A cost estimation approach for IoT projects

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Abstract. Engineering Economics and IT management made a lot of progress towards understanding the concept of the Internet of things (IoT). Nevertheless the authors consider that some aspects of IoT project cost management still need to be further developed. At the initial stage of the research the authors were interested in the existing cost estimation approaches for IoT projects. This paper is devoted to estimation of project costs at a design stage. The general findings of the literature review revealed the problem of estimating total project cost. To establish paradigms for effective implementation and use of the Internet of things in software engineering it is necessary to consider the issues of its cost estimation. The research is focused on parametric estimate, a more accurate technique for estimating total costs and defining factors which influence the cost of IoT. The object of our inquiry are the aspects of IoT technology which influence costs. The main purpose of this paper is to help customers as they need to know the project cost before the completion. The analysis of the results allowed us to draw a conclusion that Program Evaluation and Review Technique offers the advantage of accurate estimating IoT project cost.

1. Introduction

The Internet of things (abbreviated as IoT) is a computing concept which started life as the title of a presentation made by Kevin Ashton at Procter & Gamble (P&G) in 1999. Originally the term was closely connected with radio frequency identification (RFID) as a network of physical objects that contain embedded technology to interact with their internal states or the external environment. The terms coined by Kevin Ashton were used in the article devoted to the Internet of things which appeared 5 years later. This article explained varied applications of the Internet of Things (IoT) changing simple homes into smart homes and providing automation of the processes made by home appliances and "things" (for example, medical identification tags). The idea of everyday physical objects and devices being connected to a computer network using the Internet protocol suite which was considered in the article has allowed the concept to become increasingly popular. But its real resurgence occured in 2010 when the number of mobile-connected devices exceeded the world's population. The technology acquired maturity and became the basis for "foggy calculations". The concept broadened the sphere of its application having penetrated into the field of industrial facilities.

Today the internet of things is understood as a concept of designing computer networks which consist of "things" interacting with each other and the external environment [1]. In the context of technology, things are physical or virtual objects which can be identified and integrated into communication networks [2].

Thus, obtaining data, things can interact with each other in order to analyze the information and store it in their own network, however all actions, which can be carried out by devices within one network, are coordinated by human. This aspect is important from a security perspective, as this term is also considered regarding technology and social development.

Rapid growth of the concept popularity is connected, first of all, with the development of wireless networks, cloud computing, active transition to IPv6 (improved version of the IP protocol) and development of software-defined networking [3, 4].

2. The Internet of things in conditions of modern digital economy

The most basic taxonomy of IoT technologies includes three main components:
1) data processing;
2) identification;
3) measurement.

The first component covers possibilities of networks (wired and wireless) ensuring that the Internet of things will react effectively in the case of slow Internet speeds, adapt and achieve fault tolerance.

Identification is a basis for the concept of the Internet of things. Various types of optical identifiers and location sensors are embedded in diverse IoT devices. Each identifier has to perform a unique function. The traditional identifier for the object connected to network is MAC address of a network adapter.

The idea of the Internet of things consists in obtaining information from the external environment; therefore the technology has to possess measuring instruments, translating data from outside the world into machine meaningful and readable form. When all objects are combined in one network it is possible to use this data for the creation of the system of inter-machine interaction.

Experiences present new challenges for the interaction between humans and devices when the later will detect human presence or foresee his/her wishes in order to perform relevant instruction or recommendation. This is the most common concern expressed by practitioners contributing to the development of artificial intelligence and computer-based technologies. The Internet of things promises big change when the machines are able "to learn" and create necessary favorable conditions for human beings [5].

As it was mentioned the Internet of things has penetrated deep into the sphere of industrial facilities. Many companies are starting to reconsider their own ignorant view and look for the ways to use new approach of business management with the Internet of things [6-8]. The reason for this tendency is the desire to get closer to the customers who use their personal devices actively. Besides simple conveniences, such as automatic sliding doors that automatically open and close as a customer approaches them, the technology enables using biometric data for identification purposes and granting access permissions to these or those services. Devices provide customers with expected solutions on their terms and their schedule. Thus, the Internet of things is an innovation capable to capture the sphere of marketing and entertainments, as its instruments are able to satisfy customer needs implementing mood recognition technology. It is possible to draw a conclusion that in the near future the Internet of things will become a mega trend that will influence everything from our daily personal life to businesses.

There are a number of IoT market estimation methodologies to choose from. That is why these estimations would seem inexact. At the same time the situation gets totally absurd – there is much information about the exploration of the market in terms of size and profitability without specifying the method used for the assessment. As a result we have inaccurate information that complicates the assessment of complex IoT systems regarding economic characteristics of its development. According to the latest forecast, the size of the market of IoT is projected to total $ 4,3 trillion by 2020, that is 456% more than a segment share in 2014. Thus, estimates of the future market size of the IoT cover a broad range, but most pundits agree it will dwarf any other market. Taking into account the basic technology components supporting its functioning, such instruments as cloud servers, Internet and new standards for inter-machine interactions are key to its further development.

3. Parametric software cost estimating models

Accurate estimation of project costs is crucial for using IoT in software engineering, as when developing the IT projects chances of success are increased by keeping focus on the project's scope, timeline, budget and resources [8]. One of the first things a client usually wants to know about the

project is how much it will cost. Of course, it is not easy to predict the exact cost of the project. Various mathematical methods and information technologies can be used for this purpose. This is the object of our inquiry.

The total IT project costs are determined by the amount of its cost estimate. Cost estimate is estimation of resources required for the development and implementation of the project. Cost estimate is a calculation process. Taking into account the shortcomings mentioned above, it is necessary to designate the method of calculating we will use to achieve our objectives. Having analyzed the data obtained we consider that the most effective and exact estimates applied in IT sphere are the analogous estimating and parametric estimating. Analogous estimating uses a similar past project to estimate the cost of the current project. If the projects are very similar to each other, then the estimate is more likely to be exact. Parametric estimating is a more accurate technique for estimating cost which uses the relationship between variables to calculate the cost. Essentially, a parametric estimate is determined by identifying the unit cost and the number of units required for the project. The measurement must be scalable in order to be accurate. Cost estimate of the project will be received after creation of a mathematical model with a set of parameters values. A kind of parametric software cost estimation model is the Constructive Cost Model (COCOMO). The model parameters are derived from fitting a regression formula using data from historical projects.

The Use Case Points (UCP) method is a useful model of estimating cost on software development projects. It is based on the use of general-purpose modeling language (Unified Modeling Language – UML). The formula for calculations looks as follows:

$$UCP = (UUCW + UAW) \times TCF + ECF,$$

where: *UUCW* – unadjusted use case weight ; *UAW* – unadjusted actor weight; *TCF* – technical complexity factor; *ECF* – environment complexity factor.

The three-point estimation technique is a modification of PERT method (Program Evaluation and Review Technique) removing the existing uncertainties in assessment. The formula looks as follows:

$$E = (O + 4M + P) / 6, \tag{1}$$

where: *O* – the optimistic scenario for the best case; *P* – the pessimistic scenario for the worst case; *M* – the most probable scenario.

For all of the foregoing reasons, the best method for the analysis of IoT cost estimate is the method of parametric estimate as when having inaccurate information we will be able to make mathematical model and thus reveal a tendency for total cost to change. In this research we focus on identifying the parameters being in a proportional relationship with IoT cost changes.

With the estimation methods proposed we will not avoid some uncertainty factor, in this regard there is an enormous difference between IoT costs estimates provided by different analyst teams. Thus, we can conclude that it is impossible to predict the total IT project cost precisely. During the early design stages the following criteria are used to provide accurate forecasting of total cost.

1) Requirements analysis is critical to the success of any project, as during the early design stages it is necessary to define project requirements and check whether all the requirements are correct (i.e. feasible). It is possible to anticipate the most pessimistic scenario of total cost when defining the project requirements.

2) Specification of works required. The customer always needs to know the plan of works to correct expenditures. At this stage the important tasks are separated from the conditional ones, i.e. those which can be excluded in order to reduce costs harmlessly for the project.

3) Effective project documentation is very important while managing a project. One of the most widespread mistakes in the course of the project cost estimation is that they do not account for costs of documentation.

4) Qualification of employees. For fast and effective work each participant of the project should have knowledge and skills necessary or helpful to solve the problem or complete the task during the project development and implementation. As a rule, to obtain an objective estimate and forecast the associated expenses it is necessary to consider a situation where initially the employees' skill levels are lower than those required.

5) Planning and Writing Specifications. It is necessary to define all restrictions to the project in accordance with the written agreement with the client. Any additional works, not included in the terms of the written contract, can create higher total project costs.

6) Project previews are intended to provide the customers an opportunity to find changes in requirements. The more often the project is shown and discussed, the easier for the developers to take measures if the customer requirements change. The situation when a change in requirements is fraught with a variety of risks to go over budget and suffer schedule delays.

7) Wrong choice of technologies. Wrong approach to a solution is a key reason for cost overruns. To minimize this criterion, additional estimates of expenditures for learning new technologies (which are included in the total cost of the project) are often made.

Thus, the project budget is allocated as follows (table 1).

Table 1. Percentage of budget allocated for different stages of the project (prepared by the authors).

Percentage ratio	Stage	Description
20%	Specification	Defining requirements and conditions of the project
25%	Design	Development and verification of the project
20%	Development	Code writing and test execution
35%	Integration and testing	Combination of units and testing as groups in multiple ways

These estimates are made without taking into consideration software maintenance that is the modification of a software product to correct faults and improve performance. Very often maintenance consumes a large part of the project budget thus increasing the importance of previews.

Now we will consider the above-mentioned in the context of IoT. Small amount of transmitted data and simplicity are the advantages of a design stage. As the rule, the amount of data transmitted from sensors do not exceed 1 megabyte as much information is presented in the form of prime numbers, which are needed for the device to correct current behavior and ongoing work.

Simplicity is a key requirement for IoT realization. Users prefer devices providing the most user-friendly experience. To satisfy customer preferences clear and simple external interface is needed.

The first criterion which determines the total cost of IoT project is scalability. Scalability is a non-functional property of a system that describes the ability to appropriately handle increasing workloads. It can be theoretically enlarged to thousands of devices in one network. Thus there should not occur unforeseen errors or malfunction of a system when connecting a new device. It is very important, as the concept key is interaction between the objects sharing the same network. Therefore it is necessary to take into consideration the volume of the following databases (table 2).

So, we will summarize the intermediate results:
- the majority of identical projects have similar databases, this simplifies the work of developers, thus reducing total project costs;
- the databases of identical projects are characterized by huge volumes, therefore, we need to use more labor-intensive testing models and support integrated databases, i.e., incur additional costs.

The area of endeavor concerned with safeguarding connected devices and networks in the Internet of things is IoT security [9]. Besides breaching confidentiality of traditional Internet communications (repetitions, interception, distortion of information, etc.), there appear problems with protection of a consumer component [10]. The greatest danger to networks comes from devices based on inter-machine interaction (M2M). A program written by a human cannot be considered absolutely faultless and safe. There is a maintenance phase directed to correction of errors for any system. Sensors in Internet devices are not an exception. With the increasing prevalence of such devices in our life the threat to data security will grow, even for the most insignificant information. This can present a potential danger to individuals and legal entities.

Table 2. Database examples and description (prepared by the authors).

Database title	Information stored
User information	Contains both temporary and permanent information. As a rule, information about the IoT user, i.e., information associated with the user account. Data are taken in two cases: 1) To check whether a device has to react to a person. 2) To check the way it has to react if information about the person is in the database.
User location	The activity of the person is tracked and necessary device is put into operation, based on the person location. If a person is not in sensor sensitivity zone the device enters a power saving mode (for this reason the Internet of things is often used to reduce power supply costs in large enterprises).
Authorized devices	Store information about the type of equipment available in the shared network. First of all, the importance of this database consists in safety and preservation of confidential information.
User authentication	Contains authentication keys. They are used to define whether the user is authorized to access or not and for obtaining information about the user and the user location.

As to IoT, it is worth mentioning a key component in the concept name – the Internet, which is characterized by coverage over very wide areas and penetration. Information has to be transmitted through long distances without loss and distortions. Besides it has to overcome obstacles, as often we need to use the shared network being, for example, underground (underground parking). The solution to the problem is Low-Power Wide-Area Network technology (abbreviated as LPWAN). This technology was developed for inter-machine interaction and can provide interaction between different devices over distances of 30-50 km. One station can cover thousands of square kilometers and relatively low volumes of data transmitted reduce network maintenance costs. Thus LPWAN meets all required criteria and significantly reduces the total cost of the Internet of things, allowing to focus on information security and proper work of databases.

LPWAN is used as an alternative to cellular networks which were considered a good candidate for the wireless IoT-environment. Unlike its analog, the total cost of LPWAN modules is two times cheaper than of LTE modules, thus the costs of using LPWAN for IoT application is much lower, than construction of any LTE network.

The devices of an Italian open source computer hardware and software company Arduino can be used to develop IoT projects. These devices are well-known thanks to their flexibility as they can interact with buttons, motors, diodes, cameras, loudspeakers, GPS, Internet and even smartphones and TVs. These devices combine flexible low cost hardware and software that is free at the moment. Due to simplicity of training to work with hardware and software the Arduino hardware/software platform for building digital devices and interactive objects has huge community of users. Moreover Arduino is an open source, i.e., everyone can learn to design. Company services are well consumed because of the clear interface and open code to create programs. Due to availability and simplicity, clients decide to install them on their own. What is the reason? First of all, it is much cheaper and easier, and, secondly, most companies raise prices for installation services, artificially increasing the total costs of a product. The consumers have to choose: to install applications on their own, or use services offered by the qualified professionals. The former option appears to be more preferable. That is the reason why this aspect is not profitable for most companies providing a wide variety of managed IoT-oriented services; however the product gains popularity among clients.

Thus total costs essentially change depending on volumes of information stored in the databases, and costs of information security. The dependence is quite simple: the more information, the more

difficult it is to ensure safety for each component that can be stolen for causing moral and physical harm.

At the same time costs of information security depend on complexity of the system, which needs to provide reliable safety of data. Below is the graph showing dependence of information security costs on complexity of an information system prepared by the Vympel company (figure 1).
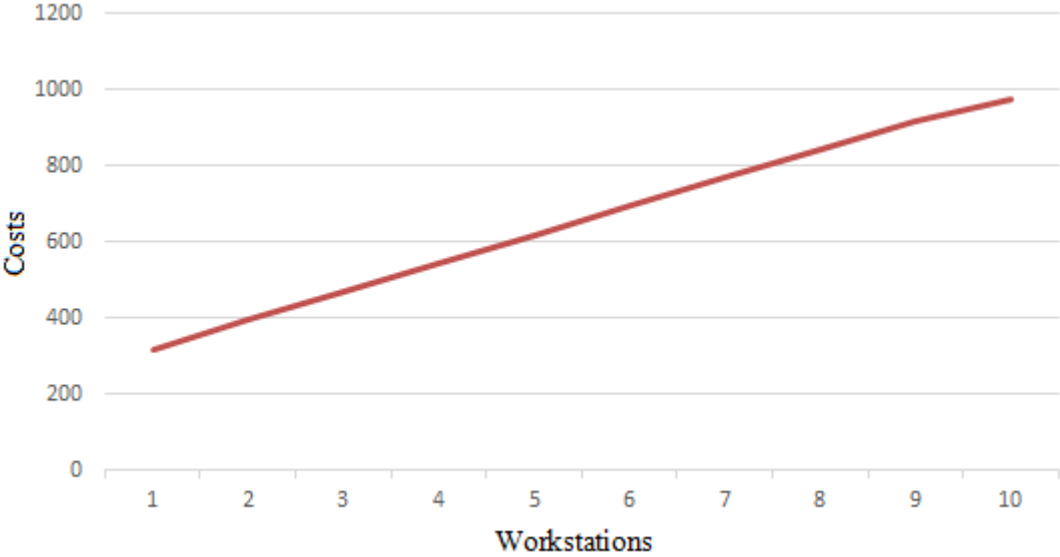

Figure 1. Dependence of costs on the number of workstations processing personal data.

Using PERT technique we will estimate the most probable IoT project costs.

For estimation we will use the platform popular for IoT projects - Microsoft – Azure. This platform has a number of advantages, such as elasticity and high availability. We will examine its application on the example of Remoto and Dealer Mobility developed by Bright Box.

Remoto demonstrates how drivers can control the vehicle from outside the car via their smartphonee. As a solution we choose Telematics Control Unit integrated with the cloud and designed specifically for the automotive environment.

Dealer Mobility is a mobile platform, which is offered to dealers in the form of a mobile app and web portal. This is an OBD device fitted into a diagnostic-related portal which continuously scans the vehicle's operating status and reports problems. It allows dealers and car owners (via a smartphone app) to access the car's vehicle diagnostic and safety data. It can also remind the owner about the scheduled maintenance visit to the dealership.

As it has already been mentioned, Bright Box uses Microsoft Azure as a strategic cloud platform. Microservices are deployed and managed into Service Fabric, a network-connected set of virtual or physical machines. Blob Storage is used to store data. A high-performance caching solution that provides availability, scalability and security is Azure Redis Cache. PostgreSQL provides capabilities for working with geographic data.

Service Fabric

The prices of this microservice depend on computing power required for the project and vary from 0,0215 US$/hour (1 core, 0.75 GB of RAM, 20 GB of temporary storage) to 10,3987 US$/hour (32 cores, 448 GB of RAM, 6144 GB of temporary storage) for one computer.

Blob Storage

The prices of data storage in this service depend on the level of access to a container and its blobs ("hot", "cold") and the chosen redundancy option. Table 3 lists the prices for 1TB per month.

Table 3. Blob Storage prices (prepared by the authors).

Period	Hot	Cold
The first 50TB per month	$0.0224	$0.0163
The next 450 1TB per month	$0.0215	$0.0163
More than 500 1TB per month	$0.0207	$0.0163

Azure Redis Cache
The price depends on the cache size, network capacity and the number of client connections. Pricing information for the distributed cache solution is presented in table 4.

Table 4. Azure Redis Cache prices (prepared by the authors).

Cache size, GB	Network capacity	Number of client connections	Price, US$/hour
6	middle	7500	0.5981
13	high	15000	1.1962
26	high	30000	2.3912
73	the highest	40000	4.7844

PostgreSQL
The prices of this service depend on the amount of computing units and the server level ("Basic", "Standard"). Data are presented in table 5.

Table 5. PostgreSQL prices (prepared by the authors).

Amount of computing units	Basic	Standard
50	0.022 US$/hour	-
100	0.0441 US$/hour	0.105 US$/hour
200	-	0.2099 US$/hour
400	-	0.4198 US$/hour
800	-	0.8397 US$/hour

Thus we will formulate optimistic, pessimistic and the most probable scenarios of costs for a 500 GB database per month (suppose it is equal to 732 hours) (see table 6). Values are presented in US$ per month.

Table 6. Scenarios of costs per month (prepared by the authors).

Scenario	Service Fabric (3 virtual machines), US$/mo.	Blob Storage, US$/mo.	Azure Redis Cache, US$/mo.	PostgreSQL, US$/mo.
Optimistic	47.3275	8.1896	437.8117	16.1305
Pessimistic	22835.5603	10.8189	3502.2586	614.6275
The most probable	3123.6206	10.8189	1750.3634	153.6568

Using the data presented in tables we obtained the following scenarios:
1) $O = 509.4594$ US$/mo. – optimistic.
2) $P = 26964.9724$ US$/mo. – pessimistic.

3) $M = 5038.46$ US$/mo. – the most probable.

We use formula (1) to estimate the most probable costs:

$$E = (509.4594 + 4 \times 5038.46 + 26964.9724) / 6 = 7938.0453 \text{ US\$/mo.}$$

Thus, the estimated most probable costs of IoT project using Azure are 7938.0453 US$ per month.

4. Conclusion

The costs of the Internet of things are measured mostly by the amount of information stored in databases. Low price of installation and LPWAN technology allows to reduce costs of the Internet component.

Within the range of IoT problems special emphasis is made on engineering economics. The program for studying the aspects of cost management aimed at identifying an adequate parametric model and included calculations using Program Evaluation and Review Technique that enabled to draw a conclusion about the IoT project cost.

Developing the concepts of the algorithmic software cost estimation model COCOMO and the parametric cost estimation method Use Case Points, it is possible to ascertain that the costs of information security will grow depending on the amount of information, thus making the importance of this aspect obvious. Moreover the authors could reveal some peculiarities of the mechanism for reducing cost of the Internet component.

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