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Evaluation of Cloud Computing Hidden Benefits by Using Real Options Analysis

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Abstract

Cloud computing technologies have brought new attributes to the IT world. One of them is a flexibility of IT resources. It enables effectively both to downsize and upsize the capacity of IT resources in real time. Requirements for IT size change defines business strategy and actual market state. IT costs are not stable but dynamic in this case. Standard investment valuation methods (both static and dynamic) are not able to include the flexibility attribute to the evaluation of IT projects. This article describes the application of the Real Options Analysis method for the valuation of the cloud computing flexibility. The method compares costs of the on-premise and cloud computing solutions by combining put and call option valuation. Cloud computing providers can use the method as an advanced tool that explains hidden benefits of cloud computing. Unexperienced cloud computing customers can simulate the market behavior and better plan necessary IT investments.

Keywords: IT infrastructure, Cloud computing, On-premise, Real options analysis, Net present value, Total cost of ownership, Volatility, Flexibility.

1 Introduction

Present time can be called the "cloud technology" era. Everyone should own or operate some cloud computing. However, what does the term cloud computing mean? Is a cloud computing solution suitable for everyone? Does it make any sense to operate organization's IT systems in a cloud computing environment? What are the real differences between the cloud computing and on-premise solutions? These and other questions still do not have one clear answer.

Service providers mostly present cloud computing as a technology that brings a competitive advantage. The core of this advantage is costs, flexibility, and high scalability (Armbrust et al., 2010). In contrast, security concerns are the biggest obstacles for cloud computing usage (Gupta, Seetharaman & Raj, 2013). By adding the self-service support and the payment for only consumed resources, cloud computing's principle reminds a provision of utility services. In addition to the established utility types of water, electricity, gas and telecommunications cloud-based services may become another commonly used commodity for which it is not necessary to think about the details of their infrastructure and operations. We can call cloud computing the "fifth" utility (Buyya, et al. 2009).

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The flexibility of utility services is the most important input parameter for the valuation of cloud computing benefits. IT systems and IT infrastructure must support organization's business requirements all the time of the organization existence and must enable any future change (Náplava, 2014). Changes in business requirements define market changes. The market share can change quickly (or slowly) up or down *(*Fig. 1*)*. What is valid today does not have to be valid tomorrow. In the case of market share growth business mostly requires more IT resources, in the case of market share decrease business mostly requires less IT resources.

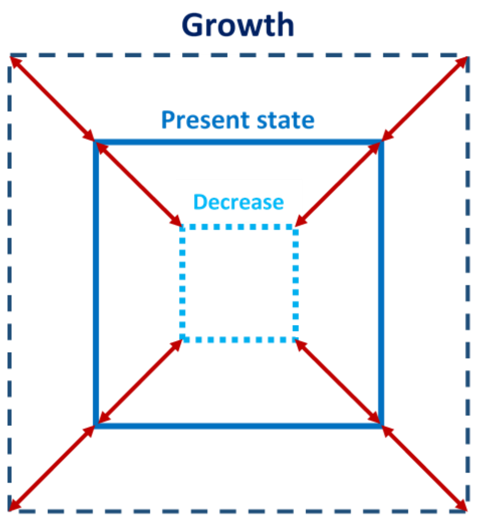

Fig. 1. *Market share changes. Source: Author.*

Before coming of cloud computing, all IT departments had to answer the following question: "What area of the rectangle in Fig. 1 should IT resources cover at the beginning of business operations and how to manage changes in the future?" It means how to size the hardware, software and other resources capacity and how to evaluate the appropriate investments. By using on-premise solutions, IT departments have a tendency to invest more than the business requires, underestimate initial investment or complicate future business expansion (Chung, Rainer & Lewis, 2003).

In this paper, we analyze the main differences between the traditional on-premise and cloud computing-based IT infrastructures and systems behavior. We propose the method for the financial evaluation of this difference based on the Real Options Analysis. The research question is: *How can be the flexibility of cloud computing compared and evaluated with the traditional on-premise IT infrastructure.*

The paper is structured as follows: after the introduction, we describe cloud computing and Real Options Analysis (ROA) method. Next, we introduce the interconnection between cloud computing and ROA. The sixth section introduces and describes our proposed evaluation method. The paper ends with the conclusion section.

2 Cloud Computing

Before we start to discuss how to evaluate cloud computing benefits, we must understand how this technology works. The base of cloud computing is a change in the meaning of the term "IT infrastructure." IT investments are made to achieve a broad range of management objectives and company management expects that this investments influence performance in some ways (Weill, 1993, pp. 547-572):

- Provide a competitive advantage by facilitating rapid response to changing needs in the market.
- Provide timely and accurate information to facilitate better decision making.
- Reduce the costs of doing business by substituting capital for labor often by automating the transactions of the firm.
- Allow the firm to compete in a market requiring a specific technology (e.g. ATMs for banks, EDI for parts suppliers).
- Provide flexibility so that firms can handle a wider array of customers' needs without cost increases.
- Provide a technological platform to enable a work of other business systems

Cloud computing emphasizes the flexibility, the rapid response, and the reduction of the costs parameters. We can find them in the most of the existing cloud computing definitions. For example, Gartner (Plummer et al., 2008) defines cloud computing as "a style of computing where massively scalable IT-enabled capabilities are delivered 'as a service' to external customers using Internet technologies." The NIST Definition of Cloud Computing (Mell & Grance, 2011) is: “Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction”.

Both definitions simply describe cloud as a shared set of resources that can be simply used by anyone and users pay only for consumed time and capacity. The five main attributes of the cloud computing are as follows (Plummer et al., 2009):

- **Service-Based:** Consumer concerns are abstracted from provider concerns through service interfaces that are well-defined. The service could be considered "ready to use" or "off the shelf" because the service is designed to serve the specific needs of a set of consumers, and the technologies are tailored to that need rather than the service being tailored to how the technology works.
- **Scalable and Elastic:** The service can scale capacity up or down as the consumer demands at a speed of full automation. Elasticity is a trait of shared pools of resources. Elasticity is associated with not only scale but also an economic model that enables scaling in both directions in an automated fashion.
- **Shared:** Services share a pool of resources to build economies of scale. IT resources are used with maximum efficiency.
- **Metered by Use:** Services are tracked with usage metrics to enable multiple payment models. The service provider has a usage accounting model for measuring the use of the services, which could then be used to create different pricing plans and models.
- **Uses Internet Technologies:** The service is delivered using Internet identifiers, formats, protocols and representational state transfer Web-oriented architecture.

For the evaluation of the cloud computing benefits, the flexibility attribute is the most important because it represents a bridge between the cloud computing described in this chapter and the Real Options Analysis described in the following chapter.

3 Real Options Analysis

Real options analysis (ROA) is the method for the valuation of investments. Most investment methods (total cost of ownership, net present value, return on investments) only calculate all investment and operation costs or compare the costs with suspected incomes. The disadvantage of these methods is that they use constant values (both costs and incomes) during the whole calculation process. They do not evaluate uncertainty, managerial flexibility, present and future risks, and market development changes. It leads to an undervaluation of investments that include higher flexibility and wrong decisions.

ROA is based on the financial theory and brings the key flexibility logics ("do not have to react but can") to all kinds of projects (Myers, 1974). The decision makers can conduct a certain action in a certain period. If we can conduct the action at one point in time, we use European option. In other cases, we use American option. ROA is using for the evaluation of the following scenarios (Trigeorgis, 1996):

- **Option to wait** – a right to postpone final investment decision for a specific time. **Option to stage** – a right to split a project into smaller parts and realize them gradually.
- **Option to interrupt** – a right for possible future project interruption. We can interrupt project for a defined time and then restart it.
- **Option to abandon** – a right to finish the project before lifetime end sell the rest of assets.
- **Option to alter operating scale** – a right to change the scale of the project (up, down) during its lifecycle.
- **Option to switch** – a right to change parameters (inputs, outputs, technology) of the project.
- **Option to innovation** – a right to innovate already finished projects by starting new ones.

For the evaluation of ROA, we can use Black-Scholes-Model (Black & Scholes, 1973) or Binomial-Model (Cox, Ross & Rubinstein, 1979). Black-Scholes-Model is continuous-time model and enables to calculate a value of European Option. Binomial-Model is discrete-time model and enables to calculate any option value. It results in a binomial tree. In our research and this paper, we use Binomial-Model of an American option.

Input parameters of the Binomial-Model are:

- **S** – Net Present Value (NPV) of the future cash flow (defined by business).
- **X** – Present Value of the investment expenditure (defined by IT department).
- **T** – Option lifecycle (defined by business).
- **r** – Risk-free interest rate (derived from the capital market).
- $\boldsymbol{\sigma^2}$ – Volatility of future cash flows (derived from the business segment).

Volatility is the parameter that covers uncertainty and flexibility. Risk segments have higher volatility value, and riskless segments have smaller volatility value. An option calculation process has the following steps.

First of all, we calculate different market development scenarios. It means we determine the NPV value of expected future cash flow ***S***. We split project's lifecycle ***T*** into ***n*** required intervals (market development detail ratio). By using volatility value, we calculate possible growth value ***u*** (equation (1)) and decrease value ***d*** (equation (2)) of the market. In other words, we predict how the expected cash flow can change in the future.

$$u = e^{\sigma\sqrt{\frac{T}{n}}} \quad \textbf{(1)}$$

$$d = e^{-\sigma\sqrt{\frac{T}{n}}} \quad \textbf{(2)}$$

Now we can construct a binary tree of possible cash flow ***S*** changes in time. An example of the **S** value development during the three periods of time **T** is in Fig. 2.

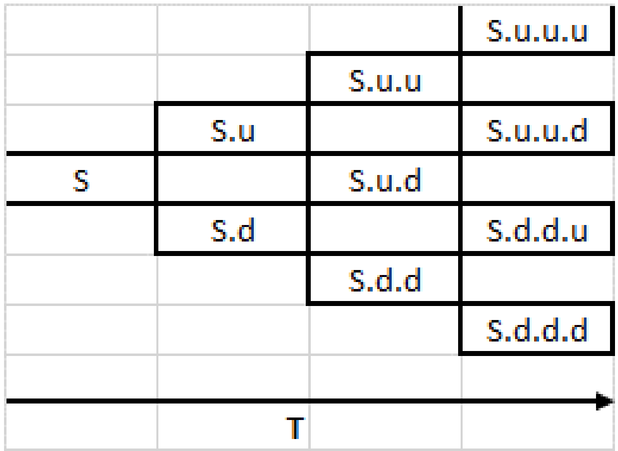

Fig. 2. *Future cash flow development. Source: Author.*

In the second step, we compare incomes and investments and calculate the "internal" option value. For options evaluating the possible positive changes in the future (option to wait or scale the project up), we subtract all necessary expenditures **X** from **S** and get so-called *call* option value. For options evaluating the negative changes in the future (option to abandon or scale the project down), we subtract the future value of cash flow **S** from expenditures **X** and get so-called *put* option value. In case the subtraction result is negative, we write value zero instead of the subtraction result because the investment or the sale of the project (or its part) does not make any sense. An example of a call option for the three periods of time **T** is in Fig. 3.

In the third step, we calculate probability values of a possible market growth "***p***" (equation (3)) and a possible market decrease "***1-p***."

$$p = \frac{(1+r)^{T/n} - d}{u - d} \quad \textbf{(3)}$$

Having these probabilities, we calculate the option values for all cells in the scatter representing a call/put option binomial tree by using equation (4).

$$\mathrm{C} = \frac{1}{1+r} \cdot (p \cdot C_u + (1-p) \cdot C_d) \quad \textbf{(4)}$$

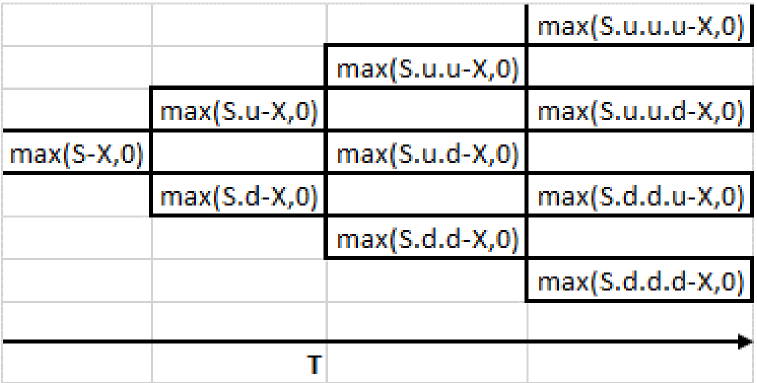

Fig. 3. *Call option binomial tree. Source: Author.*

We start from the right side of the constructed call/put option binomial tree. C_u represents grown to value, and C_d represents decreased to value in the following period. For the last period, C_u and C_d values do not exist and value C is equal to the value of the same cell from the call/put option binomial tree (Fig. 4). The most left C value (binomial tree root value) is the calculated Real Option value of the evaluated investment. It represents a value of the investment's flexibility and uncertainty.

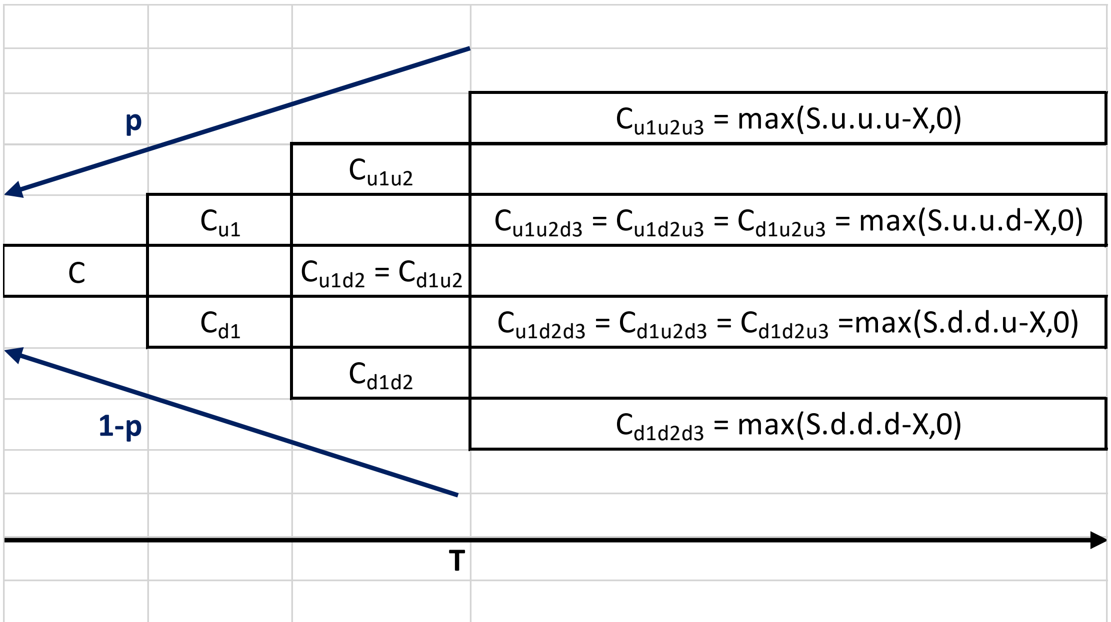

Fig. 4. *Option value calculation. Source: Author.*

The calculated option value is equal to zero or greater than zero. A zero value means that the flexibility and market uncertainty cannot bring such a project's added value that the investment would be profitable in the future. A value greater than zero represents possible, at the project's planning time unknown, incomes. We can add this value to the net present value of the investment, or we can evaluate it independently.

4 Literature Review

The ROA method exists for a long time, and decision makers use it primarily for large investments in the energy and other utility segments. Its application in IT technologies is not common. The reason why is a complexity of the method and the inability to use it by technically educated people. Experts discussed the ways of ROA usage for the evaluation of IT infrastructure investments already in 2001 (Tallon et al., 2001). The outcome of this debate was the fact that the method could be beneficial but it was necessary to simplify its usage much more to be the method easy grasp and understand.

The most important parameter identified by experts was the flexibility with regards to the future business development attribute. No environment is stable and risks that may occur at any moment cause an existence of uncertainty. Any organization must prepare for any future situation at the beginning of their existence. Also, the IT infrastructure must be flexible enough. Before coming of cloud technologies, there were significant IT investment cost problems because companies purchased either too expensive and unused infrastructure or too cheap and overloaded infrastructure that did not enable any future expansion. There exist publications describing the usage of ROA for an IT flexibility valuation (Gebauer & Schober, 2006; Schober & Gebauer, 2011).

As for the IT systems and IT infrastructure the existing literature describes the usage of ROA for the evaluation of new software implementations, existing system updates or evaluation of a reasonableness of the transition to a new software version. For example, there exists case study of SAP information system upgrade discussing reasonability of buying the newer system version that contains more features (Taudes, Feurstein & Mild, 1999). Another article describes ROA based approach to the valuation of ERP investment projects (Wu et al., 2009).

Usage of ROA for the cloud computing evaluation is not very common. The literature research led to only two papers about the usage of ROA in the context of cloud computing. The first paper comes from HP Laboratories, and describes the general evaluation of the reasonableness of the transition from on-premise to cloud computing infrastructure (Yam et al., 2011). It discusses questions when the transition to the cloud computing is reasonable and when it is better to stay in the on-premise infrastructure. The second paper analyses early termination of SaaS by using ROA method (Jede & Teuteberg, 2016). Other papers analyze migration of systems and infrastructure to a cloud computing by using total cost of ownership or net present value methods. We can find papers from both cloud computing providers and service consumers. For example case study of migration enterprise IT system to IaaS (Khajeh-Hosseini, Greenwood, & Sommerville, 2010). All these papers describe and explain different decision-making processes. We can find both complex migration frameworks (Khajeh-Hosseini et al., 2011) and simple descriptions in literature.

Most of the existing papers describe the usage of the growth option, less option to defer and very few switch option or option to abandon (Jede & Teuteberg, 2016). From the financial point of view they mostly calculate American call option value, sometimes we can find the calculation of the European put option value. This paper combines American call and put options.

5 Flexibility of Cloud Computing

Flexibility is the attribute that enables any system to change its configuration. For IT infrastructure and systems it means it is possible to add or remove different types of hardware (memory, processor, disk, new server) or software components (database, programs, libraries, services). The Fig. 5 describes flexibility of standard on-premise (own) solutions.

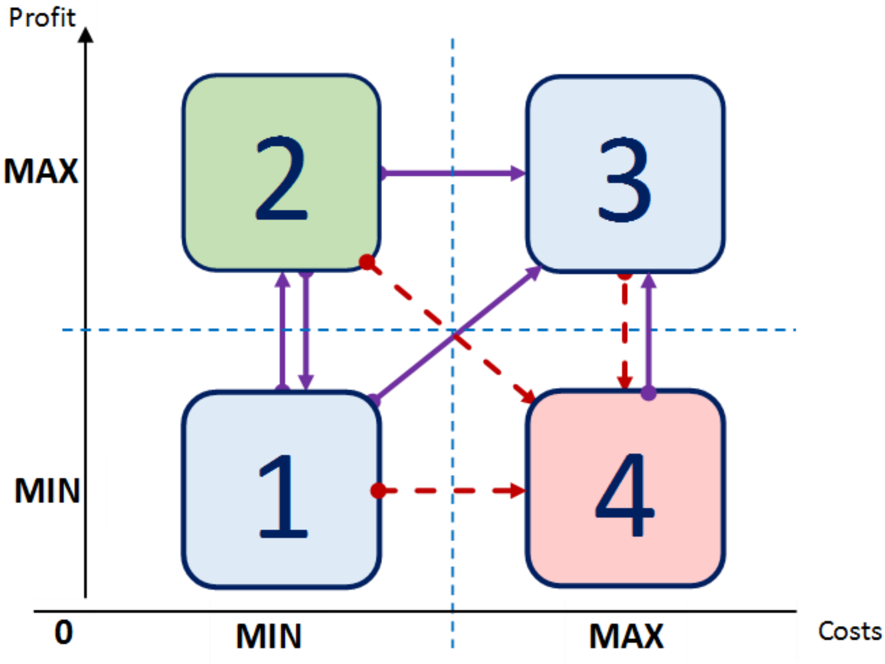

Fig. 5. *Standard IT infrastructure flexibility. Source: Author.*

There are four different quadrants describing the combination of IT investments costs (how much to invest) and market share represented by the profit (incomes) of the business. Quadrant one represents the start of business. Investments and incomes are low, and uncertainty of business is high. The company should invest only minimal and necessary costs to the IT infrastructure that enables upgrade in the future. Quadrant two represents a peak in the market share because incomes are higher than planned, and IT infrastructure is not able to support all business requirements. If the market share change is temporary, the organization quickly returns from the quadrant two to quadrant one, and it is not necessary to invest in the infrastructure upgrade. If the change seems to be permanent, the organization invests in the infrastructure upgrade and moves to the quadrant three. Similarly, the organization can move directly from quadrant one to quadrant three. This state change represents planned IT infrastructure investments based on the business strategy planning. All these transitions represent solid violet arrows between states and they describe the behavior of an organization where the IT support follows business requirements.

Red dashed arrows underline transitions of unexpected market behavior and incorrect IT support (infrastructure and system upgrade) response. The impact of bad upgrade decision represents state four. Investments are high, but the business requirements are low. Business does not consume IT resources effectively, and costs are redundant. The transition from the state one to state four is typical for the incorrect business planning and evaluation of the market behavior. The transition from the state two to state four represents an overestimation of the temporary market share growth and too quick reaction on the new IT resources requirements. The last problematic transition from the state three to the state four is the most critical state change. It represents market collapse or inability of an organization to realize long-term business goals. If there exist a probability that the market share grows up, and the organization can endow IT operations with other incomes till the business incomes are equal to the size of IT resources the organization can survive. It means it can return from the state four to the state three (solid violet arrow).

State four is the critical state because the IT investments and operational costs are higher than the business requires. A possible solution to decrease costs is to sell unnecessary resources. This solution is not effective because the later from buying we sell resources the lower price we get. Alternatively, it is impossible to sell anything. Moreover, if the organization requires these sold resources in the future, it must buy them again. This process is not optimal and flexible. Requirements changes can be slow or fast. Sometimes it is necessary to increase the size of the IT resources. Sometimes it is necessary to decrease it. From this point of view, standard on-demand IT infrastructure and systems are not flexible. The solution seems to be in the usage of cloud computing technologies.

These technologies increase the IT flexibility by adding two new transitions to the Fig. 5. We can see these changes in Fig. 6.

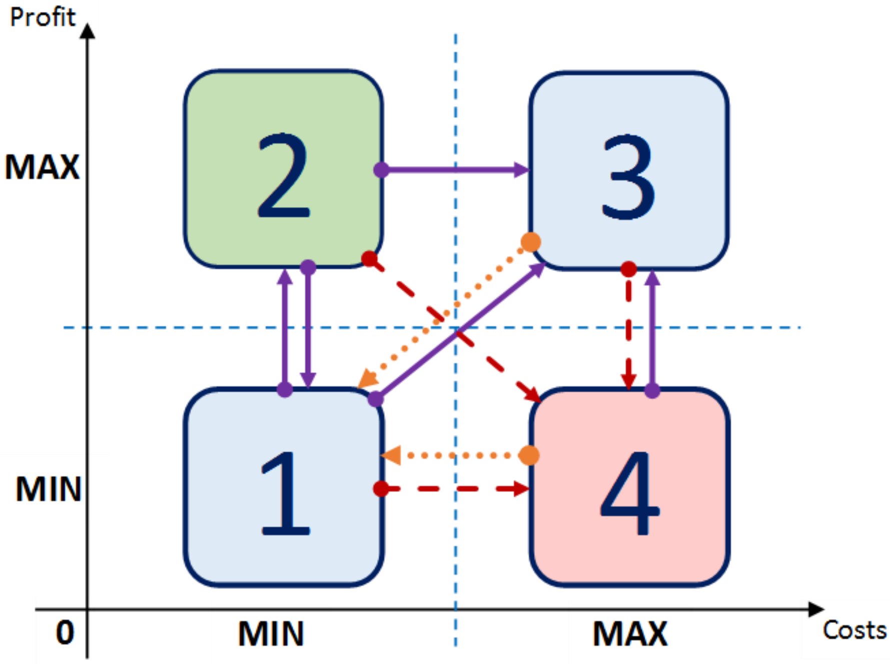

Fig. 6. *Cloud Computing extended flexibility. Source: Author.*

There are two new orange dotted arrows. The first one starts in the state three and the second one starts in the state four. Both arrows end in the state one. The transition from the state four represents a reduction of IT resources in case the IT infrastructure is unused, and costs are higher than necessary. In practice, the organization returns to state one in which the market share is low, and necessary IT investments are low too. It helps organizations to minimize impacts of incorrect planning, to minimize inaccurate reactions to market changes and overcome undesirable behavior of the market.

The transition from state three to state one gives any organization an opportunity to optimize investments and operational costs in real time. It is possible to plan not only business growth but business decrease and organization size lowering in crisis time too in this case. Missing state transitions from state three to state two and from state four to state two are not important. The state two is the temporary state, and in practice, the business should stay there only for a very short time and quickly move to the state one or state three from the state two. These transitions cover already existing transitions in Fig. 6.

6 Evaluation of Cloud Computing Flexibility by ROA

High flexibility of cloud computing brings a possibility to increase and decrease both incomes and investments at any time. Evaluation of different business scenarios is then not easy because we have to plan and evaluate all these scenarios separately first. After the evaluation of all scenarios, we have to combine them together and decide whether the flexibility is valuable or not. ROA seems to be an appropriate method for this purpose because it covers the evaluation of both business growth and decreases by using volatility attribute. The result of ROA calculation is zero value or a value greater than zero. Any value greater than zero indicates the flexibility is an important adding value of the cloud computing technology.

The following text describes the ROA application method, described in the chapter "3 Real Options Analysis", for the cloud computing flexibility evaluation. We compare and analyze standard on-premise and cloud computing infrastructures in the production stage of IT business companies (Fig. 7). To simplify calculations of all necessary costs (**X**) and incomes (**S**) IT business is reduced to companies providing IT applications and services. Production stage, in this case, means all necessary development and testing has already finished. IT company defined business plan (**S_3**) and IT resources requirements during the pilot stage. It starts production stage and decides whether to operate IT systems in a standard on-premise or a cloud computing infrastructure. The decision covers not only necessary costs **X_3** but the infrastructure flexibility too.

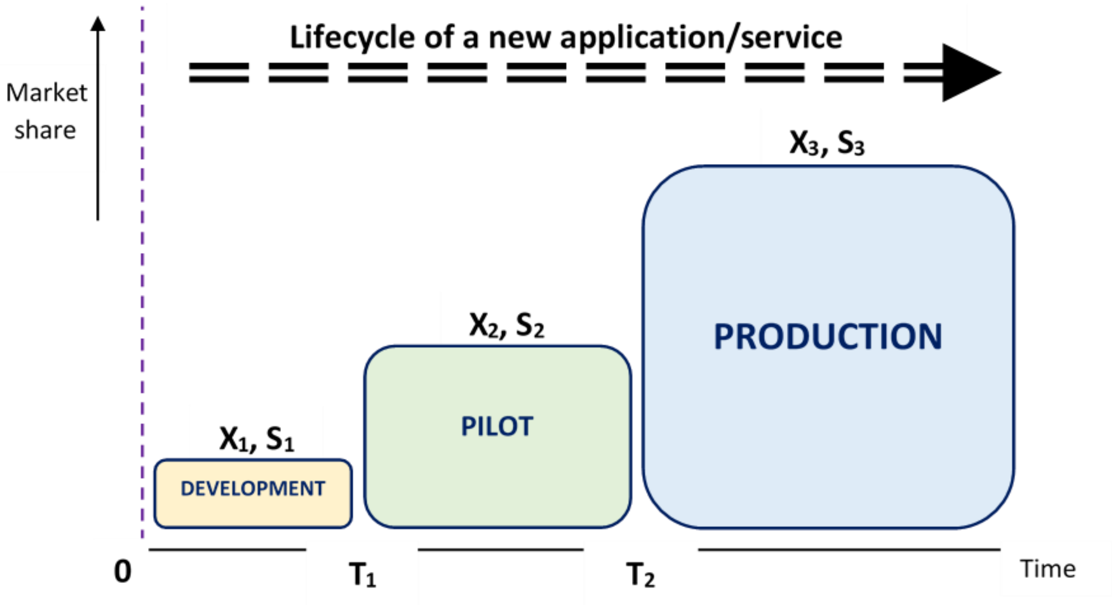

Fig. 7. *Stages of an IT systems business. Source: Author.*

Analysis starts with the following assumptions:

- The business plan is valid for the period **T**, divided into **n** periods in which we can realize an investment decision.
- In business plan defined future cash flow (incomes) equals to value **S** for both cloud computing and standard on-premise infrastructure.
- Based on the **S** value (business requirements) appropriate cloud investment is equal to the value **I_S**, and standard on-premise investment equals to **H_S** value.
- The volatility of the customer segment using provided application is equal to value **σ**.
- The risk-free interest is equal to value **r**.

- The planned costs for the on-premise solution are higher than costs for the cloud computing.

Because described ROA analysis evaluates the difference between cloud computing and standard on-premise infrastructure flexibility we have to correct the initial value $\mathbf{S_0}$ in the first step. The **S** value is the same for both solutions. If we calculate the difference of both solutions, we get the value zero. To be able to perform ROA analysis it is necessary to have S value greater than zero. For this purpose, we can use the difference between the costs of both solutions. Costs of the cloud computing solution are lower than the costs of the on-premise solution (defined assumption). Our method uses the difference of costs as an extended income. Then, the initial value of S_0 we use for the ROA binary tree construction is:

$$S_0 = H_S - I_S \quad \mathbf{(5)}$$

Now, it is possible to construct cash flow development binary tree. An example of such a tree created for four periods is in Fig. 8[1]. Middle level zero (green) contains in business plan defined values. Values in other levels represent growth (blue values in positive levels) or decrease (red values in negative levels) of incomes.

The method analyses the flexibility of cloud computing. The initials costs are therefore equal to the cloud computing costs:

$$X_0 = I_S \quad \mathbf{(6)}$$

Internal option value at the beginning is then equal to:

$$IV_0 = MAX(S_0 - X_0, 0) \quad \mathbf{(7)}$$

In the following period, the cash flow can increase or decrease. Increase describes the blue arrow pointing from the lower level to the higher. Assigned values describe changes of required investments. Because the incomes are growing it is necessary to invest in the IT resources upgrade. $\mathbf{\Delta H_{ijtu}}$ represents a growth of on-premise costs for a change from the level **i** to level **j** in time **t**. $\mathbf{\Delta I_{ijtu}}$ represents the same change in the cloud computing costs. Decrease describes the red arrow pointing from the higher level to the lower. Assigned $\mathbf{\Delta I_{ijtd}}$ represents the change (decrease) in the cloud computing costs; $\mathbf{\Delta H_{ijtd}}$ represents a change in the on-premise costs.

In Fig. 8 red arrows for positive levels and blue arrows for negative levels are missing. There is a problem with the $\mathbf{\Delta H_{ijtd}}$ value. In the case of cloud computing, there is no problem to decrease the size of IT resources (see Fig. 6). For the on-premise solution, such a change is impossible (see Fig. 5), and the value $\mathbf{\Delta H_{ijtd}}$ should be equal to zero. However, this assumption is valid only for negative levels. There, we do not have to change the on-premise infrastructure because the initial investment covers requirements from all negative levels. Only its usage is ineffective, and it is not possible to decrease costs. The growth in positive levels requires infrastructure upgrade (increased costs) but if there is decrease in the following period the on-premise resources capacity stays the same. Similarly to negative levels, it is unused.

[1] Values in the same levels are equal. For description simplification we use the same description symbols.

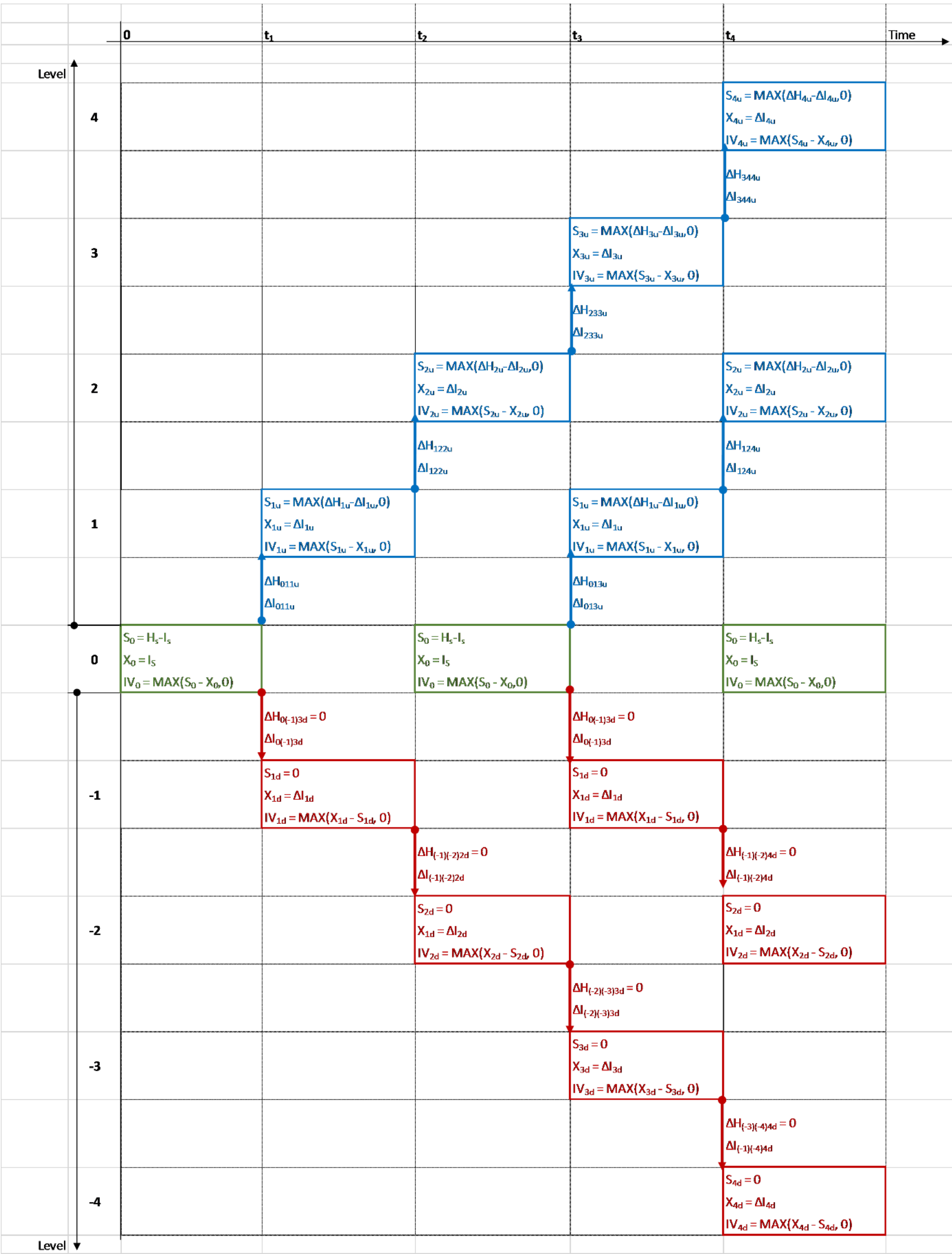

Fig. 8. *Incomplete binary tree. Source: Author.*

The method used in this paper solves the problem by assuming it is possible to decrease costs for the on-premise solution in positive levels. This assumption is based on the combination of the call and put option evaluation. For positive levels, the method evaluates a call option to wait, and in negative levels, it evaluates a put option to alter the scale. The method then merges both values in the end. By applying this assumption, it is possible to finalize the binary tree in Fig. 8 and add missing arrows. The final version of the binary tree is in Fig. 9. The red colored boxes in positive levels and the blue colored boxes in negative levels highlight the discusses states.

Now it is possible to continue in ROA evaluation and calculate **X**, **S** and **IV** values for corresponding combinations of levels and periods. Value **X** in positive level **j** at time **t** is equal to the new costs for the cloud computing (change from time **t-1** to **t**):

$$X_{jtu} = \Delta \mathrm{I}_{ijtu} \quad \textbf{(8)}$$

Value **X** in negative level **j** at time **t** is then equal to the saved costs for the cloud computing (change from time **t-1** to **t**):

$$X_{jtd} = \Delta \mathrm{I}_{ijtd} \quad \textbf{(9)}$$

Because the values **X**, **S**, and **IV** in the same level are equal, we can remove time **t** attribute and simplify the equations to (example of X values):

$$X_{ju} = \Delta \mathrm{I}_{ju} = \Delta \mathrm{I}_{iju} \quad \textbf{(10)}$$

$$X_{id} = \Delta \mathrm{I}_{jd} = \Delta \mathrm{I}_{ijd} \quad \textbf{(11)}$$

Similarly, value **S** in positive level **j** is equal to the difference between on-premise and cloud computing costs.

$$S_{ju} = MAX(\Delta \mathrm{H}_{ju} - \Delta \mathrm{I}_{ju}, 0) \quad \textbf{(12)}$$

Because in some positive levels costs of the cloud computing can be higher than costs of the on-premise infrastructure we apply function **MAX** (maximum of two values). Resulting zero value indicates that it is better to use the on-premise solution in this state. In negative level **j** value **S** is equal to zero.

$$S_{jd} = 0 \quad \textbf{(13)}$$

On-premise capacity in negative level **j** is the same as it is in the higher level **j+1** and the costs are the same. Incomes decreased, and put option value calculates saved costs for the cloud computing solution.

Now, it is possible to calculate internal option values **IV** for corresponding combinations of levels and periods. In positive levels, the method calculates a call option to wait.

$$IV_{ju} = MAX(S_{ju} - X_{ju}, 0) \quad \textbf{(14)}$$

In negative levels, the method calculates a put option to alter the scale.

$$IV_{ju} = MAX(X_{ju} - S_{ju}, 0) \quad \textbf{(15)}$$

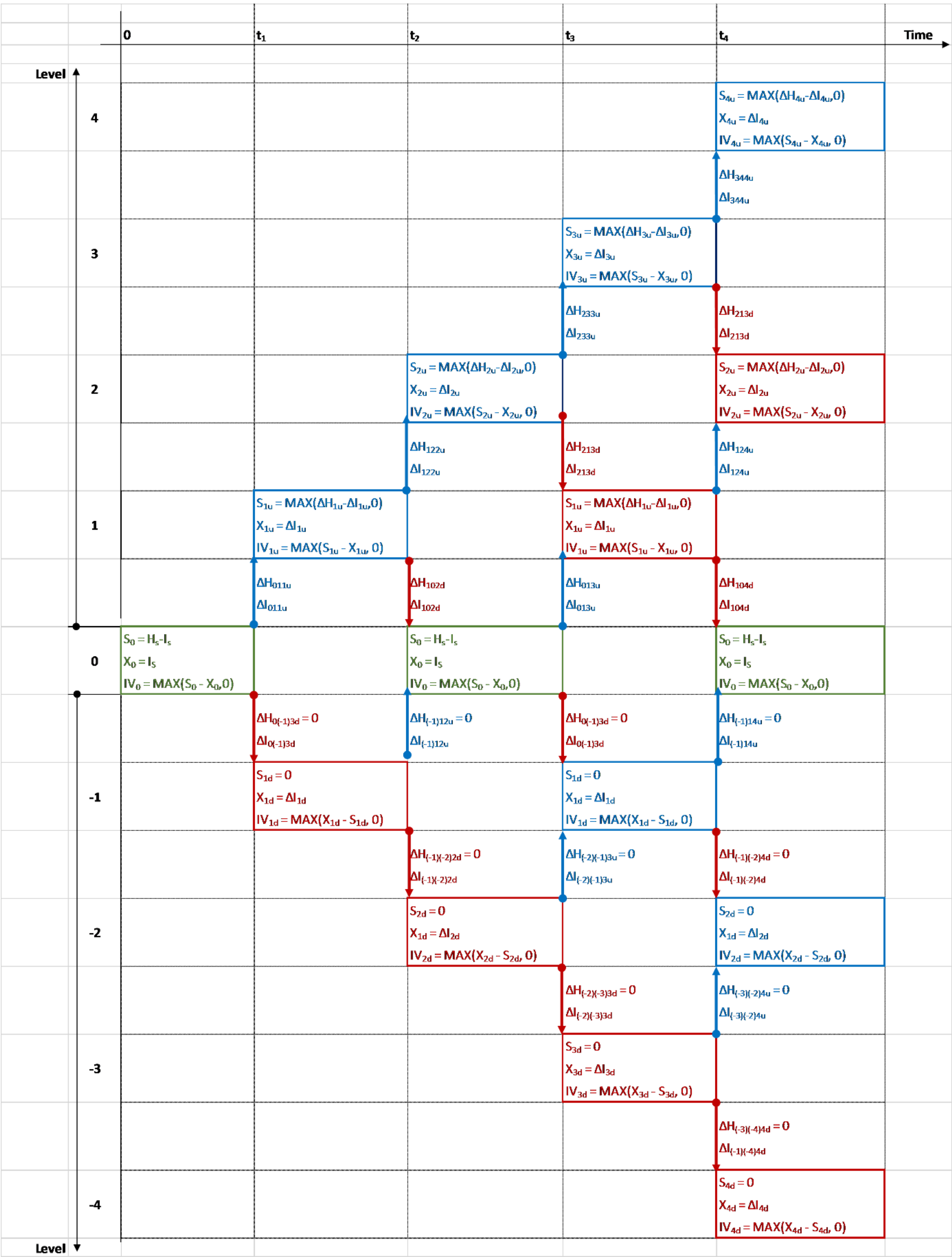

***Fig. 9.** Complete binary tree. Source: Author.*

Fig. 9 contains all described calculations for our example with four periods. The last step of the method is the calculation of a final real option value **OV**. It combines the values of calculated internal option values of the binary tree. Calculation principle describes Fig. 10. It starts from the last period and finishes at the time zero. For the last period, the option value equals to the calculated internal option value. Then, in previous periods we combine options values from the next periods.

$$OV_{jt} = f(OV_{(j+1)(t+1)}, OV_{(j-1)(t+1)}) \quad \textbf{(16)}$$

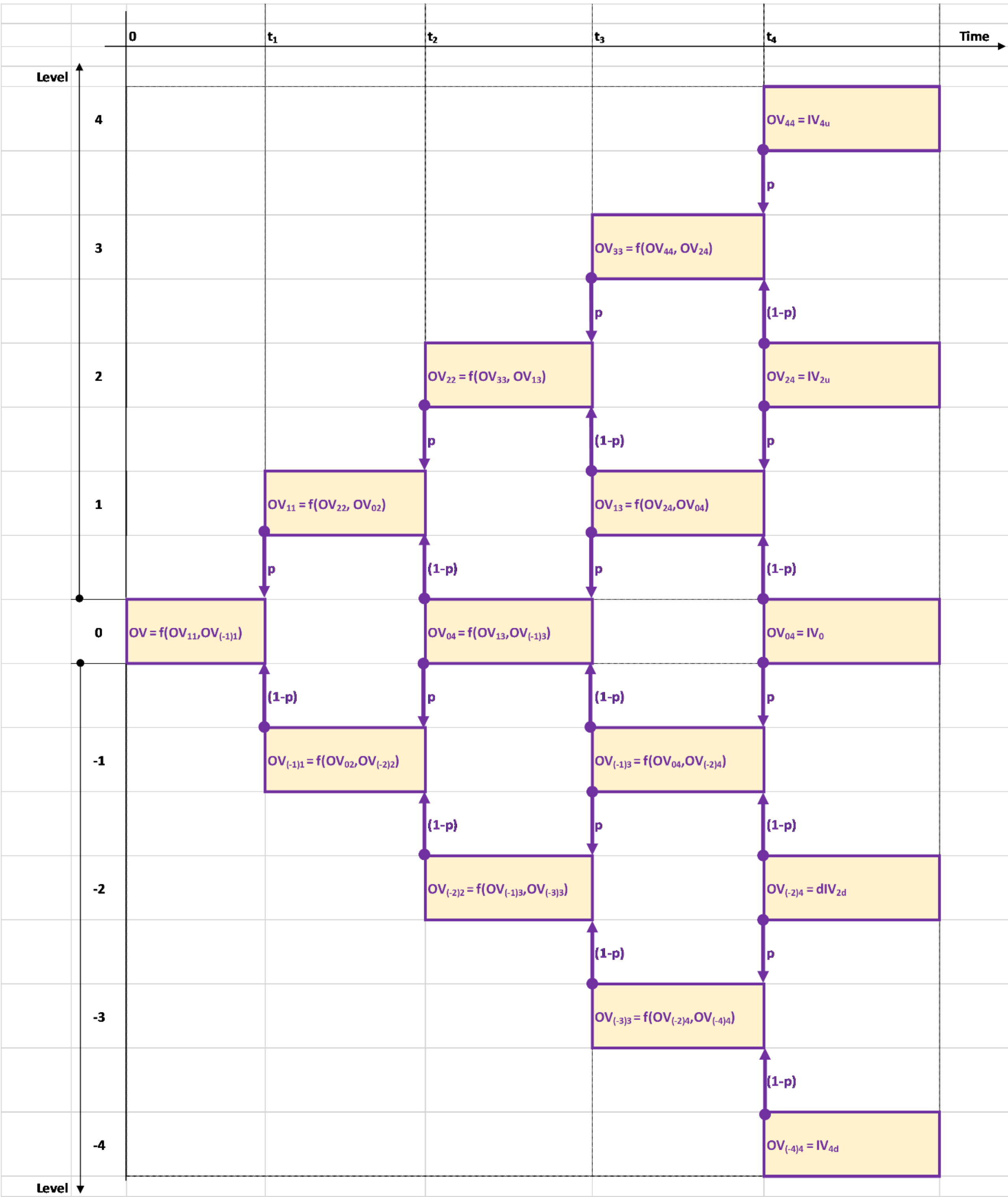

Fig. 10. *Calculation of the final option value. Source: Author.*

OV_{jt} represents option value in level **j** in period **t**. Function **f** is the function for option value calculation (equation (4)).

$$OV_{jt} = \frac{1}{1+r} \cdot (p \cdot OV_{(j+1)(t+1)} + (1-p) \cdot OV_{(j-1)(t+1)}) \quad \textbf{(17)}$$

Where **p** is the probability value, calculated by the equation (3). **OV_{00}** represents the final option value of the whole ROA analysis **OV**.

$$OV = OV_{00} \quad \textbf{(18)}$$

The calculated value represents a financial valuation of the cloud flexibility. Organizations can use it as another criterion for the selection of cloud computing or on-premise solution. If the calculated value is greater than zero, the flexibility of cloud computing solution brings organization adding value. If the calculated value is zero, there is no added value of the cloud computing flexibility.

7 Conclusion

The paper describes the first version of the Real Options Analysis method used for the cloud computing flexibility valuation. The method compares costs of on-premise and cloud computing solutions used for the satisfaction of the same business requirements. It combines calculation of call and put options. The final calculated value represents a financial evaluation of the cloud computing flexibility. The higher the calculated value is, the more flexible IT infrastructure is. If the calculated value is equal to zero cloud computing solution does not bring any competitive advantage, and IT department has to use another method for comparison of cloud computing and on-premise solutions.

Presented example is based on the assumption that the cloud computing solution is cheaper than the on-premise solution. It should also be possible to perform opposite analysis. Instead of cloud computing costs, we could apply on-premise solutions costs. Calculated value should evaluate the flexibility advantage of the on-premise solution or disadvantage of the cloud computing solution.

The described method is the subject of our research. In chapter 6, we described ambiguities of values in the binary tree. The next step of our research will focus on this part of the method. We have to analyze whether our assumptions are correct and general. We also have to perform practical experiments because we described only the method principles in this paper. We have to prove how to use this method for the valuation of on-premise solutions advantages too.

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