OLED Mobile Phones Market Research and Analysis Report

Contents

Executive Summary

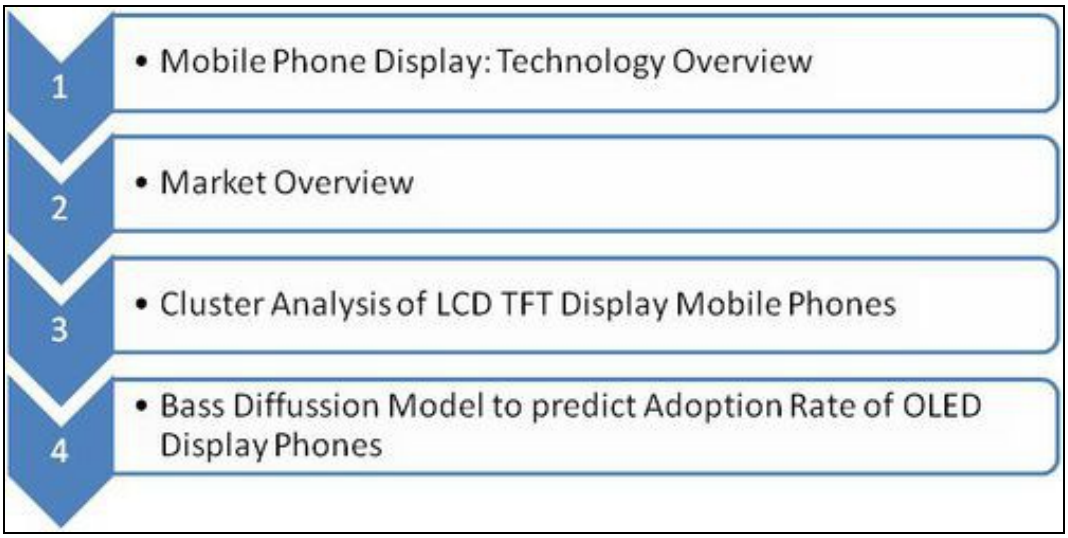
- The **OLED** (Organic Light-Emitting Diode) technology is rapidly evolving, and these improvements are changing the dynamics display screens in mobile phones, TVs, camera, etc. The report provides a technological overview of OLEDs and includes comparisons with the rival technology of LCDs.
- This report analyses the **Market for OLED display mobile phones** in terms of products, applications, market size and structure, competitive environment and technology, and determines its future prospects.
- The statistical tools of **Cluster Analysis** and **Regression** are used to determine the segments of smart-phones likely to adopt OLED displays
- **Bass Diffusion Model** for adoption of new technologies is applied to forecast sales of OLED display based mobile phones. This forecast is arrived at by modeling the sales on the historical sales data of certain proxy products and is graphically presented in the report.
- The study reveals that by 2012 cumulative sale of OLED based mobile phone is expected to reach **183 million units** and details the trend of these sales over the years

Research Objective

- To provide a **Technology Overview** for OLED Mobile Phones
- To provide a **Market Overview** for OLED Mobile Phones
- To provide a **Market Estimate** for OLED Mobile Phones
- To forecast the **Adoption Rate** of OLED Mobile Phones

Research Methodology

A **four stage analysis** was conducted:



Technology Overview

A brief understanding of the Technology behind the OLED displays forms the introduction to this report.

Market Overview

A detailed overview of the OLED Technology forms the basis of the Analysis performed using Base Diffusion Model.

Cluster Analysis

Cluster Analysis was used to determine a class of mobile handsets that is most likely to use OLED displays. Cluster analysis is a technique used to assign objects to groups (called clusters), such that objects from the same cluster are *more similar* to each other than objects from different clusters. To determine the cluster, certain attributes of a handset like input mode, display size, camera resolution, etc. were considered.

Bass Diffusion Model

The Bass Diffusion Model was used to forecast the adoption of the OLED display mobile phones by consumers. The Bass Diffusion model is a quantitative tool that describes the process of how new products get adopted as an interaction between users and potential users. In this analysis, the model was employed to forecast the sales of a new product by utilizing historical sales data of analogous products from the same product category as well as from a diverse product category. The market penetration for mobiles with OLED displays is arrived at with result for both the proxies.

Mobile Phone Display: Technology Overview

OLED (Organic Light Emitting Diodes) is a flat display technology, made by placing a series of organic thin films between two conductors. On applying an electric current, a bright light is emitted. OLEDs use organic semiconductor material instead of inorganic semiconductor material used in conventional Light Emitting Diodes (LEDs). Through a process called electrophosphorescence, OLEDs emit light in the presence of an electric current. Like any other diode, OLEDs permit electric current to pass only in one direction. Unlike diodes made from inorganic semiconductors, OLEDs are very flexible because they are only **100 to 500 nanometers** thick - the human hair is 200 times thicker than it. As a result, OLED screens are very flexible and can be made in very large sheets. OLEDs use lesser energy than LEDs as well.

The easiest way to understand OLEDs is to compare them to LCDs. LCDs are made by placing a color filter over a white backlight source ? filtering out the colors that are not wanted for each pixel. If you want to display blue, you'll have to filter out green and red. OLEDs, on the other hand, are emissive, which means that you simply need to display the colors you need for each pixel, which is made from three color (RGB) OLED ?pixels.?

Mobile Phone Display Types

There are two types of display technologies which are used in mobile phones:

1. Liquid Crystal Display (LCD)
2. Organic Light-Emitting Diode (OLED)

Recent developments in LCD are Super LCD (S-LCD) and IPS (In-Plane Switching technology) Panel. IPS technology is used in Apple?s Retina display and LG?s NOVA display. OLED technology includes developments such as Super AMOLED, Super AMOLED Plus and ClearBlack.

Difference between LCD and OLED

The LCD uses light modulating properties of liquid crystals (LCs). The liquid crystals do not emit light directly. So, a light source is needed for proper viewing. The OLED uses organic compounds that illuminate when exposed to electric currents. Hence, a backlight is not required for OLEDs. This makes OLED displays thinner than LCD displays.

Difference between AMOLED and AMLCD

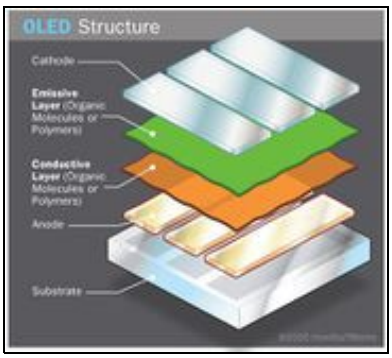
Properties	AM OLED	AM LCD
Thickness/Weight	Thinner, best is 0.05 mm; lighter	Thicker, best is 0.8 mm; heavier
Diagonal Size	Limited to small and medium sizes; largest demo is around 40"	Can be manufactured larger; largest demo is ~100"
Viewing Angle	Up to 180 degrees	Narrower, depends on liquid crystal type

Color Gamut	>100% NTSC (top emission), around 70% NTSC (bottom); high at all gray levels	Around 70%, up to 100% NTSC (LED backlight and new color filter); falls at low gray levels
Color Reproduction	Better; gamut independent of view angle	Good; gamut changes with viewing angle
Resolution	Lower; 308 dpi (SM), 202 dpi (polymer)	Higher; best is 498 dpi
Response Time	Faster, nanoseconds. No motion blur, good for 3D	Slower, milliseconds
Contrast Ratio	Higher	Lower
Sunlight Readability	Better than transmissive LCD, worse than transflective LCD	Ok if transflective
Operating Temperature	Range is larger, can operate at low temps like -40°C	Range is smaller, lowest temp is -10°C
Power Consumption	Lower at typical video content, when around 30% of pixels are on	Higher at typical video content
Lifetime	Shorter, 5K to 30K hour, but improving	Much longer, above 50K hour
Manufacturing Investment	Lower, but lack of standards keeps the investment only slightly lower	Higher
Production Cost	Expensive; low yield and complex structure, potential to be low cost	Cheaper than AMOLED
Source: DisplaySearch		

OLED Construction

An OLED can be made of a single layer of organic material but multiple layers increase efficiency and effectiveness. A typical OLED is comprised of five layers of material:

Layer	Description
Substrate layer	This layer supports the OLED and is made of clear plastic, glass, foil or other materials.
Anode layer	The anode layer is transparent and is positively charged. When an electric current is applied, this layer attracts electrons as they flow through the OLED. As with a LED, the anode forms "holes" onto which electrons fall.
Conducting layer	This layer is made of organic plastic material and transports the "holes" from the anode layer.
Emissive layer	This layer transports electrons from the cathode. It is also made of organic plastic molecules but there are different from those in the conducting layer. This is the layer that determines the color of the light emitted.
Cathode layer	This layer injects electrons into the OLED when an electric current is applied. Depending on the OLED and the color effect desired, this layer may or may not be transparent.



Source: How Stuff Works

Types of OLED Construction

OLEDs can be constructed in a variety of ways to serve a variety of functions. While each type of construction uses the layers described previously, the manner in which each layer is built alters the way the OLED functions. The six most common types of OLEDs are as follows:

Type	Description
Passive-Matrix OLED	Anode and cathode laid perpendicular to each other
	PM OLEDs are easy to make and display text and icons very effectively, particularly in small 2-inch to 3-inch screens

Active-Matrix OLED	AM OLEDs are constructed with continuous film materials
	AM OLEDs use less energy than PM OLEDs and have faster refresh rates
Transparent OLED	Constructed with transparent materials for all five layers, a transparent OLED can be made as either a PM OLED or an AM OLED
	Useful for heads-up display applications
Top-Emitting OLED	These types of OLEDs use an opaque or reflective substrate that is useful for smart card applications
	Best suited for an active-matrix design
Foldable OLED	The substrate of this type of OLED is very flexible, allowing the OLED to be folded or rolled up
	Because of their flexibility, foldable OLEDs could be attached to fabrics with a variety of applications
White OLED	These OLEDs emit white light that is brighter, more uniform and more energy efficient than that emitted by fluorescent lights
	Potential to replace incandescent and fluorescent lighting in commercial industrial, and residential applications

Advantages and Disadvantages

Advantages of OLED over LCD	As there is no backlighting, OLED displays offer deeper black levels than LCD displays
	OLED displays have better contrast ratios
	Viewing angles offered by OLEDs is more than that offered by LCDs
Disadvantages of OLED over LCD	Brightness levels of OLED display is less than that of LCD
	Color in OLED displays are often oversaturated
	The red, green and blue sub-pixels deteriorate and lose efficiency at different rates, thus color consistency worsens over time

OLED Screen Types in Mobile Phones

Type	Description
AMOLED	AMOLED relies on a TFT backplane to switch individual pixels on and off. Active-matrix displays consume significantly less power than passive-matrix counterparts. This makes them well-suited for mobile devices. AMOLED displays are manufactured by printing electroluminescent materials onto a substrate. The relatively simplistic process suggests that OLEDs will ultimately become cheaper and easier to manufacture than LCDs. The creation of the substrate is the most difficult and expensive part of the process. Currently, AMOLED screens are limited in supply. Coupled with high demand, their availability is restricted and they are found in high-end smartphones.
Super AMOLED	Super-AMOLED displays are AMOLED displays with an integrated touch function. The original AMOLED screens had reduced visibility in direct sunlight. The thickness of the touch sensor is less than 0.001mm in Super AMOLED displays. This allows the screen to provide better images and to have great visibility even in direct sunlight.
ClearBlack	Nokia introduced a display similar to Samsung?s Super AMOLED known as the ClearBlack display. The ClearBlack display makes the screen more visible in direct sunlight. A polarized filter is added to the display. This allows the viewer to see through the screen?s reflection and view the images as they would appear under more ideal conditions.
Super AMOLED Plus	The Super AMOLED Plus features a traditional three sub-pixels of equal proportion within one pixel. It has an increased sub-pixel count and density. As a result, the display is much crisper, especially when it comes to text. The tighter spacing between pixels also results in better visibility under direct sunlight. The displays are also thinner, brighter and more efficient (by 18%) than the old Super AMOLED displays.

Future OLED Mobile Screen Variations

Type	Description
Transparent Displays	Transparent OLEDs have only transparent components (substrate, cathode and anode) and, when turned off, are up to 85 percent as transparent as their substrate. When a transparent OLED display is turned on, it allows light to pass in both directions. A transparent OLED

	display can be either active- or passive-matrix. TDK began production of a see-through OLED earlier this year.
Flexible Displays	Flexible OLEDs have substrates made of very flexible metallic foils or plastics. Flexible OLEDs are very lightweight and durable. Their use in devices such as cell phones and PDAs can reduce breakage, a major cause for return or repair. Samsung is readying flexible AMOLED displays for production next year.

OLED Market Overview

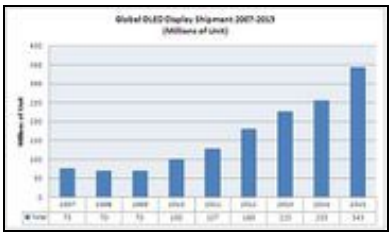
OLED Market: Revenue Overview

- The Global OLED Display Market was estimated at **$1,800 million** for the year 2010.
- The market stood at **$1,102 million** in the year 2009, and showed a growth of **63.3%** for 2010.
- The market is estimated to reach **$6,934 million** by the year 2014.

Global OLED Display Market: Revenue Forecasts 2004-2014 (in $million), Source: pira-international

OLED Market: Volume Overview

- The shipments of Organic Light-Emitting Diode (OLED) screens was estimated at **100 million** units in 2010
- The shipments of Organic Light-Emitting Diode (OLED) screens are set to rise to **326.8 million** units in 2015
- The market is going to be driven by booming demand for Active-Matrix (AM) displays for mobile handsets
- AM-OLED segment, which will boom to **261.5 million** units in 2015, up more than twelve fold from **21.1 million** in 2009



Global OLED Display Shipment 2007-2015 (Millions of Unit), Source: iSuppli

Market Potential by Geography

OLED Market Potential by Geography

The following chart illustrates the OLED Market Potential by Geography over the period 2004-2014:

This is supposed to be a flash animation. You'll need the flash plugin and a browser that supports it to view it.

Source: ICON Group International

AMOLED Market Potential by Geography

The following chart illustrates the AMOLED Market Potential by Geography over the period 2004-2014:

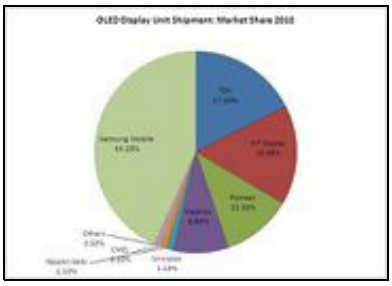
This is supposed to be a flash animation. You'll need the flash plugin and a browser that supports it to view it.

Source: ICON Group International

OLED Market Share

- **Samsung Mobile** leads the OLED Display Market with a market share of 43.2% as reported in 2010
- **TDK** is a distant 2nd with a market share of 17.5% and is closely followed by **RiT Display** with a share of 16.0%

The following chart illustrates the Global OLED Display Unit Shipment: Market Share, for the year 2010:

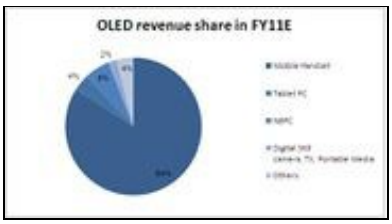


Global OLED Display Unit Shipment: Market Share 2010 , Source: Quarterly OLED Shipment and Forecast Report, DisplaySearch

OLED Market Share by Application

- **Mobile Handset application** forecast to account for 84%, followed by NBPC at 6% and tablet PC at 4% of 2011E total revenue.

The following chart illustrates the Global OLED Display total revenue: Market Share, for the year 2011E:



OLED Display Revenue: Market Share 20111E , Source: 7economy

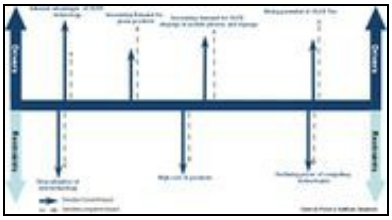
OLED Eco-System

The following dashboard illustrates all the Companies in the OLED Eco-System:

This is supposed to be a flash animation. You'll need the flash plugin and a browser that supports it to view it.
Source: OLED-info.com

OLED Market Drivers & Restraints

The following figure illustrates a **Forcefield Analysis of Market Drivers and Restraint**s for OLED Market (2011-2017):



Forcefield Analysis of Market Drivers and Restraints for OLED Market (2011-2017) , Source: Frost & Sullivan

OLED Market Drivers

The following table illustrates the **Impact Analysis of OLED Market Drivers** over a period of time:

Rank	Driver	1-2 years	3-4 Years	5-7 years
1	Inherent Advantages of OLED Technology	Medium	High	Very High
2	Increasing Demand for Green Products	Medium	High	High
3	Increasing demand for OLED Display in Mobile Phones and Signage	Medium	Medium	High
4	Rising Potential of OLED TV?s	Low	Medium	Medium

Inherent Advantages of OLED Technology

- OLED display offer sharper images and better contrast ratios, crisp colors and faster refresh rates compared to any existing display technology.
- OLED Technology also offers consumers better energy management as the whole system functions at optimal power and is of organic substrate.

- OLED displays are created by inserting thin organic films between two conductors and require no backlight; therefore, the displays are more compact and thinner.
- OLED displays, especially or television, are capable of offering viewers a viewing angle of 180 degrees
- As the benefits of OLED displays become more prominent, the demand for OLED manufacturing equipment is expected to increase in the next three to seven years.

Increasing Demand for Green Products

- The demand for lower power consumption , reduced material usage, and simplicity is expected to propel the OLED demand in the coming years
- The OLED manufacturing equipment market, however, is facing challenges due to its premium and manufacturing challenges. As Manufacturers realize the economies of scale, average selling price is expected to decline, further spurring demand.
- OLED TV market continues to evolve technologically and benefit from increasing demands for energy efficiency from consumers.

Increasing demand for OLED Displays in Mobile Phones and Signage

- Technology innovations, better functionalities and falling prices are expected to keep up the demand for OLED displays in mobile phones
- Mobile Phones accounted for over 82.0% of the Total OLED display market. With the success of mobile phones, such as the Galaxy, the demand for OLED displays for mobile applications is expected to increase
- The market is also expected to benefit from increasing demand for OLED displays used for signage
- These factors are expected to propel the sales of OLED during the medium and later part of the forecast period.

Rising Potential of OLED TVs

- The OLED market is yet to observe strong demand for TVs. High premium price and smaller display sizes are key restraints for customers. However, with increasing collaboration within the entire supply chain of the OLED market, the market is expected to experience gradual increase in attractive solutions. According to DisplaySearch, the OLED TV market is expected to generate revenue of $28 billion by 2017.
- The increasing momentum is expected to help commercialize the technology in the next five to seven years. Many display manufacturers have already set up dedicated manufacturing lines from Gen 3.5 to Gen 5.5.
- This is expected to propel OLED manufacturing equipment sales during the latter part of the forecasted period.

Source: Frost & Sullivan

OLED Market Restraints

The following table illustrates the **Impact Analysis of OLED Market Restraints** over a period of time:

Rank	Restraint	1-2 years	3-4 Years	5-7 years
1	Slow Adoption Rate of New Technology	High	High	High
2	Declining Prices of competing technologies	High	High	High
3	High cost of products	High	High	Medium

Slow Adoption Rate of New Technology

- The adoption rate of OLED Technology is comparatively slower than the initial launch of LCD technology. Consumers are complacent with the current technologies it offers then a myriad o advantages and benefits.
- The largest issues foreseen are consumer perception, cost effectiveness of the product, ease of implementation and the ability of the service to provide true blended services
- As a result, there is a significant and vital gap between new product design to volume manufacturing in the OLED market
- Increasing costs and manufacturing complexity has hindered the adoption rate of OLED manufacturing equipment, especially for larger substrate sizes
- The growth of the OLED display market and, in turn equipment sales, will rely on increasing collaboration between material suppliers, technology enablers and equipment providers. Decreased time to market and focus on R&D will be the key to attaining the desired growth trajectory.

High Cost of Products

- The high cost of OLED display has hindered adoption rates. For Example, customers, while willing to pay a premium price for quality products, hedge until the product has reached mass adoption level. A manufacturing facility typically requires an investment of $ 1 Billion to 3 Billion.
- This has restrained the demand for OLED equipment. Equipment providers are still caught in a dilemma of balancing the high cost of technology development with affordable pricing for consumers.
- Careful adjustment of prices can help minimize the impact of this restraint. Pricing strategy is crucial for success for the overall OLED market.

Declining Prices of Competing Technologies

- The LCD market is continuing to witness strong demand despite the emergence of new products in the market.
- LCD Technology is transitioning t meet increasing demands for higher switching speeds, becoming more environmentally friendly by using LED backlighting, becoming sleeker and more compact, and having better resolution.
- The LCD and other existing technologies also offer consumers the ability to buy large screen displays. This had created major barriers for increasing the adoption rate for OLED manufacturing equipment.

Source: Frost & Sullivan

Investment Landscape

The Investment Landscape in the OLED Market is illustrated in the following links:

1. Mergers & Acquisitions Landscape
2. Partnerships Landscape
3. Private Equity & Venture Capital Landscape

Cluster Analysis for TFT Display Mobile Phones

The table here summarizes the objective, methodology, procedure and result of the cluster analysis

Purpose of Study	▪ To identify the appropriate cluster for the launching of the AMOLED mobile phones under smartphone category ▪ To understand the present positioning of the leading smartphone manufacturing companies
Clustering Method (K-Means Clustering)	▪ Researcher specify the number of clusters in advance, then the algorithm calculates how to assign cases to the K clusters ▪ K-means cluster analysis uses Euclidean distance ▪ The algorithm seeks to minimize within-cluster variance and maximize variability between clusters
Samples used for clustering	▪ Samples consist of leading players in the smartphone mobile category (with reference to Gartner reports) ▪ The sample consists of smart phones announced in last three years, primarily available in the North America ▪ Samples divided in two parts - **Candybar Design** and **Clamshell/Slider Design** - with thickness being the differentiating parameter ▪ Candybar Design – 5 Clusters ▪ Clamshell/Slider Design – 4 Clusters
Parameters considered for defining clusters	▪ Camera (megapixels) ▪ Input (normal keypad, keyboard and touch-screen) ▪ Display Size ▪ WLAN ▪ Color ▪ Resolution ▪ Thickness ▪ Price
KEY FACTORS IDENTIFIED	▪ Input ▪ Display Size ▪ Price **Rationale** - Input and Display Size are related to the viewing aspect and these high end mobile phones being high priced, the consumer is expected **NOT** to be price-sensitive

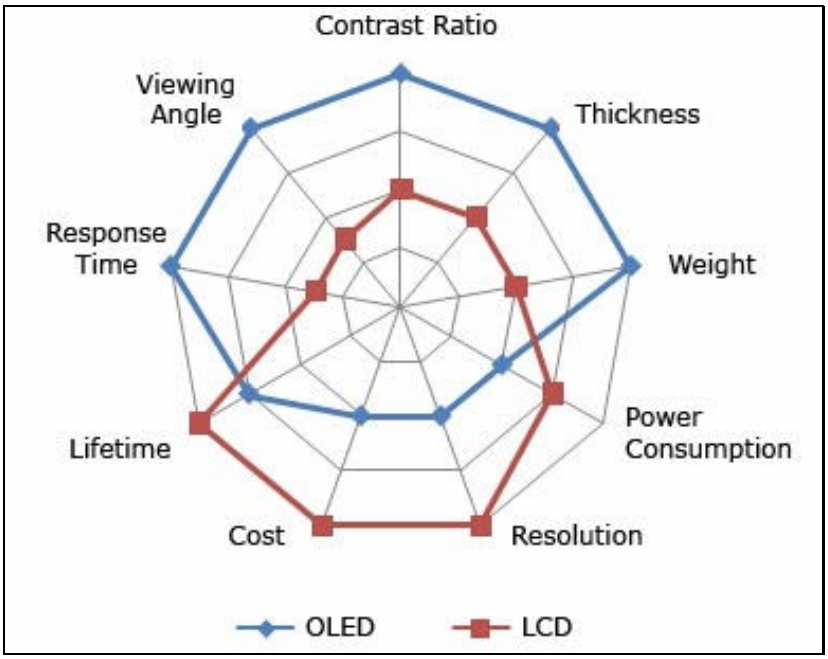
Source: Statnotes, North Carolina State University

Selection of model

Using the analysis, one cluster of smart-phones likely to move to OLED technology was identified for each of the two categories. For the next stage of the research - that of forecasting sales - would need the historical sales data of one particular model. For this purpose, **Apple iPhone** from the 2nd cluster of candy-bar phones was selected because of constraint of availability of sales data for other models like Blackberry, Nokia N96, HTC Dreamers etc.

A Comparison of LCD and OLED technologies

The *radar graph* here shows the comparison between OLED and TFT LCD.



ComparisonSource

The graph depicts the following things:

1. OLEDs are *thinner* than LCDs.
2. OLEDs are *lighter* in weight.
3. OLEDs consume *more power* than LCDs but OLEDs have an inherent advantage in that they only consume power when they emit light while an LCD backlight consumes constant power regardless of the image being displayed.
4. OLEDs *cost more*: The Cost of an AM-LCD is currently about half that of a comparable AM-OLED display. This is due to the maturity of LCD manufacturing processes and facilities. OLED manufacturing facilities suffer from low yields, currently at 60%-70%.
5. OLEDs have a *shorter lifespan* as compared to LCDs.
6. OLEDs have a *faster response time* of .01ms while LCDs have a response time about 8-12ms.
7. OLEDs have a *superior viewing angle* of 180 degree while LCDs have a lower viewing angle.

Cluster Analysis

Methodology

Sample Definition: The sample space consists of moblie phones by leading players in the smart-phone mobile category. These models were identified from Gartner reports. The models of smart-phones launched in the last three years in North America were considered.

Sample Space: After defining the sample, the various key attributes of smart-phones like camera, display, etc. were defined. The data for these attributes for all the models was collected from the company websites as well as the following websites:

- www.phonearena.com
- www.phonegg.com
- www.mobile.am

The pricing information was obtained from

- www.fonearena.com
- www.india-cellular.com
- www.naaptaol.com
- www.mobilestore.com
- www.indiatimes.com.

After aggregating the data we used the **k-clustering** method to identify the different clusters for the samples. This technique aims to partition *n* observations into *k* clusters in which each observation belongs to the cluster with the nearest mean. Hence clusters of phones with similar attributes is achieved.

Samples were segregated into two broad categories - candy-bar phones and clamshell or sliding phones - with thickness being the differentiating parameter. This was done in order to mitigate any error due to the design of the phone(i.e. candybar,clamshell,slider), since the thicknes of the mobile could be a cause for erroneous results.

Cluster analysis results

The sheet below shows the clusters formed for the candy-bar phones.

				CLUSTER 1					
Model No.	Camera	Input	Display Size	WLAN	Color	Resolution	Thickness	Price	Cluste
Apple iPhone 3G(8GB)	2	2	3.5	1	16	320x480	12.3	31000	1
i910	5	2	3.2	1	256	240x400	12.5	37249	1
				CLUSTER 2					
Model No.	Camera	Input	Display Size	WLAN	Color	Resolution	Thickness	Price	Cluste
HTC P3470	2	2	2.8	0	65	240x320	15.7	18500	2
HTC Touch Cruise	3	2	2.8	1	65	240x320	15.5	24800	2
HTC Touch Diamond	3.2	2	2.8	1	65	480x640	11.5	26500	2
HTC Touch Viva	2	2	2.8	1	65	240x320	15.8	18490	2
HTC X7510	3	2	5	1	65	480x640	16	24999	2
i780	2	2	2.6	1	256	320x320	13.3	20449	2
				CLUSTER 3					
Model No.	Camera	Input	Display Size	WLAN	Color	Resolution	Thickness	Price	Cluste
5320 Express Music	2	0	2	0	16	240x320	15	10200	3
5800 Express music	3.2	2	3.2	1	16	360x640	15.5	21000	3
6124 Classic	2	0	2	0	16	240x320	15	9000	3
6220 Classic	5	0	2.2	0	16	240x320	15	17600	3
E63	2	1	2.36	1	16	240x320	13	12000	3
i200	2	0	2.3	0	65	240x320	11.8	11499	3
i450	2	0	2.3	0	256	240x320	11.8	14000	3
N 6120	2	0	2	0	16	240x320	15	16600	3
N78	3.2	0	2.4	1	16	240x320	15.1	14900	3
N79	5	0	2.4	1	16	240x320	15	21000	3
Pearl 8100	1.3	0	2	0	65	240x260	14.5	21999	3
				CLUSTER 4					
Model No.	Camera	Input	Display Size	WLAN	Color	Resolution	Thickness	Price	Cluste
E71	3.2	1	2.36	1	16	240x320	10	19800	4
i550w	3.2	0	2.6	0	256	240x320	13.8	14990	4
N 5700	2	0	2.2	0	16	240x320	17	11025	4
N73	3.2	0	2.4	0	65	240x320	19	11000	4
N82	5	0	2.4	1	16	240x320	17.3	19200	4
BlackBerry 7130c / 7130g	0	0	2.6	0	65	240x260	18	14990	4
				CLUSTER 5					
Model No.	Camera	Input	Display Size	WLAN	Color	Resolution	Thickness	Price	Cluste
Curve 8310	2	1	2.65	0	65	240x320	15.5	24990	5
BlackBerry 8820	0	1	2.6	1	65	240x320	14	31990	5
Curve 8300	2	1	2.65	0	65	240x320	15.5	23999	5
BlackBerry 8800	2	1	2.6	0	65	240x320	14	29990	5
BlackBerry Bold 9000	2	1	2.85	1	65	480x320	15	34900	5
BlackBerry Curve 8330	2	1	2.65	0	65	240x320	15	24990	5

Candy bar
The sheet below shows the cluster formed for the clamshell/sliding phones.

Cluster 1										
S.No.	Model No	Camera	Input	Display Si	WLAN	Color	Resolutio	Thickness	Price	Clusters
1	N 6650	5	0	2.2	0	1	1	25	20000	1
2	N95 8GB	5	0	2.8	1	1	1	21	24500	1
3	E66	3.2	0	2.4	1	1	1	13.6	20000	1
4	6210 Navi	3.2	0	2.4	0	1	1	14.9	16000	1
5	N85	5	0	2.6	1	1	1	16	22500	1
				Cluster 2						
S.No.	Model No	Camera	Input	Display Si	WLAN	Color	Resolutio	Thickness	Price	Clusters
1	N96	5	0	2.8	1	1	1	18	34999	2
2	N97	5	3	3.5	1	1	2	15.9	33500	2
				Cluster 3						
S.No.	Model No	Camera	Input	Display Si	WLAN	Color	Resolutio	Thickness	Price	Clusters
1	HTC Drear	3.2	3	3.17	1	3	7	17	20000	3
				Cluster 4						
S.No.	Model No	Camera	Input	Display Si	WLAN	Color	Resolutio	Thickness	Price	Clusters
1	N76	2	0	2.4	1	1	1	13.7	14100	4
2	N 6290	2	0	2.2	0	1	1	20.8	13875	4
3	N75	2	0	2.4	0	1	1	20	17538	4
4	HTC Shadc	2	1	2.6	1	3	1	15	7500	4
6	E65	2	0	2.2	1	1	1	15.5	12500	4
7	i620	2	1	2.2	1	3	1	11.8	16250	4
8	N 6110	2	1	2.2	0	1	1	20	13200	4

Clamshell_slider

Definition of Attributes:

- **Camera** : resolution in Megapixels
- **Input method**: two types of input methods - touchscreen and keyboard
- **Display size**: diagonal length of the displeay screen
- **Resolution**: display resolutions
- **Color**: display color
- **Thickness**: total thickness of the phone

The cluster analysis results and subsequent profiling of those clusters are summarized below:

Candy - Bar Phones

Clusters	Cell phones	Profile
1	Apple iPhone, Samsung i910	* Cluster 1 consists of high end cell phones * Cell phones falling in this cluster are touch screen phones with large display size * This is mainly targeting the premium market which is not price sensitive as the mobile phones in this cluster are priced high
2	HTC P3470, HTC touch cruise, HTC touch diamond, HTC touch viva, HTC X7510, i780	* This cluster includes cell phones with moderate display size and having touch screen facility * Cell phones in this cluster are in the price range of medium to high, so it is targeting the upper middle to high class. * Almost all the mobile phones falling in this cluster are having WLAN facility indicating that this cluster target trendy class people and people who prefer online games and downloads on mobile phones
3	Nokia 5320 express music, Nokia 5800 express music, Nokia 6124 classic, Nokia 6220 classic, Nokia E63, i200, i450, N6120, N78, N79, Pearl 8100	* Mobile phones in this cluster are targeted at the middle class as these phones are of moderate price and normal input * They have small display size and moderate camera resolution, which is in sync with their target market * Average thickness
4	E71, i550W, N5700, N73, N82, Blackberry 7130c/7130g	* This cluster consists of mobile phones having high camera resolution and normal input indicating that this cluster is for people who give high preference to clicking photographs on mobile phones

		* They have small display size with most of them not having the WLAN facility, so this is for people who low on using the browsing facilities * The target segment for this cluster is the middle class segment as the mobile phones are also moderately priced
5	Curve 8310, Blackberry 8820, Curve 8300, Blackberry 8800, Blackberry bold 9000, Blackberry curve 8330	* It includes mobile phones having input through qwerty and with average display size * Target market is Business class people who prefer using email facility on mobiles * The mobile phones are low on camera resolution * All the mobiles in this cluster are high priced indicating that the targeted segment for this cluster is not price sensitive

Clamshell Phones

Clusters	Cell phones	Profile
1	N6650, N95 8GB, E66, 6210 navi, N85	* This cluster consists of medium to high priced mobile phones and is targeted at upper middle class * These mobile phones have high camera resolution and normal keypad input * All the mobiles in this cluster have average display size having 16M colors
2	N96, N97	* It includes mobile phones which are high priced and targeted at affluent people who are not price sensitive * The mobile phones in this cluster are characterized by high camera resolution, big display size and moderate thickness * WLAN facility and high graphic resolution in these mobile phones will attract people who prefer downloading and playing online games
3	HTC dream	* Mobile phones in this cluster are moderately priced and, targeted at the middle class and the upper middle class segment * These phones have high thickness and high camera resolution * These phones are WLAN enabled and have both qwerty keypad and touch screen input
4	N76, N6290, N75, HTC shadow, E65, i620, N6110	* This cluster consists of mobile phones with low camera resolution and mainly has normal keypad for input * These phones have medium display size and medium to high thickness * These are low to moderately priced phones targeted at the middle class segment

Prices for AMOLED screens

Market data was collected for the prices of OLED screens by various manufacturers

Company Name	Model Number	Size	Resolution	Colors	Price/unit(in USD)		
					0-99	100-999	1000 ++
Chung Yuan Technology Co., Ltd		2.2"	220x176		20.00	16.5	
Digiprotek Markcom India P Ltd.(Densitron)	C0201QILK-C	2	176xRGBx220	262K	25.69	24.92	20.67
	C0240QGLA-T	2.4	240xRGBx320	262K	35.97	34.9	27.83
	P0340WQLC-T	3.45	480xRGBx272	16M	85.65	83.1	47.72
	P0430WQLC-T	4.3	480xRGBx272	16M	119.90	116.32	85.84
GLYN GmbH & Co. KG(CMEL)	C0201QILKC	2	176x220	262K	25.00		15
	C0240QGLAT	2.4	240xRGBx320	262K	30.00		20
	C0283QGLDT	2.83	240xRGBx320	262K	38		26
	P0340WQLCT	3.4	480xRGBx272	16M	60.00		35
	P0430WQLCT	4.3	480xRGBx272	16M	90		63
A4G Technologies(OSD)	OSD020AMQCIF	2	176x220	262K	22.50	20.98	19.10
	OSD024AMQV	2.4	240x320	262K	30.20	28.57	25.40
	OSD0283AMQV	2.83	240x320	262K	38.30	36.16	33.63
	OSD0340WQLC	3.4	480x272	16M	69.50	67.25	42.48

	OSD0430WQLC-T	4.3	480x272	16M	109.00	87.00	72.00
Blaze Technology	BDO-0240QGLA-T	2.4	240xRGBx320	262K			20.8
	BDO-0283QGLD-T	2.83	240xRGBx320	262K			26.85
	BDO-0340WQLA-T	3.4	480x272	16M			39.5
	BDO-0430WQLA-T	4.3	480x272	16M			90.6

Bass Diffusion Analysis

One of the most important functions during the launch of a new product is to forecast the demand for that product, as it guides many other critical decisions faced by the company. Companies can schedule their production activities once they have an idea about the demand in the coming months or years. At a high level, Bass Diffusion Model is used to determine the shape of the curve representing the cumulative adoption of the new product. Bass describes the individuals who decide to adopt an innovation independently of the actions of others as *innovators*. Those who respond to the influences of the social system and obtain information about a new product from those who have already adopted the product are termed as *imitators*.

Proxies for analysis

The use of the model has been made by using the historical sales data of *proxy* products to forecast sales for OLED display mobile phones with an assumption that OLED display mobile phones would mimic the diffusion patterns of the proxies. Hence it was important to select the proxies carefully. We used the following for this forecast:

- iPhone - since this was the latest revolution in mobile phone devices and consumers would show a similar adoption behavior for a new mobile phone technology even though it comes at a price premium
- LCD/Plasma TVs & Monitors - consumers spent more money to purchase screens with superior quality by significantly increasing their budget
    - ♦ LCD and Plasma TVs and LCD monitors were treated as a single analogous product(by ascribing different weights to these) for the forecast

Forecasting OLED display phone sales using Analogous Products

The following products from different product categories were considered:

1. LCD TV
2. Plasma Display TV
3. LCD Monitor

They were considered to be befitting analogies because of the following similarities:

Similarities	LCD TV, Plasma Display TV, LCD Monitor
Display Sensitivity	Customers going for LCD TV, Plasma Display TV or LCD/TFT-LCD Monitor are display sensitive, they prefer better visuals, so it is used as an analogous product as OLED provides better display features.
Price Sensitivity	Customers adopting LCD TV, Plasma Display TV or LCD/TFT-LCD Monitor are likely to pay price premiums for better display, so it is used an analogous product as OLED offers better resolution at marginally high price.

Weighted average for the analogous products: Weights for modeling co-efficients for the analogous products such as LCD TV, Plasma Display TV and LCD monitor had been assigned.
To judge the similarity of analogous products to OLED, we examined two criteria.

a. Market Structure
b. Product Characteristics

Criterion	Description
Market Structure	Market Structure is similar because LCD TV, Plasma Display TV and LCD Monitor are innovations in high end technology display field, provides better viewing experience to customer and are costly.
Product Characteristics	Product characteristics are similar as these products also provides better clarity in display with high resolution, better contrast ratio, wide viewing angle and with less response time.

The **S-Graph** for the cumulative projected sale of OLED display mobiles modeled on analogous products

This is supposed to be a flash animation. You'll need the flash plugin and a browser that supports it to view it.

◊ In 2009 and 2010 OLED Mobile Phone market would grow slowly driven by *innovators*
◊ From 2011 to 2015, market will grow rapidly due to the *early adopters*
◊ In 2016 and 2017, market will growth will dwindle as *late adopters* take to the phones
◊ 2018 onwards growth will peter, as the laggards pick up the last few models and the market will saturate
◊ From 2016 the technology will near obsolescence and a new technology would replace it

Comparison of Adoption rate of Innovators with those of Imitators
The model helps to determine sales to innovators and imitators for each year:

This is supposed to be a flash animation. You'll need the flash plugin and a browser that supports it to view it.

This graph shows that a small number of innovators will kick-start the sales. OLED display mobile Phones will get off to a slow start in first 2 years. Once a ***critical mass*** is reached by the end of the second year, strong imitative effects will take over as the innovators decrease.

Detailed Analysis

The detailed modeling with a description of parameters and mathematical equations can be viewed here:
Bass Diffusion Analysis for OLED display phones

OLED Mobile Phone Projections Based on I-Phone

The **S-Graph** for the cumulative projected sale of OLED display mobiles modeled on analogous products

This is supposed to be a flash animation. You'll need the flash plugin and a browser that supports it to view it.

◊ From Q1,'09 to Q3,'09, the OLED display mobile phone market would grow slowly, driven by *innovators*
◊ From Q4,'09 to Q4,'10 market will grow rapidly due to the *early adopters*
◊ From Q1,'11 and Q3,'11 market growth will dwindle as *late adopters* take to the phones
◊ Q4,'11 onwards growth will peter, as the laggards pick up the last few models and the market will saturate
◊ From Q4, the technology will near obsolescence and a new technology would substitute it

Comparison of Adoption rate of Innovators with those of Imitators
The model helps to determine sales to innovators and imitators for each year:

This is supposed to be a flash animation. You'll need the flash plugin and a browser that supports it to view it.

This graph shows that a small number of innovators will kick-start the sales. OLED display mobile Phones will get off to a slow start in first three quarters. Once a ***critical mass*** is reached by the end of the Q3, strong imitative effects will take over as the innovators decrease.

Detailed Analysis

The detailed modeling with a description of parameters and mathematical equations can be viewed here:
Bass Diffusion Analysis for OLED display phones

Comparing projections

Since disparate product categories had been used for the two forecasts, the two were compared to cross validate the results *<<excel sheet with calculations>>*

This is supposed to be a flash animation. You'll need the flash plugin and a browser that supports it to view it.

◊ Looking at the forecast for OLED display mobile phones based on analogous products and on iPhone, both are seen to be *convergent*
◊ This validates the forecast

Sneak Preview of some models using OLED technology

Source: appleiphoneapps.com

1. Apple iPhone - It?s nothing official at the moment, but word on the street is that Apple might have chosen a series of OLED displays for its next round of handsets. Such a move would certainly be in the best interests of battery life, as the iPhone isn?t noted for its battery capabilities. Considering the amount of new features that were announced in the iPhone 3.0 firmware update, it would be fairly practical to have a capacitive OLED display in the future.

 Source: Mobile Phone Reviews	**2. Nokia** - **Nokia 6600** Slide Mobile Phone is a 3G device with large OLED display and 3.2 megapixel camera. It has curved edges and with a weight of 110g is a bit heavy to hold. The 2.2? screen supports 16 million colors and comes with QVGA resolution. The dimensions of the phone are 90 x 45 x 14mm.
 Source: ATT Phones	**3. Samsung** - **Samsung A877** features include a 3.2-inch WQVGA AMOLED touchscreen, a 3 megapixel camera, GPS, HSDPA and Bluetooth. And as well at it supports AT&T?s 3G service.
 Source: Itechnews	**4. Sony** - **Sony Ericsson Z555** features a 1.9-inch LCD display, an OLED 128×36 external display, a 1.3 Megapixel camera with 4x digital zoom.
 Source: Unwiredview	**5. LG** - One of the first handsets to get the new AM OLED, is already advanced **LG SH150** DMB TV phone.

Source: Itechnews

6. Motorola - The **MOTO U9** is a Quad-band phone with a 2-inch QVGA LCD display, a 1.45-inch secondary OLED display, integrated music player, Bluetooth, 25MB internal memory and a microSD card slot.

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