**The Abdus Salam**

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**THE NEW ERA FOR INTERNET OF THINGS**

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# Summary

After a long period of evolution, the Internet of Things became a service which is already perceived as to have significant expansion on Government, Industry, Enterprise and Home. The new possibility of exchange data with things that are physically around us (devices, buildings, objects) raised, in terms of world market, strong interest and expectation: Government and home sectors are assumed, according to present market analysis, to be the leading sectors by 2020; on the other side, Companies will have the best revenue opportunity as they create networks and infrastructures for IoT devices.

There is realistic believe that Internet of Things will provide an important impact on market preference and, consequently, on global economy. Because of this, it seemed worth of interest to analyze the economic feasibility of this new service. The estimate was done by using the traditional model of Internal Rate of Return (IRR), for which the variables to consider are: the investments made by providers, the annual expenses necessary (personal and maintenance), and the final revenue produced.

The existing forecasts (Industry and Researchers) that could be straight used concerned the expansion of IoT devices and the global revenue expected from a consistent market. On the other side, given the enormous number of Companies still entering the business, it was difficult to derive the main global IoT investment and to estimate it over time. The Companies do not have significant infrastructure to create (LAN, CLOUD and NODES): their objective is, rather, to open up new data Centres worldwide as to gain a leadership position. Another obstacle was the mathematical approach used by industry to represent the growth of IoT and the future revenue: the exponential function, even if accounts for high values over time, needed to be harmonized with the realistic framework of market (potential demand, trend of cost of devices) so that original data had to be adjusted.

Final result was accompanied by a “Sensitivity Analysis” as to understand possible variation of final IRR as a function of change of variables. In addition, final result has been checked using the model MIRR (Modified Internal Rate of Return) for a more complete exercise and suggestion.

# 1 – Brief history of IOT

Products and devices, commonly used in social and industrial sectors, have gradually been turning from objects, assembled by mechanical and electrical parts, into complex objects, equipped with built-in sensors, software, microprocessors able to catch, storage and transmit data. In this sector, an important role was carried by the industrial research which made possible for producers to build small and economic tags as to promote the production of smart objects at low costs. According to a number of Industry analysts, the original Information Technology (IT) got a revolutionary development over a period of about 35 years driven by the technology evolution.

Starting 1980, many significant and positive experiments have been carried out. Among others, process of order and bill paying at a supermarket was automated successfully, an analogue wearable computer was produced and an aid to the blind was made. Members of the Carnegie Mellon Computer Science department installed micro-switches in the Coke vending machine and connected them to a departmental computer so they could see, from terminals, how many bottles were present in the machine and whether they were cold or not.

The second wave of IT revolution arrived with the explosion of the Internet in the 1990. The Internet made possible the interconnection of enterprise activity with the outside world. The system provided a new resource to enterprises which enabled manufacturing firms to achieve a better productivity and allowed them to connect different Company sectors using large computing systems.

The last step involving the evolution of IT was the so called “third computing revolution” in 1998. The manufactured products themselves have been affected by the technology and special experiments took place. Computers were being built into the objects produced.

# 2 – Defining Internet of Things

The term “Internet of Things” was, firstly, used by Professor Kevin Ashton (Cambridge University) during a conference made in 1999. The original concept assigned to the term was perceived as “a third computing revolution” and was intended as a complex innovative extension of the Internet to accommodate things. Through RFID (Radio Frequency Identification) and sensor technology, computers would have became able to track connected things, to observe and identify the object surrounding the human. Such kind of control would have expected to help reduce waste, loss and costs.

In the same year 1999, Professor Kevin Ashton was co-founder of an Investigation Centre which involved, at international level, many Companies and a number of Research Universities. The initial objective of the Centre was to understand how RFID (Radio Frequency Identification) might have been used to replace barcode system*.* One of the experiments made was to use RFID to control of manufacturing problems: a connection was established among parts and products while they were being made.

When single objects were equipped with special tags, the first problem to solve was to produce tags adequately small as to be compatible with the hosting objects. This practice meant that data necessary to the communication between things should have been put in memory elsewhere. The Internet was the obvious place to start with, hence the phrase “Internet of Objects” or “Internet of Things” became a clear reference point and the origin of the Internet of Things that we have today.

# 3- IOT market forecast: exponential approach

According to the data available up to 2015, the Internet of Things is growing fast and it is expected to continue to accelerate in the next future. There are many factors that may stimulate the market preference. First is the new version of the Internet Protocol (IPv6) which may enable almost unlimited number of devices to be connected to networks. Another factor is that many network providers have adapted their networks as to facilitate connection and to offer cost reduction. A third interesting factor concerns the potential opportunity of economic profits that IoT, according to its unexpected process of expansion, might assure over the next 20 years.

In the following Table, the IoT forecast made by some providers is given: from the year 2013 up to the year 2020. The estimates differ from source to source according to the perception of researchers and to the different expectation they got from the present situation they start. In the year 2015, the low estimate is 4,9 billion devices (Gartner) while the high estimate is 18,2 billion devices (Cisco) with a ratio of 3,7. In the year 2020, the low estimate (Gartner) is 25 billion devices while the high estimate (Cisco) is 50 billion devices with a ratio of 2,00.

This level of uncertainty may derive from the different approaches used by the two Companies to make their forecasts. In general, it seems that many Companies are optimistic about the success of Internet of Things and assumed that market preference and advance in technology might provide positive expansion of the new service.

**Table 1- worldwide IOT (billion of devices): Industry estimates**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Years** | **IDC** | **BII** | **GARTNER** | **HARBOR** | **ABI** | **CISCO** |
| **2013** | **9,10** | **2,00** |  |  | **13,00** | **11,20** |
| **2014** | **11,40** |  | **3,80** | **6,00** | **16,00** |  |
| **2015** | **13,70** |  | **4,90** |  |  | **18,20** |
| **2016** | **16,30** |  |  |  |  |  |
| **2017** | **19,20** |  |  |  |  |  |
| **2018** | **22,20** |  |  |  |  | **34,80** |
| **2019** | **25,20** | **23,40** | **19,00** | **21,70** | **35,00** | **42,10** |
| **2020** | **28,10** |  | **25,00** |  | **40,90** | **50,10** |

[**http://postcapes.com/internet-of-things-market-size**](http://postcapes.com/internet-of-things-market-size)

**http://www.forbes.com/sites/gilpress/2014/08/22/Internet-of-things-market-estimate**

Data (2013-2014) and estimates (2015-2020) above, collected from Industry and Researchers, show an exponential growth over time: Companies give strong interest to the new IoT service and show confidence in this approach. An average growth IoT function has been estimated in **Annex 1.** There**, Table 1** gives, per Company, the evaluation of yearly trend according to an exponential function. **Table 2** compares the arithmetic mean of original reference values with the arithmetic mean of theoretical exponential growth. From the comparison, an average exponential function was calculated together with two confidence limits. They are shown in **Graph 1**:

**Average growth of IOT Y0 = 5,722\*e(0,224\*n) billion**

**High confidence limit Y1 = 7,724\*e(0,224\*n) billion**

**Low confidence limit Y2 = 4,238\*e(0,224\*n) billion**

**“n” included in the exponent = number of years (1,2,3…)**

# 4. The potential market demand

To check whether the exponential function represents the best fitting of IoT growth in the future, reference was made to the growth of Internet subscribers over time. The comparison is justified since the main condition to access IoT system is to have a prior connection to Internet. In other words, Internet users represent the potential demand for Internet of Things.

Data relevant to the growth of Internet users come from “Internet Live Stats” elaboration (by ITU) where the increase of Internet users is given for a period of 22 years (1993-2014). The rate of growth is high (average 50% per year) from 1993 up to 2002; then reduces (average 15% per year) from 2003 up to 2011; finally, from 2011 up to 2014 shows a lower rate of increase (8% per year). This is the typical trend of a logistic function which reasonably adapt to the growth of potential demand. In **Annex 2** (**Table 1**) is given the approach of a logistic curve to the original data available. Its equation is:

**Internet users = Y = 4544,92/(1+e(-0,21\*(n-12)))**

**n = number of years (n=1,2,3…)**

**Correlation “data-logistic” = 100,00%**

The function is plotted in **Graph 1** (**Annex 2)**. Final results obtained have been used, in the following **Table 2,** to estimate the ratio between Internet users and the population.

**Table 2 – Internet users vs population – (2013-2030)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Internet users** | **World population** | **Internet/population** |
| 2013 | 2,743 billion | 7,162 billion | 38,30% |
| 2014 | 2,966 billion | 7,244 billion | 40,94% |
| 2015 | 3,174 billion | 7,326 billion | 43,32% |
| 2020 | 3,948 billion | 7,753 billion | 50,92% |
| 2025 | 4,317 billion | 8,105 billion | 52,61% |
| 2030 | 4,462 billion | 8,584 billion | 52,00% |

**http://www.internetlivestst.com/internet-users**

It might be said that, whether none of the present market frames (technology and market preference) will change over time, the Internet users would represent about 52% of population in the long term.

# 5 – IOT market analysis: the logistic approach

At this stage, the assumption that Internet users represent the potential demand for IoT devices would suggests that IoT devices might better follow the growth function of Internet users. As support to this hypothesis growth of IoT devices, from 2013 up to 2020, gradually decreases from 25,4% (2014) to 11,5% (2020). It seems, then, more reasonable and more realistic to think that the growth of IoT devices follow a logistic function. The new long term estimate was obtained with reference to the original exponential function and is shown in **Annex 3**. The approach gave:

**IoT devices = Y = 136,52/(1 + e(-0,32\*(n-11))**

**n = number of years – (n = 1,2,3…)**

**Correlation logistic/exponential = 99,57%**

To get a further comparison, the number of IOT devices per Internet user is calculated in the following **Table 3**. The final result is the ratio between IoT devices and Internet users which seems to be acceptable according to some general consideration made by industry in this field.

**Table 3 – Number of IoT devices vs Internet users – (logistic approach)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Iot devices** | **Internet users** | **Iot/Internetusers** |
| 2013 | 6,45 billion | 2,742 billion | 2,35 |
| 2014 | 8,60 billion | 2,966 billion | 2,90 |
| 2015 | 11,39 billion | 3,174 billion | 3,59 |
| 2020 | 40,21 billion | 3,948 billion | 10,18 |
| 2025 | 90,58 billion | 4,317 billion | 20,98 |
| 2030 | 125,01 billion | 4,462 billion | 28,02 |

From the above exercises, the following final results can be derived:

1. Almost 52% of population will be connected to Internet in the long run (2030);
2. IoT device logistic trend is expected to reach 125 billion by 2030;
3. IoT devices exponential trend would have reached 14,97 trillion by 2030.
4. Either IoT devices and Internet users have a trend to saturation;
5. Whether 50% of Users have 10 IoT devices, the other 50% are expected to have 46.

# 6. The IOT network structure

The main network infrastructures supporting IoT service are the followings:

* **The smart sensors.** Wireless sensor network nodes are low cost devices which operate at low power supply (battery). The physical objects, that are being connected, will possess one or more sensors for collecting specific data such as location, health monitoring, remote maintenance, mobile payment, temperature. Today, sensors are found in many everyday devices, and some of the latest smart phones come with at least ten embedded sensors.
* **The local network.** A Wireless Sensor Network (WSN) is a network that lets interconnection among sensors scattered over the area under control as to collect and exchange data: the information can be shared in real-time or collected and shared at defined intervals.Important is that the local network have a WSN node (gateway) which can translate local Protocol into Internet Protocol: in this way, sensors can exchange information over the Internet network.
* **The Internet network.** The first obvious networking technology candidate for an Iot device is Wi-Fi, because it is so ubiquitous. Certainly, Wi-Fi can be a good solution for many applications: almost every house that has an internet connection has a Wi-Fi router. However, Wi-Fi needs a fair amount of power. Low-cost and low power solutions will come with the new networking technologies.
* **The Internet Protocol**. The original Internet Protocol for connection to Internet addresses was the so called “version 4” (IPv4) and goes back to 1982. IPv4 had a capacity of about 4 billion theoretical public addresses, so that, when Internet was opened for commercial and social use, it revealed insufficient to address current and expected future needs. In 1998 a new Internet Protocol was designed with a larger addressing scheme and was introduced as the Internet Protocol “version 6” (IPv6). The extended scheme offered by IPv6 enables a virtually unlimited number of addresses, overcoming the scarcity issues of IPv4.
* **End-user devices.** Desktop, laptop, smartphone, or enterprise data system that receive and manipulate data, or PC and mobile devices.

The capital investment necessary to provide the whole connection devices-users, includes part of the existing Internet network and of the Internet Protocol since they let routing the IoT traffic. There are additional infrastructures that Companies should provide in an IoT network. Mainly: the sensors, the local network and the cloud network.

From the little information existing in this sector, new data from Juniper Research has revealed that retailers seeking to capitalise on IoT technologies will spend an estimated $2,5 billion in hardware installation costs, nearly a fourfold increase over this year’s estimate $670 million spend. The hardware spend includes Bluetooth Beacons and RFID tags. In the first instance, Bluetooth Beacons enable visibility over footfall as well as the ability to push relevant information to consumers’ smartphones. Meanwhile, RFID aids in real-time asset tracking reduced labour costs and even dynamic pricing according to stock level and online price.

# 7. Estimate of annual IoT investment

The Internet of Thing has potentially the capacity of changing, from management point of view, the approach to business, from product design to partnership strategy. In 2015 the Industrial Internet Consortium commissioned a project to find out how Companies were evaluating new opportunities in the market and what was considered the best approach to use with the significant investment involving IoT. The conclusion was, at the end of a research, that traditional investment models simply don’t work when it comes to IoT-related investing. When investing their capitals in a project the Companies usually plan a project whose main objective is to recover the highest amount of return on a relatively small investment and in a short period.

Given the current status of IoT investment, many Companies interviewed said they were more interested in acquiring people with experience in specific areas like software and technologies. Few information exist about the investment dedicated to IoT expansion. The period 2012-2015 seems to have been a time of preparation for industry that had to well understand the economic impact of new service before moving into planning their investment and their presence in a worldwide market. During this early period, the favourable growth of IoT service convinced the Companies to invest in business units worldwide as to plan new data centres and provide their control in the market.

Concerning the network implementation, there were available few estimates by Companies. In particular, IDC Company gave investment estimates for the period 2014-2020. The Industry provided an investment forecast limited at the period 2014-2018. The Company GARTNER forecasted investment for two years only: 2015 and 2019. The following **Table 4** summarize the data collected: they appear sufficiently uniform as to be comparable. There is a significant convergence at the year 2020.

It seems that there is convergence when establishing the investment at the year 2020.

No reference was found that could separate the investment per network components, consistent with the network structure described above: it should have provided details that might have helped to get a better knowledge about the allocation of investing funds

**Table 4. Estimated worldwide investment and forecast 2014-2020**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Years** | **GARTNER** | **INDUSTRY** | **IDC** | **Average** |
| 2014 | 939,00 | 698,60 | 655,80 | 764,47 |
| 2015 | 1183,00 | 817,36 | 767,29 | 922,55 |
| 2016 | 1414,00 | 956,31 | 897,72 | 1089,34 |
| 2017 |  | 1118,89 | 1050,34 | 1084,62 |
| 2018 |  | 1309,10 | 1228,90 | 1269,00 |
| 2019 |  |  | 1437,81 | 1437,81 |
| 2020 | 3010,00 |  | 1700,00 | 2355,00 |

In **Annex 4** is given the estimate of investment, made by the three Companies above, according to exponential growth: the period was extended from 2013 up to 2025. The general average was calculated together with two confidence limits (+20%; -20%) as to account for deviation from the average.

The functions are:

**Average investment forecast = Y = 777,2\*exp(0,139\*n)**

**High limit for investment = Y = 932,6\*exp(0,139\*n)**

**Low limit for investment = Y = 621,7\*exp(0,139\*n)**

# 8. Annual IoT investment: logistic approach

Before going on with the exponential growth of investment, it seemed appropriate to compare the trend of investment with the growth of IoT devices. The unit cost per IoT device over time might take to accept the exponential function or decide for an alternative curve.

The exercise was made in **Annex 5,** where the cost per IoT device was calculated as ratio between the exponential investment and the IoT devices, over time: relevant result is that the unit cost per IoT device, first reduces from 2013 up to 2022 and, then, increases. This is not in line with the general expectation of a continuous cost reduction over time: so the exponential function showing IoT investment has been approached by a logistic function.

The investment function has been adjusted accordingly:

**Adjusted investment = Y =6181,602/(1+exp(-0,22\*(n-10)))**

**Correlation invest/adjusted invest = 99,66%**

The above adjusted investment will be used in the IRR model as one of the necessary variables. It is, in this frame, assumed to represent the global investment to provide IoT service: it is composed by part of investment relevant to the main network (Internet) and of the additional investment necessary for the smart devices, the intelligent nodes, local network. By no doubt, the direct impact with a real case will help very much decide the level of such investment to consider.

# 9. Internet of Things: expected revenue

All forecasts of revenue for Internet of Things highlight the economic impact and the social benefits of networked IoT technologies. These analysis entrust an enormous number of Iot devices which will find application in many industrial and social sectors. The researchers recognize economic gains in industry, in terms of cost savings, efficiencies in manufacturing, municipal infrastructures and enhanced productivity growth. On social side, the advantages are assumed, as well, to be consistent as preventive health care, minimized accidents, patient monitoring, home protection.

In addition, Hospital might cut down on costs through accurate patient monitoring and pharmaceutical management. Small city technologies can help municipalities to improve service delivery and save resources through infrastructure monitoring and automatic optimization. Not last are the advantages in agriculture, security, energy.

Connected things (like automated machines) have existed in the past. But, the new devices and the creation of smart ordinary objects are reinventing the user sector by making available digital sensing, computing and communication capabilities.. This functionality provides both new and previously passive objects with a “digital voice” and the ability to create and deliver an information stream reflecting their status and that of their surroundings environment. Such developments did radically change the market sensitivity by creating new services and new profitable scenarios.

It may happen that, within next years, some level of built-in intelligence and connectivity will become standard, but this cannot stop the expansion of IoT service; the competitive opportunities provided to the market do not come from the digitization of a product or of a service but from the new business models offered by the new technology.

# 10. IoT revenue: exponential approach

Data and estimates collected from the forecast of researchers are given in the following **Table 5** which covers the period 2013-2025. Even in this case the figures provided seem to be reasonably compatible. Hundreds of companies are currently moving into this industry, so that the Company have the expectation of a significant increase of revenue by IoT which is associated with an exponential trend.

**Table 5 – worldwide IoT revenue (trillion USD) – industry estimate**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Years** | | **CISCO** | **McKinsey** | **GSMA** | **IDC** | **BII** | **Morgan** | **Gartner** |
| **2013** | **1** | **1,60** | **1,80** | **1,80** | **1,93** | **1,88** | **1,30** | **1,90** |
| **2014** | **2** | **2,28** |  |  |  |  |  |  |
| **2015** | **3** |  |  |  | **2,71** |  |  |  |
| **2016** | **4** |  |  |  |  |  |  |  |
| **2017** | **5** |  |  |  | **3,78** |  |  |  |
| **2018** | **6** |  |  |  |  |  |  |  |
| **2019** | **7** |  |  |  | **5,65** | **5,60** | **5,60** |  |
| **2020** | **8** |  |  | **4,50** | **7,07** |  |  | **7,1** |
| **2021** | **9** |  |  |  |  |  |  |  |
| **2022** | **10** | **14,40** |  |  |  |  |  |  |
| **2023** | **11** |  |  |  |  |  |  |  |
| **2024** | **12** |  |  |  |  |  |  |  |
| **2025** | **13** |  | **8,70** |  |  |  |  |  |

In **Annex 6 ( Table 1)** the forecast made by the each of the above Companieswas associated with an exponential function to calculate the annual expected growth. In the same **Annex 6**, the average exponential curve is shown in **Graph 1** together with two confidence limits:

**Growth function of IOT revenue Y0 = 1,451\*e(0,178\*n) billion**

**High confidence limit Y1 = 1,741\*e(0,178\*n) billion**

**Low confidence limit Y2 = 1,161\*e(0,178\*n) billion**

**“n” included in the exponent = number of years (1,2,3…)**

# 11. Iot revenue: logistic approach

Before accepting an exponential growth of IoT revenue, it seemed interesting to compare global revenue with the growth of IoT devices. The price per Iot device over time might clarify whether the trends of revenue and Iot devices are compatible with an exponential representation.

The exercise is made in **Annex 7**, where the price per IoT device was calculated as ratio between the exponential revenue, obtained so far, and the adjusted trend of IoT devices: relevant result is that the unit price per IoT device first reduces from 2013 up to 2018 and, then, increases over time. This is not in line with the economic frame so far built up, so the exponential function representing IoT revenue have been approached by a logistic function: the comparison gave 99,75% correlation.

The revenue function has been adjusted consequently:

**Adjusted revenue Y = 18,36/(1+exp(-0,286\*(n-10)) trillion USD**

**Adjusted price/IoT = Rev/IoT: Y = 299,6 – 59,2\*ln(n) USD**

# 12. IoT: the Internal Rate of Return

From economic point of view, when designing a project for IoT service, a sequence of investment (and expenses) is assumed over time and is compared with a sequence of revenue: the annual difference is the so called “Cash-Flow”. The Internal Rate of Return (IRR) is the interest rate at which the Net Present Value of all the Cash-Flow, over the project life, equals zero. The indicator is used to evaluate the attractiveness of a project or investment: if the IRR of a new project exceeds a company’s required rate of return, that project is assumed to be desirable. If IRR falls below the required rate of return, the project should be rejected. The formula for IRR is the following:

**0 =CF0 + CF1/(1+r) + CF2/1+r)2 + CF3/(1+r)3 + …. CFn/(1+r)n**

Where CF0 is the initial investment, relevant to the starting value of network assets; CF1, CF3, CFn are the Cash-Flow for the periods 1,2,3…n; and “r” is the Internal Rate of Return that makes the Net Present value of project equal to zero.

The model is simple and gives a straight indication about the feasibility of a project, making, as well, easy the comparison among different economic plans. Within this frame, IRR becomes attractive, but there are limits to its usefulness. For example, IRR works when a project has an initial cash outflow followed by one or more cash inflow; in other words, Internal Rate of Return is interpreted as the annual equivalent return on a given investment. To help a more complete evaluation of the indicator, a “Sensitivity Analysis” usually accompanies the main calculation of IRR: by modifying the three variables (Investment, Expenses, Revenue), one at time, a new IRR can be calculated. And a relationship can be established between the original IRR and its variation as a function of variables.

The following **Table 6** gives the final return estimate using the traditional IRR model.

**TABLE 6 – Traditional IRR calculation**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Revenue** | **Investment** | **Expenses** | **Cash-flow** |
| 1 |  | 1847.12 |  | -1847.12 |
| 2 | 1300.00 | 890.50 | 222.63 | 186.88 |
| 3 | 1690.00 | 1052.29 | 263.07 | 374.64 |
| 4 | 2180.00 | 1236.61 | 309.15 | 634.24 |
| 5 | 2800.00 | 1444.13 | 361.03 | 994.84 |
| 6 | 3550.00 | 1674.67 | 418.67 | 1456.66 |
| 7 | 4440.00 | 1927.05 | 481.76 | 2031.19 |
| 8 | 5470.00 | 2198.90 | 549.73 | 2721.38 |
| **Internal rate of return estimate** | | | | **35,77%** |

For some time now, finance textbooks and academics have suggested that a practical and more realistic alternative to the original frame of IRR can be obtained whether the annual positive Cash-Inflow are used for reinvestment in the same or in other projects. The original IRR model, in fact, does not assume that the project under analysis generates available Cash Flow to reinvest.

Under this new concept, between two project with equal original IRR, the project that becomes more attractive is the one whose reinvested Cash-Flow provide the best additional return.

Despite flows that can lead to poor investment decisions, IRR will likely continue to be used widely during capital budgeting discussions because of its strong intuitive appeal. Executives should at least cast a sceptical eye at IRR measures before making investment decisions.

# 12 IoT profitability: the Sensitivity Analysis

As it was already said, the input variables for a traditional IRR model are:

* Final revenue for IoT system
* Equipment capital costs
* Equipment operating costs

The Sensitivity Analysis is a process which is used to analyse how the value of a project can be affected when one single input variable changes, leaving the other variables constant. The range assigned usually varies from -20% up to +20%. Recalculating the value of Internal Rate of Return, at every change, takes to the following TABLE:

**Sensitivity Analysis for IoT IRR**

|  |  |  |  |
| --- | --- | --- | --- |
| **Range** | **Revenue** | **Investment** | **Expenses** |
| + 20,00% | 53.27% | 25.38% | 33.22% |
| + 10,00% | 44.79% | 30.65% | 34.50% |
| 0,00% | 35,77% | 35,77% | 35,77% |
| -10,00% | 25.92% | 40.79% | 37.03% |
| -20,00% | 14.71% | 45.72% | 38.29% |

The various figures calculated above lay over a straight line: that is, the graphical representation of the Table includes three straight lines, one for Revenue, the other for Investment and the last one for Expenses. The three lines cross at the common point (IRR = 35,77%): intermediate value of IRR can be derived easily over the range selected.

The main information that can be derived from the Sensitivity Analysis are:

* Determine which variables have the biggest impact on the project value;
* Determine the critical value of a variable that makes the project non viable;
* Determine the potential value of project when variables fall in the positive range;
* Determine which variable must be estimate more accurately.

# 13. the Modified Internal rate of Return

The Modified Internal Rate of Return (MIRR) is a powerful and frequently used investment performance indicator. It is a variation of the traditional Internal Rate of Return calculation in that it computes IRR with explicit reinvestment rate and accounts for the reinvestment of only positive Cash-Flow at a given investment rate. Three alternative solutions have been calculated, using each time a different rate of reinvestment. To calculate the relevant MIRR, the following steps are used:

1. Calculate the net Cash-Flow for each period;
2. Calculate the Future Value of Cash-Flow starting from the second year
3. Sum up the Future Value of all Cash-Flow over the period = FV total reinvestment
4. Divide the sum above by the original investment (at year 1)
5. Take the n-root of the above ratio (nth-root = 1+MIRR)
6. Subtract the unity (1) to the ratio = MIRR

The exercise is shown in the following Table:

**Adjusted Cash-Flow to account for reinvestment at following rates.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Years**  **Table 6** | **Cash-Flow**  **rate = 10%** | **Cash-Flow**  **rate = 15%** | **Cash-Flow**  **rate = 20%** |
| 1 | 1847.12 | 1847.12 | 1847.12 |
| 2 | 331.07 | 432.26 | 558.02 |
| 3 | 603.36 | 753.53 | 932.22 |
| 4 | 928.59 | 1109.29 | 1315.16 |
| 5 | 1324.13 | 1513.03 | 1719.08 |
| 6 | 1762.56 | 1926.43 | 2097.58 |
| 7 | 2234.31 | 2335.87 | 2437.43 |
| 8 | 2721.38 | 2721.38 | 2721.38 |

The values obtained for MIRR are the followings:

1. In case of a rate of reinvestment of 10%, the sum total of Future Value of revised Cash-Flow is 9905.40; its ratio to the initial investment is 9905.40/1847.12 = 5.3626. The seventh-root of 5.3626 is 1.27115; the MIRR, in this case is 27,12% (1,27115-1).
2. If the rate of reinvestment of 15%, the sum total of Future Value of revised Cash-Flow is 10791.80; its ratio to the initial investment is 10791.80/1847.12 = 5.84. The seventh-root of 5.84 is 1.2868; the MIRR, in this case is 28.68% (1.2868-1)
3. As last exercise, a rate of reinvestment of 20% was chosen. The sum total of Future Value of revised Cash-Flow is 11780.89; its ratio to the initial investment is 11780.89/1847.12 = 6,48. The seventh-root of 6,48 is 1,305909; the MIRR, in this case is 30,59% (1,305909-1).

Final results are all less optimistic than the previous IRR calculated: the rate of return is, anyway, still acceptable. It is difficult, at this stage, to decide whether the MIRR model is more realistic than the IRR model since the range of results covered by IRR model and its Sensitivity Analysis may give a sufficient economic information as to take decision on the original project.

Rather, the IRR calculation may give more than one indicator when the Cash-Flow of a project shows positive and negative value over time. In this case a MIRR model can provide a single result and this is an interesting advantage. By using this approach, the MIRR summarizes the flow of Cash-Flow down to just two numbers: a single initial investment amount at present time and a total accumulated capital amount at the end of holding period.

The relevant process involves the following steps:

1. Calculate the net Cash-Flow for each period (n = years of the project);
2. Calculate the sum of Present Value of negative Cash-Flow (PV = CF/(1+i)^n);
3. Calculate the sum of Future Value of positive Cash-Flow (FV = CF\*(1+1)^n);
4. Calculate MIRR from number 2 and 3 above: **MIRR = (FV/PV)1/n – 1)**

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