Kuwait	1.623
4	Turkcell Turkey	1.567
5	Mobily Saudi Arabia	1.338
6	Orange Israel	1.153
7	du UAE	1.145
8	Cellcom Israel	0.964
9	Orange Jordan	0.955
10	Nawras Oman	0.934
11	Omantel Oman	0.924
12	Jawwal Palestine	0.861
13	Viva Kuwait	0.842
14	STC Saudi Arabia	0.606
15	Vodafone Qatar	0.515
16	Wataniya Palestine	0.232

Table 22: A&P model results

There are only two mobile operators in the UAE, and both of them in the study were found to be fully efficient in 2011. This implies that the mobile market conditions and circumstances in the UAE are driving the mobile operators to function as efficiently as possible. Both, Etisalat and du, have been given several awards for their corporate, innovation and engineering, marketing and customer care and management performances during 2011. They both launched long-term evolution (LTE)[14] networks during 2011 delivering fast mobile data speeds across the country.

Etisalat has worked on improving its operational efficiency by introducing work forces, programs and systems to increase its staff functionality, its overall process efficiency, and its customers experiences and to simultaneously reduce revenue losses.

du, on the other hand, has worked throughout the year on reorganizing its processes and reinforcing operational and financial controls. This has enabled the company to better manage its employees and its capital expenditure.

[14] The 4th generation of mobile network technology that is being deployed by mobile operators to deliver very fast data speeds of up to 100Mbps in the downlink and 50Mbps in the uplink.

Etisalat and du both emphasize the importance of the human capital in their operations and continuously work on developing and improving their performance. Etisalat's human resource team initiated several major programs in 2011 clustered around customer service, frontline training, and job-specific skill gaps, and geared towards organizational efficiency and effectiveness across all operations. Similarly, du has worked on solidifying its reputation as employer of choice in the UAE and continued on increasing its employee engagement level by developing training programs in partnership with one of the world's leading business schools, INSEAD.

As for Turkey, two out of its three mobile operators are covered in this study, and the two were fully efficient in 2011. The investment in the mobile industry is increasing in Turkey. In 2011, the mobile penetration rate has increased and led to a decrease in the number of fixed line subscribers. The mobile-to-mobile traffic has increased from 48% in 2006 to 82% in 2011. The two mobile operators, Avea and Turkcell, mainly focused on offering innovative services for their customers, and were both granted awards for their 2011 achievements.

The relatively most efficient among the 16 mobile operators, Avea, despite being the youngest operator in Turkey, had the highest number of new subscribers in 2011 and the highest number of postpaid subscribers. While the average revenue per user (ARPU) in the mobile industry is decreasing globally, Avea was able to increase its ARPU by 7% in 2011. It covers 98% of the Turkish population and had invested well during 2011 in its employees, infrastructure and technology to offer its customers good quality communication with innovative value added services. It is the only operator in Turkey with research and development (R&D) certification from the Turkish Ministry of Industry and Commerce. Its R&D is not only focused on creating new services but is also involved in several international mobile health projects.

Unlike Avea, Turkcell is one of the oldest mobile operators in Turkey and has the biggest portion of the mobile market share. To retain its subscribers' base, Turkcell has launched prepaid and postpaid plans to meet the different customers' needs and has focused on expanding its coverage and on improving the speed of its mobile internet service. In addition to developing its network technically, the company has enhanced its sales, marketing and customer services by providing its employees with the necessary trainings from Turkcell Academy.

On the other hand, the study showed that the situation is different in Kuwait, Saudi Arabia and Israel. Some of the operators were fully efficient in those countries and some were not. Wataniya Kuwait, Mobily Saudi Arabia and Orange Israel were fully efficient while their counterparts, Viva Kuwait, STC Saudi Arabia and Cellcom Israel were operating inefficiently during 2011.

Similar to Etisalat, du, Avea and Turkcell, the three operators Wataniya Kuwait, Mobily Saudi Arabia and Orange Israel had focused in 2011 on providing excellent network quality, on offering innovative services and on delivering the best possible customer service for their subscribers. In order to do so, they worked at improving the efficiency of their internal processes and providing their employees with the needed trainings to strengthen their skills and their commitment to the companies.

5.4 Comparison between the DEA Results and the Mobile Operators' Performance Indicators

The DEA applied on the DMUs under study measured and ranked the mobile operators based on their relative technical efficiency scores. Table 23 presents a comparison between the A&P rank and the ranking obtained from the 16 mobile operators' four performance indicators the:

1. EBITDA Margin
2. ROA
3. Total Asset Turnover
4. Profit Margin

Operator	A&P Rank	A&P Score	EBITDA margin Rank	EBITDA margin	ROA Rank	ROA	Total Asset Turnover Rank	Total Asset Turnover	Profit Margin Rank	Profit Margin
Avea Turkey	1	2.09	13	0.12	16	-0.63	1	1.84	14	-0.34
Etisalat UAE	2	1.85	1	0.55	9	0.07	11	0.45	8	0.16
Wataniya Kuwait	3	1.62	3	0.46	1	1.59	2	1.18	1	1.35
Turkcell Turkey	4	1.57	11	0.31	6	0.13	14	0.28	2	0.47
Mobily Saudi Arabia	5	1.34	7	0.37	5	0.14	9	0.53	5	0.25
Orange Israel	6	1.15	10	0.32	11	0.06	3	0.84	11	0.07
du UAE	7	1.15	9	0.33	8	0.09	5	0.73	10	0.12
Cellcom Israel	8	0.96	8	0.34	7	0.10	6	0.72	9	0.13
Orange Jordan	9	0.96	6	0.40	12	0.01	8	0.62	12	0.02
Nawras Oman	10	0.93	2	0.53	2	0.16	7	0.66	6	0.25
Omantel Oman	11	0.92	5	0.44	3	0.16	12	0.42	3	0.38
Jawwal Palestine	12	0.86	4	0.45	4	0.16	10	0.48	4	0.33
Viva Kuwait	13	0.84	16	0.01	15	-0.11	4	0.74	13	-0.15
STC Saudi Arabia	14	0.61	12	0.23	10	0.07	13	0.34	7	0.21
Vodafone Qatar	15	0.52	14	0.09	13	-0.06	16	0.14	16	-0.42
Wataniya Palestine	16	0.23	15	0.05	14	-0.09	15	0.26	15	-0.35

Table 23: Comparison between the DEA and financial ratios results

The results showed a significance difference between the ranking obtained from the A&P model and that obtained from each of the four financial ratios. Those financial ratios are assessed by mass investors and are strongly related to the mobile operator's market success.

Nevertheless, this study has showed that the performance indicators which investors usually look at do not reflect the actual level of efficiency the mobile operator is functioning at.

5.5 Conclusion

This chapter presented and analyzed the findings of the study. The results of the PFP highlighted the need of the DEA that takes into account multiple inputs and outputs to measure the efficiency of the mobile operators. 7 mobile operators were found to have been functioning at full efficiency during 2011 while 9 were operating inefficiently.

The comparison between the efficiency level of the mobile operators under study and the four performance indicators showed that the performance ratings do not properly reflect how efficient the mobile operators were during 2011.

Chapter 6- Conclusions and Recommendations

6.1 Introduction

This chapter concludes the thesis by providing a summary of the development of the main study and an analysis of the results. It furthermore discusses the limitations of the study and suggests recommendations for areas of future work.

6.2 Summary and Analysis of Main Results

6.2.1 Summary

As set out in the introductory chapter, telecommunications, and more specifically the mobile industry, is becoming an essential part of the society and is playing a major role in improving the efficiency in the various economic activities.

This study is the first to measure the efficiency in the mobile industry in the Middle East. It applied two methodologies, the partial factor productivity (PFP) and the data envelopment analysis (DEA).

The PFP used 6 ratios to measure the productivity of the mobile operators. Each operator showed a different level of productivity for each of the 6 ratios. The inconclusive results obtained from the PFP affirmed the need for a methodology that takes into account the multiple inputs and multiple outputs to provide with one single efficiency ratio, such as the DEA.

Three models of DEA were applied. First the basic constant returns to scale CCR model was implemented. Then the study applied the BCC model to allow for variable returns to scale considerations. Finally the A&P model was applied to be able to rank the fully efficient mobile operators.

The results of the CCR model showed that 7 of the mobile operators under study were fully efficient and 9 were operating inefficiently during 2011. The results of the BCC model demonstrated that the inefficiency of the 9 mobile operators is mainly due to scale inefficiency rather than pure technical efficiency.

Simultaneously, the A&P model ranked Avea Turkey as the most efficient among the 16 mobile operators during 2011, followed by Etsialat UAE, Wataniya Kuwait, Turkcell Turkey, Mobily Saudi Arabia, Orange Israel and finally du UAE.

Furthermore, the study compared the efficiency scores obtained from the DEA methodology with four financial ratios as performance indicators for the 16 Middle Eastern mobile operators. The comparison revealed that there was no relation between the levels of efficiency of the mobile operators and their four financial ratios.

6.2.2 Analysis of main results

Although it is important to know the specific efficiency of a mobile operator so that it can be compared to other mobile operators, the results discussed in chapter five lead to the conclusion that the most important objective of efficiency measurement is improvement.

The DEA is a useful model for planning the improvements for the 9 inefficient DMUs. The Efficiency Measurement System, EMS, 1.3 was a very suitable software for determining the efficiency scores of the mobile operators using the three different DEA models. However, to go further in the analysis and to be able to obtain a report on the needed improvements, a new software had to be used.

Among all the available software, the DEA Frontier was selected. The DEA Frontier is a Microsoft excel add in for solving data envelopment analysis models. The software was developed by Joe Zhu[15], a professor of Operations and Industrial Engineering.

The DEA Frontier software can be downloaded from the following link http://www.deafrontier.net .

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[15] Zhu is an expert in methods of performance measurement and his research interests are in the areas of operations, productivity, performance evaluation and benchmarking. He published and co-edited several books focusing on performance evaluation using DEA. Zhu has over 90 published articles and is ranked number 7 with respect to h-index and number 3 with respect to the total number of published papers on DEA.

The first step in getting a report on the improvements was to prepare the data in the relevant format in excel and to use the DEA Frontier excel add in. The CCR and the BCC models were both ran to make sure there were no discrepancies between the results obtained from the DEA Frontier and the ones previously obtained from the EMS software. The results of both models matched 100%.

Once the CCR model was ran, a "target" report showing the improvements needed is automatically generated by the software.

Since this study is concerned with the input orientation, the needed improvements mainly focus on a decrease in the inputs used by the mobile operators to maintain the same level of output, as shown in the below table.

DMU No.	DMU Name	Efficient Input Target		
		Number of Employees	TA	CAPEX
1	Cellcom Israel	6,989	2,234,386,129	136,042,441
2	Orange Israel	7,891	1,920,577,000	126,828,000
3	Orange Jordan	2,104	891,565,023	49,187,602
4	Mobily KSA	4,121	9,997,680,221	1,031,368,759
5	STC KSA	12,722	17,993,300,168	1,250,255,037
6	Viva Kuwait	397	376,023,108	85,881,599
7	Wataniya Kuwait	997	7,321,57,987	1,576,677,729
8	Nawras Oman	952	727,167,895	660,626,751
9	Omantel Oman	1,268	1,567,833,610	52,619,974
10	Jawwal Palestine	783	698,000,170	38,185,639
11	Wataniya Palestine	95	65,834,067	36,638,977
12	Vodafone Qatar	208	1,168,129,709	34,068,903
13	Avea Turkey	2,700	947,316,600	452,061,858
14	Turkcell Turkey	3,071	17,186,699,999	501,256,000
15	Etisalat UAE	11,150	14,520,553,527	481,426,400
16	du UAE	2,984	3,282,623,335	351,539,300

Table 24: Target report generated by the DEA Frontier

The values present in table 24 are the target amount of inputs which the mobile operators should be using to become fully efficient. The report showed that the target values for the 7 fully efficient operators are the same as their actual ones.

For the 9 inefficient mobile operators, the target values were compared with the actual ones to show the improvements they need to undergo to maximize their efficiency and reach the efficiency frontier.

The below table designates the needed percentage decrease in each of the inefficient DMUs input factors.

	Employees	**Total Asset**	**CAPEX**
Cellcom Israel	-3.6%	-3.6%	-3.6%
Orange Jordan	-4.5%	-4.5%	-4.5%
Nawras Oman	-6.6%	-6.6%	-6.6%
Omantel Oman	-53.9%	-7.6%	-7.6%
Jawwal Palestine	-13.9%	-13.9%	-13.9%
Viva Kuwait	-15.8%	-15.8%	-15.8%
STC Saudi Arabia	-39.4%	-39.4%	-39.4%
Vodafone Qatar	-48.5%	-49.5%	-61.7%
Wataniya Palestine	-76.8%	-76.8%	-76.8%

Table 25: Improvements needed for the inefficient mobile operators

The 9 inefficient mobile operators need to decrease their input levels by the above percentages and to maintain the same 2011 level of output to become fully efficient.

The DEA has proved to be an appropriate tool not only for measuring and comparing the relative efficiencies of mobile operators in the Middle East, but also for offering a suggestion on the improvements which the relatively inefficient mobile operators have to abide with to able to compete with their regional counterparts.

6.3 Limitations

The DEA is an established powerful non-parametric technique and has been widely used and applied in the measurement of efficiency in the telecommunications sector. This study has provided strong support for the use of DEA in measuring the relative efficiency of mobile operators in the Middle East.

However, there were limitations for using the DEA in this study. These limitations fall under two categories:

1. DEA technique and its drawback
2. Collection of mobile operator's data in the Middle East

DEA assumes all DMUs under study are homogenous, but this in fact may not always be true. One feature in the DEA is the assignment of weights to the factors of production. As the weights assigned change, the results of the computation change. For this reason, it was decided in this study to allow the weighting to be done by the technique itself. To set weights for all the factors of production requires a deeper and more thorough analysis for each mobile operator. Because of the mobile operators' non-transparency on their internal management strategies and input capacities, it was not possible to have the weights allocated prior to running the DEA models.

The most significant limitation of DEA, however, remains in its inability to measure the absolute efficiency of a DMU. It only provides a measure of relative efficiency and demonstrates how well a DMU is operating compared to its peers but not compared to a theoretical maximum. For example, the case of one mobile operator, if the data is unavailable for a number of other mobile operators with comparable characteristics, the concept of DEA and comparison of efficiencies becomes invalid.

Another limitation of this study is in the data collection. The data used in this study is only for 16 mobile operators in the Middle East and for the year 2011 only. The number of employees figure for past years was not available. And the data for all the mobile operators in the region was not obtainable since not all operators publicly share their operational and financial data.

6.4 Recommendations

This study provided a framework for measuring and comparing the relative efficiencies of mobile operators in the Middle East. Mobile operators are confronting a lot of challenges, and operating as efficiently as possible is becoming very crucial.

The mobile market is facing increased competition. Competition is coming from mobile operators among themselves and from external parties such as voice over IP (VoIP) providers and internet service providers (ISP). VoIP providers are hindering the mobile operators' revenues from international voice calls, whereas the ISPs are threatening the mobile operators' broadband revenue. This is why operators are going to compete for data packages and international traffic. Prices are falling, and mobile operators in highly penetrated markets will start to re-price service packages to win customers regardless if it is profitable or not.

In response to competition, mobile operators are in the process of rolling out Long Term Evolution (LTE) hoping to get a premium price form the upgrade of customers from 3G to LTE. However, LTE will not bring the anticipated revenue. Amidst the fierce competition, mobile operators will be forced to reduce their LTE prices as well.

Operators will try to limit their losses by earning revenue from new value added services (VAS). VAS might help in compensating part of the revenue but it will be unlikely for it to replace all the lost revenue. The greatest value that mobile operators will gain from VAS will be more of a marketing image rather than financial gain.

There does not seem to be a new technology which will be able to create new revenue for mobile operators. For this reason, investors in the telco industry should be careful. They have previously enjoyed high returns, but the share prices will start to decrease. Mobile operators have invested a lot of money to obtain licenses and are now forced to offer low prices for their services. To be able to compensate for the high licenses prices paid; mobile operators will have two solutions: either massive cost cutting or consolidation. The consolidation the mobile market will witness will be of two types: light consolidation where two or more operators build an infrastructure together, or the classic consolidation where two or more operators will be merged into one.

Taking the above challenges into account, mobile operators, globally and in the Middle East, do not have a choice but to be operating in the most efficient manner to be able to generate the highest revenue possible from the industry. Since, as shown in this study, the mobile operators' financial ratios do not reflect efficiency, the operators' managements and regulators should apply a model, similar to the proposed DEA model in this study, for efficiency measurement.

Regulatory bodies, such as telecom regulatory authorities (TRAs), in the Middle East have the capability of obtaining data on all the mobile operators within their country of operation. Each TRA should apply the DEA on the country level to measure the efficiency of the local operators and then compare it with their regional and global counterparts to suggest further areas of improvements for increasing efficiency.

References

A Charnes, W. W. (1978). Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research*, *2*, 429-444.

Chun-Hsiung Liao, D. B. (2009). Comparing Operational Efficiency among Mobile Operators in Brazil, Russia, India and China. *China & World Economy*, *17*, 104-120.

Chun-Hsiung Liao, H.-Y. L. (2011). Measuring operational efficiency of mobile operators in Japan and Korea. *Japan and the World Economy*, *23*, 48-57.

Farell, M. J. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*, *120*, 253-290.

Farrell, M. J. (1957). The Measurement of Prodcutive Efficiency. *Journal of the Royal Statistical Society*, *120*, 253-290.

Giles, M. (2013). *Global and regional mobile revenue trends.* Atlanta: Wireless Intelligence.

Giokas D.I., P. G. (2002). Comparing the operational efficiency of the main European telecommunications organizations: A quantitative analysis. *Telecommunications Policy*, *26*, 595-606.

Giokas D.I., P. G. (2000). Evaluation productivity efficiency in telecommunications: Evidence from Greece. *Telecommunications Policy*, *24*, 781-794.

Gruber, H., & Koutroumpis, P. (2010, October). Mobile telecommunications and the impact on economic development. *Panel draft for the 52nd Economic Policy Panel*.

Hsiang-Chih Tsai, C.-M. C.-H. (2006). The comparative productivity efficiency for global telecoms. *International Journal of Production Economics*, 509-526.

ITU. (1984). *The Missing Link.* Geneva: Independent Commission for Worldwide Telecommunications Development.

ITU, I. T. (1999). *World Telecommunication Development Report.* Geneva: ITU.

Jin-Li Hu, W.-K. C. (2008). Efficiency and Productivity of Major Asia-Pacific Telecom Firms. *Chang Gung Journal of Humanities and Social Sciences* , 223-245.

Leff, N. (1984). The output contributions of computer equipment and personnel: a firm level analysis for economic development: an example from telecommunication. *Economic Development and Cultural Change , 2*, 255-276.

Per Andersen, N. C. (1993). A Procedure for Ranking Efficient Units in Data Envelopment Analysis. *Management Science , 39*, 1261-1264.

Rajiv D. Banker, Z. C. (2010). Technological progress and productivity growth in the U.S. mobile telecommunications industry. *Annals of Operations Research , 173*, 77-87.

Seyoshi, T. (1998). Privatization of Nippon Telegraph and Telephone: was it a good decision. *European Journal of Operational Research , 107*, 45-61.

Uri, N. (2001). Measuring the impact of price caps on productive efficiency in telecommunications in the United States. *The Engineering Economist , 46*, 81-115.

Vineeta Nigam, T. T. (2012). Benchmarking of Indian mobile telecom operators using DEA with sensitivity analysis. *Benchmarking: An International Journal , 19*, 219-238.

William W Cooper, L. M. (2011). *Handbook on Data Envelopment Analysis.* London: Springer.

William W. Cooper, L. M. (2011). *Handbook on Data Envelopment Analysis.* London: Springer.

Young-Yong Lee, Y.-T. P.-S. (2000). The impact of competition on the efficiency of public enterprise: The case of Korea Telecom. *Asia Pacific Journal of Management , 17*, 432-442.