A Survey paper on IOT for Enterprises

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ABSTRACT:
The Internet of Things (IoT), also called the Internet of Everything or the Industrial Internet, is a new technology paradigm envisioned as a global network of machines and devices capable of interacting with each other. The IoT is recognized as one of the most important areas of future technology and is gaining vast attention from a wide range of industries. This article presents five IoT technologies that are essential in the deployment of successful IoT-based products and services and discusses three IoT categories for enterprise applications used to enhance customer value. In addition, it examines the net present value method and the real option approach widely used in the justification of technology projects and illustrates how the real option approach can be applied for IoT investment. Finally, this article discusses five technical and managerial challenges.

Keywords:Finiteelement,Cam clayModel,Application

INTRODUCTION:

1.   TheInternetofThings(IoT)

The Internet of Things (IoT), also called the Internetof Everything or the Industrial Internet, is a newtechnology paradigm envisioned as a global networkof machines and devices capable of interacting witheach other. The IoT is recognized as one of the mostimportantareasoffuturetechnologyandisgainingvast attention from a wide rangeof industries.

The true value of the IoT for enterprises can befully realized when connected devices are able tocommunicatewitheachotherandintegratewithvendor-managedinventorysystems,customersup-port systems, business intelligence applications, andbusinessanalytics.

This paper forecaststhat theIoT will reach26billionunitsby2020,upfrom0.9billionin2009,andwillimpacttheinformationavailabletosupplychain partners and how the supply chain operates.From production line and warehousing to retaildeliveryandstoreshelving,theIoTistransformingbusinessprocessesbyprovidingmoreaccurateandreal-time visibility into the flow of materials andproducts.

 Firms will invest in the IoT to redesignfactory workflows, improve tracking of materials,andoptimizedistributioncosts.Forexample,bothJohn Deere and UPS are already using IoT-enabledfleet tracking technologies to cut costs and improvesupplyefficiency. In addition to manufacturers' adoption of the IoT,variousserviceindustriesareintheprocessofadoptingtheIoTtoincreaserevenuethroughen-hancedservicesandbecomeleadersintheirmar-kets.Disney'sMagicBandisanewwristbandwithRFIDchipsthatservesasaticketandconnectstoDisney'sdatarepositoryregardingparkvisitors.Kroger'snewIoT-basedsystem,RetailSiteIntelli-gence,isonecompleteretailplatformofvideoanalytics, wireless devices, POS devices, handheldsensors,IPcameras,andvideomanagementsoft-warethatwasdesignedtohelpcustomershaveabettershoppingexperiencebymoreeasilyfindingthe products they want and saving time at checkout.Theadoptionofthistechnologyisrapidlygainingmomentumastechnological,societal,andcompet-itivepressurespushfirmstoinnovateandtransformthemselves.As IoT technologyadvancesand increas-ingnumbersoffirmsadoptthetechnology,IoTcost-benefitanalysiswillbecomeasubjectofgreatinterest.BecauseofthepotentialbutuncertainbenefitsandhighinvestmentcostsoftheIoT,firmsneedtocarefullyassesseveryIoT-inducedopportu-nityandchallengetoensurethattheirresourcesare

spentjudiciously.

This article begins with a discussion of the fiveessentialIoTtechnologiesusedforthedeploymentof successful IoT-based products and services andidentifies three IoT categories for enterprise appli-cations. Then, it examines a net present value ap-proachandarealoptionapproachwidelyusedinthejustification of technology projects and discusseshow real option valuation can be applied to IoTinvestment.Finally,thisarticlediscussesfivetechni-cal and managerial challenges: data management,datamining,privacy,security,andchaos.

2. EssentialIoTtechnologies

Five IoT technologies are widely used for the deploy-mentofsuccessfulIoT-basedproductsandservices:

1. radiofrequencyidentification(RFID);

2. wirelesssensornetworks(WSN);

3. middleware;

4. cloudcomputing;and

5. IoTapplicationsoftware.

2.1. Radiofrequencyidentification(RFID)

Radiofrequencyidentification(RFID)allowsauto-maticidentificationanddatacaptureusingradio waves,atag,andareader.Thetagcanstoremoredata than traditional barcodes. The tag containsdata in the form of the Electronic Product Code(EPC), a global RFID-based item identification sys-temdevelopedbytheAuto-IDCenter.Threetypesoftags are used. Passive RFID tags rely on radio fre-quency energy transferred from the reader to thetag to power the tag; they are not battery-powered.Applications of these can be found in supply chains,passports, electronic tolls, and item-level tracking.ActiveRFIDtagshavetheirownbatterysupplyandcan instigate communication with a reader. Activetags can contain external sensors to monitor temper-ature, pressure, chemicals, and other conditions.Active RFID tags are used in manufacturing, hospitallaboratories, and remote-sensing IT asset manage-ment. Semi-passive RFID tags use batteries to powerthe microchip while communicating by drawing pow-erfromthereader.Activeandsemi-passiveRFIDtagscostmorethanpassivetags.

2.2. Wirelesssensornetworks(WSN)

Wirelesssensornetworks(WSN)consistofspatiallydistributedautonomoussensor-equippeddevicestomonitorphysicalorenvironmentalconditionsandcancooperatewithRFIDsystemstobettertrackthestatusofthingssuchastheirlocation,temperature,andmovements(Atzori,Iera,&Morabito,2010).WSNallowdifferentnetwork topologiesandmultihopcommunication.Recenttechnologicaladvancesinlow-powerintegratedcircuitsandwirelesscommu-nicationshavemadeavailableefficient,low-cost,low-powerminiaturedevicesforuseinWSNapplica-tions(Gubbi,Buyya,Marusic,&Palaniswami,2013).WSNhaveprimarilybeenusedincoldchainlogisticsthatemploythermalandrefrigeratedpack-agingmethodstotransporttemperature-sensitiveproducts(Hsueh&Chang,2010;White&Cheong,2012).WSNarealsousedformaintenanceandtrackingsystems.Forexample,GeneralElectricdeployssensorsinitsjetengines,turbines,andwindfarms.Byanalyzingdatainrealtime, GEsavestimeandmoneyassociatedwithpreventivemain-tenance.Likewise,AmericanAirlinesusesensorscapableofcapturing30terabytesofdataperflight forservicessuch aspreventivemaintenance.

2.3. Middleware

Middlewareisasoftwarelayerinterposedbetweensoftware applications to make it easier for softwaredevelopers to perform communication and input/output.ItsfeatureofhidingthedetailsofdifferenttechnologiesisfundamentaltofreeIoTdevelopersfrom softwareservicesthatarenot directlyrelevant

to the specific IoT application. Middleware gainedpopularity in the 1980s due to its major role insimplifying the integration of legacy technologiesinto new ones. It also facilitated the development ofnewservicesinthedistributedcomputingenviron-ment. A complex distributed infrastructure of theIoT with numerous heterogeneous devices requiressimplifying the development of new applicationsand services, so the use of middleware is an idealfit with IoT application development. For example,Global Sensor Networks (GSN) is an open sourcesensor middleware platform enabling the develop-ment and deployment of sensor services with almostzero programming effort. Most middleware archi-tectures for the IoT follow a service-oriented ap-proach in order to support an unknown and dynamicnetworktopology.

2.4. Cloudcomputing

Cloud computing is a model for on-demand access toasharedpoolofconfigurableresources(e.g.,com-puters, networks, servers, storage, applications,services, software) that can be provisioned as In-frastructure as a Service (IaaS) or Software as aService (SaaS). One of the most important outcomesof the IoT is an enormous amount of data generatedfromdevices connectedtotheInternet(Gubbiet al., 2013). Many IoT applications require massivedata storage, huge processing speed to enable real-time decision making, and high-speed broadbandnetworks to stream data, audio, or video. Cloudcomputing provides an ideal back-end solution forhandling huge data streams and processing them forthe unprecedented number of IoT devices and hu-mansinrealtime.

2.5. IoTapplications

TheIoTfacilitatesthedevelopmentofmyriadindustry-oriented and user-specific IoTapplications.Whereas devices and networks provide physicalconnectivity,IoT applicationsenabledevice-to-device and human-to-device interactions in a reli-able and robust manner. IoT applications on devicesneed to ensure that data/messages have been re-ceived and acted upon properly in a timely manner.For example, transportation and logistics applica-tions monitor the status of transported goods suchasfruits,fresh-cutproduce,meat,anddairyprod-ucts. During transportation, the conservation status(e.g., temperature, humidity, shock) is monitoredconstantlyandappropriateactionsaretakenauto-matically to avoid spoilage when the connection isoutofrange.Forexample,FedExusesSenseAwaretokeeptabsonthetemperature,location,and

other vital signs of a package, including when it isopened and whether it was tampered with along theway.
While device-to-device applications do not nec-essarily require data visualization, more and morehuman-centered IoT applications provide visualiza-tiontopresentinformationtoendusersinanintui-tiveandeasy-to-understandwayandtoallowinteraction with the environment. It is importantfor IoT applications to be built with intelligence sodevices can monitor the environment, identify prob-lems, communicate with each other, and potentiallyresolveproblemswithouttheneedforhumanintervention.

3. IoTapplicationstoenhancecustomervalue

Despite growing popularity of the IoT, few studieshave focused on categorization of the IoT for enter-prises(e.g.,Chui,Löffler,&Roberts,2010).Based on the technology trends and literature review,this article identifies three IoT categories for enter-prise applications: (1) monitoring and control, (2)big data and business analytics, and (3) informationsharing and collaboration. Understanding how thesethree IoT categories can enhance the customervalue of an organization is a prerequisite to success-fulIoTadoption. This article next discusses the threeIoT categories, along with an illustration of real-world IoT applications developed to enhance cus-tomervalue.

3.1. Monitoringandcontrol

Monitoringandcontrolsystemscollectdataonequip-ment performance, energy usage, and environmentalconditions,and allowmanagers and automatedcontrollerstoconstantlytrackperformanceinrealtimeanywhere,anytime.Advancedmonitoringandcontrol technologies such as smart grid and smartmeteringrevealoperationalpatterns,spotareasofpotentialimprovement,orpredictfutureoutcomesandoptimizeoperations,leadingtolowercostsandhigherproductivity.
The smart home is known to be at the forefront ofinnovation regarding IoT monitoring and controlsystems.Theprimaryvaluepropositionsarefamilyand property protection and energy savings. Forexample,theVerizonHomeMonitoringandControlnetwork uses a wireless communications technologydesigned specifically for remote control applica-tionsinhomeautomation.IoT-enabledhomeappli-ancesanddevicescanbemonitoredandcontrolledoutside the user's home through a computer, tablet,orsmartphone.TheVerizonHomeMonitoringand

Control network allows users to adjust the lights,control the climate, manage the security system,receive automatic event notifications, and evenlockandunlockdoors.

TheIoTisalsousedtomonitorandcontrolvariouscomponents in cars. The primary customer valuepropositions are drivers' personalized experienceand satisfaction. Ford and Intel teamed up in 2014to explore new opportunities to personalize the userexperience using facial recognition software and amobilephoneapp.Thejointresearchproject,called Mobile Interior Imaging, incorporates per-ceptual computing technology to offer improvedprivacy controls and to identify different driversand automatically adjust features based on an in-dividual's preferences. The in-car experience isthen personalized further by displaying informationspecifictothedriver,suchashis/hercalendar,music,andcontacts.Thecustomervaluepropositionsare appropriately integrated into the connectedcar environment to provide another revenue streamforFord.

3.2.   Bigdataandbusinessanalytics

IoT devices and machines with embedded sensorsand actuators generate enormous amounts of dataand transmit it to business intelligence and analyticstoolsforhumanstomakedecisions.Thesedataareused to discover and resolve business issues—suchaschangesincustomerbehaviorsandmarketconditions— toincreasecustomersatisfaction,andto provide value-added services to customers. Busi-ness analytics tools may be embedded into IoTdevices, such as wearable health monitoring sen-sors, so that real-time decision making can takeplaceatthesourceofdata.

The IoT and advances in business analytics nowmakeitpossibletocapturevastamountsofindividualhealth data. The IoT enables healthcare serviceproviders to personalize patient care. New IoT tech-nologies provide data about a patient's everydaybehaviors and health, creating opportunities for careproviderstoinfluencepatientsfarmorefrequentlyandeffectively.Forexample,Humana'sHealthsense eNeighbor[1] remotemonitoringsystemreportschangesinthemember'snormalpatternsofmove-mentandactivityto Humanacaremanagers—viain-

home sensors that measure routine daily activitieswithdataanalytics— tohelptriggerinterventionsandhelppreventadverseeventsfromescalatingtoemer-gencyroomvisitsorhospitalstays.

IoT-based big data are also transforming thehealthcare product industry. For example, Proctor& Gamble developed the Oral-B Pro 5000 interactiveelectrictoothbrushtoprovideuserswithasmarter, more personalized oral care routine. The interactiveelectric toothbrush records brushing habits with mo-biletechnologywhilegivingmouth-caretipsalong-sidenewsheadlines.Thisinnovationprovidesuserswith unprecedented control over their oral care.Tests of the interactive electric toothbrush haveshown that when connected, brushing time increasesfrom less than 60 seconds with a manual toothbrushto 2 minutes and 16 seconds with an electric tooth-brush, surpassing the 2-minute session recommendedbydentalprofessionals.

3.3.   Informationsharingandcollaboration

Information sharing and collaboration in the IoT canoccur between people, between people and things,andbetweenthings.Sensingapredefinedeventisusuallythefirststepforinformationsharingand   collaboration. In the supply chain area, infor-mation sharing and collaboration enhance situa-tional awareness and avoid information delay anddistortion.Forexample,ifsensorsareplacedthroughout a retail store where refrigeration is nec-essary, alerts can be sent to the store manager'smobiledevicewhenevertherefrigeratorsmalfunc-tion. The manager can then check the employeestatusreporttoseewhoisavailableandsendtask assignments to that employee via his or herIoT-enabledmobiledevice.

To enhance information sharing and collaborationwithshoppers,Macy'sisdeployingshopkick'sshop-Beacon technology, an enhanced mobile location-based technology that uses ultrasound BluetoothLow Energy (BLE). ShopBeacon provides shopkickappuserswithpersonalizeddepartment-leveldeals, discounts, recommendations, and rewards.AsshoppersenterMacy's,shopBeaconremindsthose shopkick app users who have opted in. Thisenhancement in Macy's information sharing withshoppers allows for increased consumer engage-ment and promotional and marketing relevancy thatlead to higher customer satisfaction and increaserevenues.InSeptember2014,followingapilottestoftheapplication,Macy'sdecidedtorolloutshop-Beacon   in all of its 4,000 U.S. locations. Other majorretailerssuchasTarget,AmericanEagleOutfitters,and JCPenney also partnered with shopkick andlaunched shopBeacon in 2014. Due to competitivepressure, there is expected to be a rapid adoption ofshopBeaconatothernationalretailers,too.

4.   EvolutionofthefoundationalIoTtechnologies
Various types of IoT applications have emerged, andthewillingnessofenterprisestoutilizethemis

growingrapidly.AccordingtoBradley,Barbier,andHandler (2013), the IoTwill generate $14.4 trillion invalue; the combination of increased revenues andlower costs will migrate among companies and in-dustries from 2013 to 2022. From an industry per-spective,fourindustriesmakeupmorethanhalfofthe $14.4 trillion in value. These leading four indus-triesintermsofvalueatstakeincludemanufactur-ing at 27%; retail trade at 11%; information servicesat9%;andfinanceandinsurance,alsoat9%.Otherindustries such as wholesale, healthcare, and edu-cation lag behind in terms of value generation, witha range between 1% and 7%. Much of the value formanufacturerscomesfromgreateragilityandflex-ibility in factories, and from the ability to make themost of workers' skills. Additionally, a large amountof the value for retailers comes from connectedmarketing and advertising. Geographic distributionsof the value are heavily driven by each region'srelativeeconomicgrowthrateandbytherelative

sizeofindustrysectorineachregion.IntheUnitedStates, $4.6 trillion of value is most prevalent in theservices area. However, in China, $1.8 trillion ofvalue is derived from rapid economic growth, mainlyinthemanufacturingsector. Table1showsprojectedevolutionintheareaoffoundational IoT technologies: network, softwareand algorithms, hardware, and data processing.The network is the backbone of the IoT. It refersto uniquely identifiable objects (things) and theirvirtual representations in an Internet-like structure.Networktechnologyismovingtounobtrusivewire-freecommunicationtechnologythatallowsdevice-to-device applications to be deployed more flexibly.Network technology is evolving toward a context-awareautonomousnetwork.
Objectsrelyonsoftwaretocommunicateeffec-tively with each other and to deliver enhancedfunctionalityandconnectivity.SoftwareshouldbedevelopedwiththeIoT'sinteroperability,

Table1.EvolutionofkeyIoTtechnologies

	Before2010	2010—2015	2015—2020	Beyond2020
Network	● Sensornetworks	● Self-awareandself-organizingnetworks ● Sensor networklocation transparency ● Delay-tolerantnetworks ● Storagenetworksand powernetworks ● Hybrid networkingtechnologies	● Networkcontext awareness	● Networkcognition ● Self-learning,self-repairingnetworks
Software andAlgorithms	● Relationaldatabase integration ● IoT-orientedRDBMS ● Event-basedplatforms ● Sensormiddleware ● Sensornetworks middleware ● Proximity/ Localization algorithms	● Large-scale,open semanticsoftware modules ● Composablealgorithms ● NextgenerationIoT-basedsocialsoftware ● NextgenerationIoT-basedenterprise applications	● Goal-oriented software ● Distributedintelligence, problemsolving ● Things-to-Thingscollaboration environments	● User-oriented software ● Theinvisible IoT ● Easy-to-deployIoT software ● Things-to-Humanscollaboration ● IoT4All

Source:AdaptedfromSundmaeker,Guillemin,Friess,andWoelfflé(2010,p.74)

Hardware	• RFIDtagsandsome sensors • Sensorsbuiltintomobiledevices • NFCinmobilephones • Smallerand cheaper MEMstechnology	• Multiprotocol, multistandards readers • Moresensorsandactuators • Secure,low-costtags (e.g.,SilentTags)	• Smartsensors (biochemical) • More sensorsandactuators (tinysensors)	• Nanotechnologyand new materials
DataProcessing	• Serialdataprocessing • Paralleldata processing • Qualityofservices	• Energy,frequency spectrum-awaredata processing • Dataprocessing contextadaptable	• Context-aware dataprocessing anddataresponses	• Cognitiveprocessing and optimization

connectivity,privacy,andsecurityrequirementsin mind. The focus of software development isshifting to user-oriented, distributed intelligenceandmachine-to-machineandmachine-to-humancollaboration.

ThenewsthatGoogleispaying$3.2billionincashto buy Nest, a smart thermostat business, demon-strates the value of hardware in the IoT. Hardware isinnovatively designed and robustly produced, drivenby the consumerizedIoT devices which have myriadfeatures, functionalities, and operating environ-ments. While RFID tags and sensors have been thefocusofhardwareinnovation,miniaturizationof hardware and nanotechnology is leading theenergy-efficient,low-powerhardwareevolution.

IoT devices generate enormous quantities of datathatneedtobeaggregatedandanalyzedinrealtimeto provide information regarding status, location,functionality,andenvironmentofthedevices.Thetraditional data processing method does not workwellinthereal-timestreamingdataprocessoftheIoT environment. Since processing large quantitiesof IoT data in real time will increase workloads ofdata centers at an exponential rate, data processingwill become more context-aware, optimized, andcognitive.

IntheIoT environment,alargenumberofdevicesareconnectedwitheachother,anditisnotfeasibletoprocessallthestreamingdataavailableto those devices. Context-aware data processingenables sensors and devices to use context-specificinformation such as location, temperature, and theavailability of a certain device to decide what datato collect and interpret to provide relevant infor-mation to other devices or users. For example,context-aware data processing can deliver rele-vant information to a user by knowing the user'scurrent location (e.g., within a department store,a park, or a museum). Cognitive data processingintegrates the human cognition process into IoTapplications. Rather than being programmed todeal with every possible data-processing need, acognitivedata-processingapplicationistrainedusing artificial intelligence algorithms to sense, pre-dict, infer, and learn tasks and environments. Forexample,cognitivedataprocessingusesimagerec-ognition techniques to understand the surroundingenvironment, processes data for a user, and utilizesfeedback from the user to learn further. The opti-mization of data processing is critical to timelyprocessing of the continuous stream of massiveamounts of data. Technological advances in opti-mized data processing help make timely decisionsintime-criticalbigdataapplicationssuchassmart grids, environmental monitoring, and smartmanufacturing.

5.   IoTinvestmentopportunitiesandevaluation(netpresentvaluevs.realoptionapproach)
OursurveyshowstheIoTispenetratingawiderangeofindustriesincludingretailing,manufactur-ing, healthcare,insurance,   home appliances,heavyequipment,airlines,andlogistics.ThebenefitsofIoTtechnologiessuchasRFID-basedmerchandisetrackingandhomenetworkingareconcreteandimmediatelymeasurable.OtherIoTtechnologiessuchasintelligentautomobilesandintelligenthos-pitalrobotsystemsareintheexperimentalstageandtheirbenefitsmayberealizedinthelongterm.WhiletheIoTisrelativelynew,investmentoppor-tunitiesabound,alongwiththedevelopmentofvariousfoundationaltechnologiessummarizedinTable1.Companiesareexpectedtotakeadvantageofthewaveof IoTinnovationsinthecomingyears.Ingeneral,companiesaregoingtotakeanim-

mediateinvestmentorawait-and-seeapproachtoinvestmentbasedonthematuritylevelofthespecificIoTtechnologies.Thissectiondiscussestwoinvestmentevaluationmethodswidelyusedinthe justificationoftechnologyprojects.

5.1. Netpresentvalueandrealoptionapproach

With so much potential value in the investment ofIoTtechnology,firmsneedanappropriatemeasureby which to properly assess its risks and rewards.The standard measure firms typically use to valueprojects,netpresentvalue(NPV),isinappropriateto use for several reasons. Chief among these in thiscircumstance is that it ignores flexibility in invest-ment such as reversibility and scalability in theevaluation horizon. No other technology investmenthas the flexibility that information technology in-vestments in general have (Fichman, Keil, &Tiwana,2005). All of the aforementioned IoT technologiesmayhavehadvaluearisingfromflexibilityininvestment.Thus,NPVtendstoundervalueaproject's worth and is not suitable for high-riskprojects. In order to value the IoT more appropri-ately,realoptionvaluationmaybeanappropriateevaluation method. The following section discusseshow the real option valuation can be applied for IoTinvestment.

5.2. Realoptions

As implied by their namesake, real options are theright——but not the obligation——to take an actionduring a period of time. These include the optionstoexpand,contract,andwait.Realoptionscan

Table 2.Typesof real option approaches

TypeofOption	Description
OptiontoAbandon/Switch	Thisoptiongivesm anagementtheoptiontoabandonaprojectthatisoperatin dsellorredeploytheassets.
OptiontoContract	Similartotheoptiontoabandon,thisgivesm anagementtheoptiontoscaleba tthatisoperatingataloss.
OptiontoDefer/Postpone	Thisgivesm anagementtheoptiontowait/learnmoretoseeifaprojectwillbe
OptiontoExpand	Thisgivesmanagementtheoptiontoexpand/scaleuptheprojectbased s.

prove particularly valuable in fields of high uncer-taintyandrisk,suchasinformationtechnology.AsreviewedbyLiandJohnson(2002),twomainchar-acteristicsmakerealoptionsanappropriateappli-cation for IT investments. First, IT projects typicallyrequire high initial investments and are often irre-versible. Second, IT investments can have very highuncertainty and risk. IT projects such as IoT projectsinherentlycontaintechnicaluncertaintyaswellasmarketuncertainty(Fichmanetal.,2005).Also,ITcan advance at a rapid pace and change directionquickly. These characteristics make real option val-uation ideal in valuing IoT investment projects, asitcancapturevaluethatotherwisewouldbeoverlooked.

Good managers intuitively understand real op-tions.Theyunderstandthatsimplecashprofitsarenot the only value a project can add; other oppor-tunities may arise from engaging in projects. Realoption valuation allows management to quantifythese options to more accurately reflect the valueofaprojectandtohavearealstrategicimpactonthe value of a project. Table 2 lists four generaltypesofrealoptions.

There are several examples of how real optionsareusedinvaluationtoday.Anyfirmthatoperatesin a field of high uncertainty (e.g., pharmaceuti-cals)islikelytoemployrealoptions.Pharmaceuti-cal companies face uncertainty not only in drugdevelopment(akintoITtechnicaluncertainty)butalso in other external factors such as regulationsand patents (akin to IT market uncertainty). Realoption valuation is also used with movie deals. Moviestudiosoftenpurchaserights——thatis,realoptions——to produce films. Film rights give the purchasingstudiotherightbutnottheobligationtoproduceamovie.[Notethatthisisnotthecostofproducingthemovie,simplythevalueoftherighttoproduceit.]Afterrightsarepurchased,studioscanthenemploysurveysandanalysistodeterminew hetherornotaproduction will be profitable. If the timing is notright, these options allow the studio to wait andperhapsproducethefilmatalatertime.

5.3. Valuation

Like financial options, real options can be calculatedusing the Black-Scholes model or decision trees. Forreal options, using decision trees may be moreappropriate, as that will allow setting up possibili-ties of the project according to what managementbelieves them to be. When valuing real options, it isespecially important to stage the problem

correctlyand to understand how real options are analogous tofinancial options. Table 3 provides a guide on howtheyarerelated.

S represents the present value of cash flows fromthe project; X represents the cost to invest in theproject; s^2 represents the riskiness of the project; Trepresents the period of time in which managementcan take an action; and r represents the risk-freeratetheinvestmentcapitalwouldearn.

Usingdecision treestocalculatetherealoptionvalue,onecanstagethepossiblevaluesaprojectcantake,exercisetheoptionattheoptimaltime /valueoftheproject,anddiscountbackwardinordertofindthe value of the option. For example, with a one-period decision tree, we begin with the startingvaluetoday,S_0,andmoveforwardoneperiod.Thevaluecaneitherincreasetoa$S_u$ordecreasetoaS_d.Fromherewecanuset herisk-freerate,r,anddetermine

RealOptions	Variable	FinancialOptions
PresentValueofProject	S	CurrentStockPrice
InvestmentCostofaProject	X	OptionExercise Price
Riskiness/UncertaintyoftheProject	s^2	Stock PriceUncertainty
TimeWindowoftheProject	T	TimetoExpiration
TimeValueofMoney	r	Risk-freeRate

the probability of success (p) and failure (1-p),determine the expected payoffs using the projectvalue less the investment amount, and essentiallyworkbackwardtodeterminethevalueoftheoption.

5.4. Realoptionsexample

Herewefferanexample.Acompanyislookingtoinvest in new smart vending machines that willreducecostsandincreaseprofits.Managementbe-lievesthereisaprobabilityof0.55thattherewillbea high demand in this technology with a marketvalue of $140m, and a probability of 0.45 that therewill be a low demand in this technology with amarket value of $40m. Figure 1 shows a decisiontreewithoutrealoptions. Ifthecostofinvestinginthistechnologyattimezero is $100m and the discount rate is 8%, then fromasimpleNPVcalculationthevalueoftheprojectis

—$12.04m,which thestandardNPVrejects.

PresentValueofCashInflow

$$\frac{(140m)(0.55)+(40m)(0.45)}{(1.08)^1} = \$87.96m$$

NPV = $87.96m—$100m = —$12.04m

However, management can use a real option ap-proach to evaluate this investment as a phased fi-nancing and scaling option. The company could startwithapilotprojectandbetterlearnthemarketovertime. In the following year, management could avoidfull investment of $100m into this smart vendingmachinetechnologyifthemarketturnsouttobe $40m, and only invest in this technology if themarket turns out to be $140m. Therefore, manage-ment can value the option using a decision treethattakesthehighervalueastheexercisedoption. The option value of this project from therealoptionperspectiveis($140m—$100m)*0.55+($0m)*0.45 = $22m/$(1.08)^1$ = $20.37m. As long as thepilot project costs less than $20.37m, this pilot proj-ect with a following investment in the smart vendingmachinetechnologyisworthdoing.Figure2shows the option value calculation, discounted back oneperiod.

Whilethisexamplewassimplifiedforreadersfromnon-finance backgrounds, more complicated scenar-ioscanbeanalyzedusingthesameprinciples.ManyIoTprojectshaveunclearprojectscopesandgoalsand are using breakthrough technologies; in suchscenarios, there is a higher risk of project failureandgreaterirreversibilityofinvestmentsthanwithtraditionaltechnologyprojects.Ourexamplehigh-lights the value of real option approaches to IoTprojects.

6. ChallengesinIoTdevelopment

Based on the survey of IoT practices, this sectiondiscusses challenges in IoT development by enter-prises. As with any disruptive innovation, the IoTwillpresentmultiplechallengestoadoptingenter-prises. For example, due to the explosion of datageneratedbyIoTmachines,Gartner(2014)suggestedthatdatacenterswillfacechallengesinsecurity,theenterprise, consumer privacy, data itself, storagemanagement,servertechnologies,anddatacenternetworking. This section discusses five technical andmanagerial challenges: data management, data min-ing,privacy,security,andchaos.

6.1. Datamanagementchallenge

IoT sensors and devices aregenerating massiveamounts of data that need to be processed andstored.Thecurrentarchitectureofthedatacenteris not prepared to deal with the heterogeneousnature and sheer volume of personal and enterprisedata (Gartner, 2014). Few enterprises would beable to invest in data storage sufficient to house allthe IoT data collected from their networks. Con-sequently, they will prioritize data for operationsor backup based on needs and value. Data centerswill become more distributed to improve process-ing efficiency and response time as IoT devicesbecomemorewidelyusedandconsumemorebandwidth.

Figure1.   Adecisiontreewithoutrealoptions

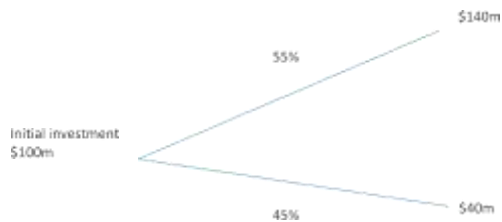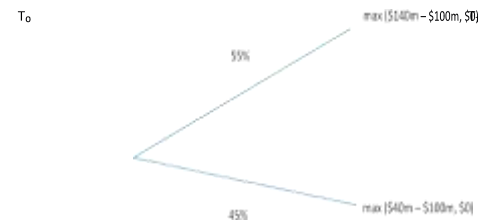Figure2.   Adecisiontreewithrealoptions

6.2. Dataminingchallenge

As more data are available for processing and analy-sis,theuseofdataminingtoolsbecomesanecessity.Dataconsistnotonlyoftraditionaldiscretedata,butalsoofstreamingdatageneratedfromdigitalsensorsin industrial equipment, automobiles, electrical me-ters,andshippingcrates.Thesestreamingdataareabout location, movement, vibration, temperature,humidity,andevenchemicalchangesintheair.Dataminingtoolscaninvokecorrectiveprocessestoad-dressimmediateoperationalissuesorinformman-agers of discoveries regarding competitors' strategicmovesandcustomers'preferencechangesthatwillimpacttheirshort-termandlong-termbusinessactivities.

Data need to be tamed and understood usingcomputer and mathematical models. Traditionaldata mining techniques are not directly applicableto unstructured images and video data. Coupledwith the need for the advanced data mining toolsto mine streaming data from sensor networks andimageandvideodata,thereisashortageofcompetent data analysts. McKinsey Global Insti-tuteestimatedthattheUnitedStatesneeds140,000 to 190,000 more workers with analyticalskills and 1.5 million managers and analysts withanalytical skills to make business decisions basedontheanalysisofbigdata(Manyikaetal.,2011).

6.3. Privacychallenge

As is the case with smart health equipment andsmartcaremergencyservices,IoTdevicescanpro-vide a vast amount of data on IoT users' locationandmovements,healthconditions,andpurchasingpreferences——allofwhichcansparksignificantpri-vacyconcerns.Protectingprivacyisoftencounter-productive to service providers in this scenario, asdatageneratedbytheIoT

iskeytoimprovingthequalityofpeople'slivesanddecreasingserviceproviders'costsbystreamliningoperations.TheIoTis likely to improve the quality of people's lives.According to the 2014 TRUSTe Internet of ThingsPrivacy Index, only 22% of Internet users agreed thatthebenefitsofsmartdevicesoutweighedanyprivacyconcerns (TRUSTe, 2014). While the IoT continuesto gain momentum through smart home systemsand wearable devices, confidence in and acceptanceof the IoT will depend on the protection of users'privacy.

6.4. Securitychallenge

As a growing number and variety of connecteddevicesareintroducedintoIoTnetworks,the
potential security threat escalates. Although theIoT improves the productivity of companies andenhances the quality of people's lives, the IoT willalso increase the potential attack surfaces for hack-ers and other cyber criminals. A recent study byHewlett Packard (2014)revealed that 70% of themost commonly used IoT devices contain seriousvulnerabilities.IoTdeviceshavevulnerabilitiesdue to lack of transport encryption, insecure Webinterfaces, inadequate software protection, andinsufficientauthorization.Onaverage,eachdevicecontained 25 holes, or risks of compromising thehome network. Devices on the IoT typically do notusedataencryptiontechniques.
Some IoT applications support sensitive infra-structures and strategic services such as the smartgrid and facility protection. Other IoT applicationswill increasingly generate enormous amounts ofpersonal data about household, health, and finan-cialstatusthatenterpriseswillbeabletoleveragefor their businesses. Lack of security and privacy willcreate resistance to adoption of the IoT by firms andindividuals.Securitychallengesmayberesolvedbytraining developers to incorporate security solutions(e.g., intrusion prevention systems, firewalls) intoproducts and encouraging users to utilize IoTsecu-rityfeaturesthatarebuiltintotheirdevices.

6.5. Chaoschallenge

TheevolutionofIoTtechnologies(e.g.,chips,sensors,wirelesstechnologies)isinahyper-accelerated innovation cycle that is much fasterthan the typical consumer product innovation cycle.There are still competing standards, insufficientsecurity, privacy issues, complex communications,andproliferatingnumbersofpoorlytesteddevices.If not designed carefully, multi-purpose devices andcollaborative applications can turn our lives intochaos. In an unconnected world, a small error ormistake does not bring down a system; however, in ahyper-connected world, an error in one part of asystemcancausedisorderthroughout.Smarthomeapplications and medical monitoring and controlsystems consist of interconnected sensors and com-municationdevicesandcontrollers.Ifasensorofamedical monitoring and control system malfunc-tions, the controller may receive an incorrect sig-nal, which may prove fatal to the patient. It is notdifficult to imagine smart home kits such as thermo-stats and residential power meters breaking down orbeing attacked by hackers, creating unexpectedsafety problems. The Internet bandwidth can getsaturatedwithdatatrafficofproliferatingdevices,creating system-wide performance problems. A sin-gledevicemayhaveaninsignificantproblem,but

10

for the system as a whole, the chain reactions ofotherconnecteddevicescanbecomedisastrous.Toprevent chaos in the hyper-connected IoT world,businesses need to make every effort to reducethecomplexityofconnectedsystems,enhancethe security and standardization of applications,andguaranteethesafetyandprivacyofusersany-time,anywhere,onanydevice.

CONCLUSION

Because the IoT is such a recent development, thereis still a paucity of studies on the social, behavioral,economic, and managerial aspects of the IoT. Thismakes it very challenging for companies to makeinformeddecisionsasregardsIoTadoption/implementation.Ourarticleisoneofthefirststudieson a conceptual model of IoT applications for enter-prises.InthisarticleweidentifiedthreecategoriesofIoT applications: monitoring and control, big dataandbusinessanalytics,andinformationsharingandcollaboration. We also presented investment oppor-tunities and investment evaluation with NPV andreal options. Finally, we discussed five challengesinimplementingIoTapplicationsforenterprises.

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