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EVALUATION OF ARCHITECTURE OPTIONS IN SYSTEMS ENGINEERING

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1. Introduction

The goal of the EU-Project AMISA – *Architecting Manufacturing Systems and Industries for Adaptability* – is to optimize system's architecture towards maximum lifecycle value.
All systems and products are designed to fulfill the needs of their stakeholders. The more accurately they are able to meet these needs, the higher is their value to the stakeholder. This is not a one-point-in-time problem, but applies to the whole product life cycle. Design for Adaptability aims at minimizing the gap between stakeholder needs and the capability of a system or product to fulfill them. Minimizing this gap is a two dimensional issue. On the one hand the customer needs and requirements might change throughout the service life, resulting in an expected value gain of the system. On the other hand the system undergoes wear out and obsolescence. When talking about the stakeholder of a system, this refers mainly to the owner and the use of the system. From the view point of the manufacturer, this would be his customer.
Correspondingly, [Hashemian 2005] describes adaptations as the response of a system to new service or operational requirements. Adaptations always involve modifications to the internal structure of the system. Design for Adaptability (DfA) is a comparatively novel design paradigm. Its goal is to provide design teams a framework that helps to "maximize the reuse of design information" [Fletcher et al. 2009].
There is still a lack of understanding on the concept of adaptability, how to systematically design adaptability into systems and how to quantify the degree of adaptability of a system. This is the reason for the implementation of the European research project AMISA (Architecting Manufacturing Industries and Systems for Adaptability), whose goal is to develop a quantification methodology for adaptability [European Commission 2011].
In order to determine which adaptions can contribute to fulfilling that goal it is essential to have the capability to evaluate the value that adaptions provide in relation the the cost of making them possible.

2. Background and motivation

There are various reasons for system components to lose value and obsolesce. [Willems et al. 2003] distinguish between physical changes and changing requirements as thetwo reasons for products or components to become obsolete. Physical changes, such as wear,aging or corrosion can be encountered by the adaptation categories named *remanufacturing*, *repair* or *maintenance*. Otherwise they lead to increased operational cost and less functionality, safety and quality. Changes in requirements can be caused by legislation, changed values, technical progress or fashion trends and can be encountered by the adaptation categories named *upgrading/downgrading*, *rearrangemement*, *enlargement/reduction* or *modernization*. Adaptations always require some kind of changes to the

underlying procuct. [Fricke et al. 2000] give two different reasons, which necessitate a product to be changed. The first one is that requirements actually change and the second one is that requirements are documented or understood incompletely or incorrectly during the development phase. The latter case requires a later adjustment, even though the actual requirements have not changed. [Fricke et al. 2000] further classify the reason for changing requirements into the three so-called moving targets "Competitors", "Customers" and "Technological Evolution". They also emphasize that adaptations of products are necessary, since "today's dynamic environment results in continuous changing customer needs and, consequently, changing product requirements". They regard this issue as especially problematic if the development time of a given product lasts longer than the time span between two changes. This is the case, for example, with electronic devices within a car. Electronics exhibit a half-life that is short compared to the development time of car. Therefore, [Fricke et al. 2000] conclude that every engineer has to cope with unexpected changes no matter how precise the forecasts are.
[Browning and Honour 2008] explain the advantages of adaptability using the example of the life cycle value (LCV) of a system. As depicted in figure 1 they argue that an increased adaptability also increases the LCV of a system. This is because they assume that adaptability allows for a higher number of small upgrades instead of just a few big upgrades along the life cycle.

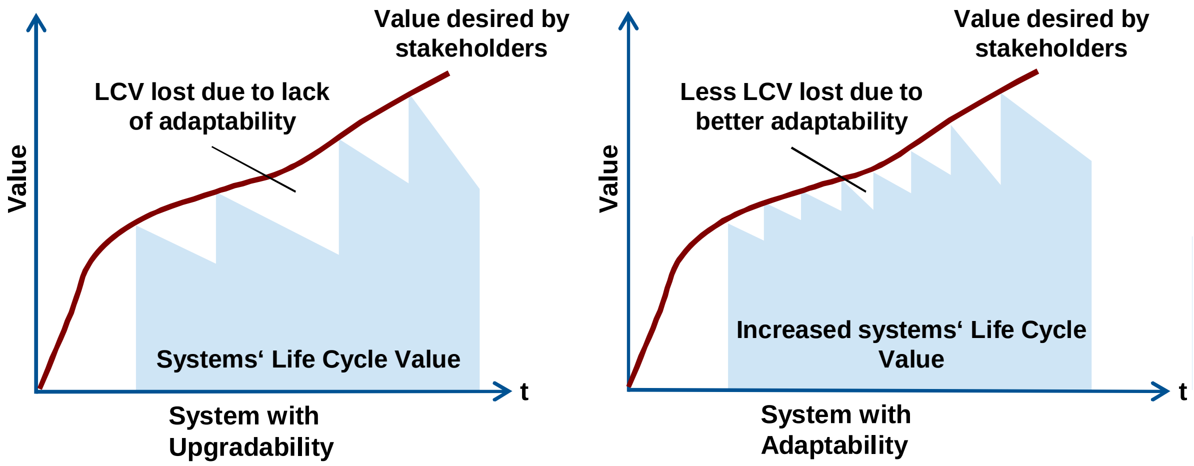

Figure 1. Increased Life Cycle Value due to increased adaptability [Browning and Honour 2008]

The value loss due to the lack of adaptability is represented by the area between the "Value desired by stakeholder" curve and the "Life Cycle Value of the system" saw toothed block. This area is the same as the value gap illustrated in Figure 1. This area is decreased by the higher number of upgrades. On the other hand, adaptability expands the life cycle time of the system, i.e. the system remains in service for a longer time and postpones the purchase of a new system.
[Fricke et al. 2000] also demand to implement a structured change management process during the product development and put "change management" and "decision management" on the same level. Changing requirements can also be regarded as one form of uncertainty in design. Uncertainty is present in the majority of engineering applications due to limited available data. [De Neufville 2004] provides a good overview on the issue of uncertainty management and defines uncertainty as "the entire distribution of possible outcomes". In his opinion, uncertainty management is very important in the field of engineering systems. Designing systems for uncertainty automatically leads to a different system architecture than that of systems that are designed with the concepts of best practice engineering. This is the case because systems considering uncertainty might need reconfiguration in order to meet new requirements. Altough uncertainty is often considered a negative issue, [De Neufville 2004] emphasizes the upside of uncertainty. He states that uncertainty management is not solely risk management, i.e. dealing with the protection of the system and its users, but relates to opportunities as well. This is because the statistical uncertainty distribution works in both the negative as well as the positive direction (comp. figure 2). Therefore, [De Neufville 2004] emphasizes that

designers must not only build indestructible and secure systems but also have to enable them to develop and adapt to changing conditions.

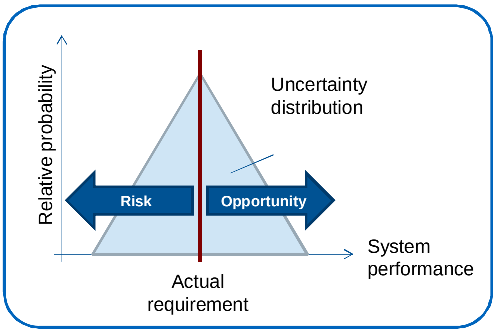

Figure 2. Risk and opportunities of uncertainty (comp. De Neufville 2004)

3. State of the art

Product architecture

The term "product architecture" (or more general "system architecture") describes the relation between the functions and the components of a product (or system): [Ulrich 1993] defines product architecture as the way how "the function of a product is allocated to physical components". He separates product architecture into the three aspects of (1) how the functional elements are arranged, (2) how the functional elements are mapped to the physical components and (3) how the interfaces between interacting components are specified. Similarly, [Whitney et al. 2004] define system architecture as "the description of the entities of a system and the relationships between those entities", in which the entities can either be functions of physical components. They state that architecture is important for many engineering fields, such as physical products, engineering systems, computer networks or software. They also describe the product architecture as the characteristics of a system that determine its "ility". [Harzenetter 2002] describes product architecture as a fundamental process during the development of a system, since it not only defines the components and modules of a system but it also determines the organization of the development project.

Definition of options

[McCafferty and Wasendorf 1998] describe options as "the legal rights, acquired for a consideration, to buy or sell something at a predetermined price by a certain time in the future". This point of time is called "expiration date" or "maturity date" wheras the price is defined as "exercise price" or "strike price" [Black and Scholes 1973]. For this definition the characteristic of the mentioned "something" does not matter: it could, for example, be a share, a house or any other contract.

Financial options

At the stock markets the idea of options is a rather old one: in the beginning an option could only be exercised at the expiration date of the option. These kinds of financial options are today called "European-style-options". On the other hand, if options can be exercised at any time up to the expiration date, they are called "American-style options" [Ward 2004]. Analysts also distinguish "call options" and "put options". A "call option" is "the right to buy a single share of common stock" [Black and Scholes 1973] whereas a "put option" is the right to sell shares [Higham 2004]. One has to keep in mind that within the automotive industry the term option is often used with a very different meaning from the one presented here for the financial world. It is used with the meaning of the possibility of choice when configuring a car.
The following paragraph will concentrate on the European call option. [Higham 2004] provides a definition as giving "(…) its holder the right (but not the obligation) to purchase from the writer a prescribed asset for a prescribed price at a prescribed time in the future". Since the exercise price [Black and Scholes 1973] is fixed, the buyer will only make profit if the market value of the asset at

the time of the expiry date is worth more than the striking price; the exact profit depends on the performance of the asset. Theoretically, the maximum profit is unlimited. In the event of the asset price being lower than the striking price, the buyer does not lose any money, since he is not obliged to exercise his option. The seller, on the other hand, might lose a great (theoretically unlimited) amount of money, and it is impossible for him to make profit. These uneven positions are balanced by the price for the option, also referred to as "option value" [Higham 2004] which the buyer has to pay to the seller – regardless of whether he will exercise his option later or not. Taking into account the option prize OP, the profit of the option for the buyer depends on the asset prize at expiry date S(T) and the exercise prize X and can be calculated as:

$$\text{Profit} = \max (S(T) - X - OP, - OP) \tag{1}$$

The maximum loss of the option holder is equal to the option prize and he will make profit as soon as the asset prize is exceeds the sum of the exercise prize and the option prize. This results in the pay-off diagram illustrated in figure 3.

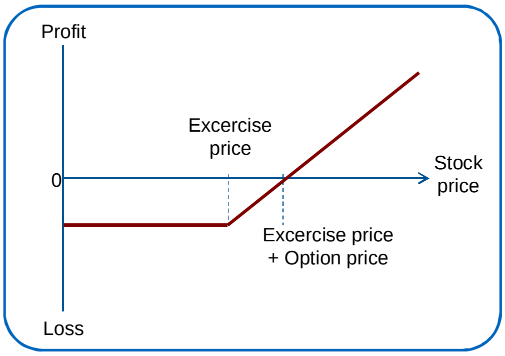

Figure 3. Pay-off diagram [Higham 2004]

Until the 1970s the option value was established completely intuitively by the traders [Moore and Juh 2006], [Engel and Browning 2008]. In 1973 [Black and Scholes 1973] published a paper about the pricing of options that attracted a great deal of attention. They derived a formula, which became an important tool in today's finance theory and is widely known as the *Black-Scholes formula*. As for all models, certain boundary conditions apply [Black and Scholes 1973], the most relevant being:

- The short-term interest rate is known and is constant through time.
- The stock price follows a random walk in continuous time with a variance rateproportional to the square of the stock price. Thus, the distribution of possible stockprices at the end of any finite interval is lognormal and the variance rate of the returnon the stock is constant.
- The stock pays no dividends or other distributions.
- The option is "European," that is, it can only be exercised at maturity.
- There are no transaction costs in buying or selling the stock or the option.

The input parameters needed to utilize the approach are listed in the following table.

Besides the Black-Scholes formular, two other main approaches for the calculation of option value exist, the binominal lattice approach as well as the Monte Carlo Simulation [Hull 2011].

In finance, the binomial options pricing model provides a generalizable numerical method for the valuation of options. The approach introduced by [Cox et al. 1979] uses a dicrete time, lattice based model of variable market value over time. In general, binomial options pricing models do not have closed-form solutions. The binomial lattice model and the Black–Scholes formula are based on similar assumptions and for European options the binomial model and the Black–Scholes formula essentially converge in calculation of Option Value as the number of time steps increases. [Rieger 2009]

Monte Carlo Simulation models calculate thousands of random possible paths of the evolution of stock prices and the resulting pay-off. The Option Value is obtained by averaging and discounting the pay-offs of the different paths [Rieger 2009].

Table 1. Input parameters used in the Black-Scholes formula [Black and Scholes 1973]

Parameter	Symbol	Description
Current stock price	S(T)	The current stock price
Exercise price	X	The excercise (or strike price) is the fixed price defined the holder of the option has to pay in case of activation the option
Interest rate	R	The short term interest rate (assumed to be const. over time)
Volatility	v	The volatility of the stock; statistical measure which expresse the uncertainty of the stock price
Maturity	T	Time span between now (t) and the expiration date (t')

All three approaches require the input data given in table 1 and both the binominal lattice model as well as the monte carlo simulation support the option value calculated in the black scholes formular for European type options for European options, but offer greater flexibility as to diverging option types, influence factors and boundary condtions. [Rieger 2009]

Real options

Real options are derived from the financial area. But in contrast to the financial options, real options are not only linked to money but they deal with physical assets. [Myers 1984] provides the examples of trading "a Federal lease for offshore exploration for oil or gas" as well as selling objects on the second hand market. The main difference between financial and real options is that the financial options are restricted to the decision of either selling or buying stocks, whereas real options more broadly evaluate the option to "do something" [Wang 2005] Since real options always deal with physical assets, these options usually last longer and are also more complex than financial options [Myers 1984]. Furthermore, [Myers 1984] proposes that option pricing might also be useful to estimate the value of strategic decisions. For instance, [Ford and Sobek 2005] suggest applying a real options approach for product development decisions.

[McGrath and MacMillan 2000] emphasize the analogy between real options and financial option contracts, as in both cases one deals with "a limited-commitment investment in a asset with an uncertain payoff that conveys the right […] to make further investments should the payoff look attractive." Additionally, they state that real options are usually less liquid than financial options and – above all – real options are more difficult to evaluate than financial ones since "the real value of an investment to one firm may differ a lot from its value to another firm" [McGrath and MacMillan 2000]. This is due to the value of any investment, i.e. real option, is not a universally valid number but depends critically on the resources and the competences available within a firm. For any quantification method that will be derived, the magnitude of the calculated real option values will always depend crucially on the estimated probability of taking the option. [McGrath and MacMillan 2000] believe that precisely calculating the option value of real options is not meaningful but that instead "real options reasoning represents a robust and coherent way of thinking about highly uncertain situations".

Being convinced of the options idea, [De Weck et al. 2004] state that real options provide flexibility and they therefore consider real options within technical systems as technical elements initially embedded into a design. This provides the decision makers "the right but not the obligation […] to react to uncertain conditions".

Similarly, [Engel and Browning 2008] state that real options analysis combines technical with market considerations and also "hints at a way to estimate the value of system flexibility". Challenges however are related to the acquisition of accurate data. [Eschenbach et al. 2007] conclude that especially the volatility, which is required for the Black- Scholes equation as the measure of uncertainty, is too difficult to ascertain. In the same way [Wang 2005] describes the volatility as the weakest part of the evaluation of real options. Although it is the key input data of the real option analysis, at the same time its value is especially difficult to determine. He further states that for some real options applications it might even be impossible to estimate because of unavailable data.

Therefore, he regards the insights obtained during the real option analysis in some cases to be “more important than a specific quantitative result” [Wang 2005].

Options in product development

Further developing the idea of real options, [De Neufville 2002] suggests distinguishing two types of real options in an systems engineering context: Real options ‘on’ projects and real options ‘in’ projects (ROOP and ROIP, respectively). The first one deals with the decisions whether to launch a technical project or not. In contrast to the classic financial options, these deal with technical issues instead of assets. It does not concern the system design itself but it rather treats the underlying technical system as a “black box”. Therefore, the decision taker does not require any technical knowledge about the underlying technical system. [De Neufville 2002] calls these “real options ‘on’ projects”. Another important difference to financial options is the longer time horizon of the real option ‘on’ projects compared to financial options. Also, the value of financial options can be determined by utilizing data of its past performance, whereas real options ‘on’ projects necessitate uncertain assumptions of the future.

“Real options ‘in’ projects”, on the other hand, take account of the options within a technical system design. In this case the decision taker requires detailed inside knowledge of the underlying system and again utilize uncertain assumptions of the future in order to evaluate the option accurately [De Neufvill 2002] . Instead of evaluating investment opportunities (as ROOP do) real options ‘in’ projects concentrate on evaluating the flexibility of a design [Wang 2005]. While ROOP are relatively easy to define, ROIP are not. Within an engineering system there are always numerous design variables. Each of those represents a possible ROIP for the designer. Therefore, ROIP are more difficult to define than ROOP and the identification of the appropriate option that might lead to the desired flexibility is a significant task of ROIP [Wang 2005] .

4. Architecture options

Within the AMISA project the concept of option theory is taken further into the domain of systems engineering and defined as ***Architecture Options*** [European Commission 2011] to indicate the architecting of adaptable systems. Architecture Options provide a quantitative means for decision support on the degree of adaptability to design a system for and optimizing the respecitve system‘s architecture towards maximum lifetime value to its stakeholders. Ultimately, those options should be incorporated into a system have the highest ratio of option value to option cost.

Hence, an architecture option describes a possible future system adaption the stakeholder has a right to but not an obligation to activate. This might be a system upgrade, for example the exchange of a certain component, or a change of system scope that might consist of many singular adaptions. In this paper one respective examples is presented and utilized to expand the analogies to option theory.: The upgrade of a navigation system of an unmanned vehicle. The optimization of the systems architecture towards future adaption is aimed for.

Within this chapter the application of option theory on the architectural level of technical systems is examined. The chapter follows a top-down approach and and begins with discussing the basic setup of options in an engineering context as to the type of option that is analog and the calculation method most suitable. Then the main mathematical terms used in the calculation method are addressed and finally the interpretation of the singular input parameters for the calculation of option value is conducted. The focus is put on the correct interpretation and establishment of analogies as to the meaning of input variables and comprehending the ”big picture”.

5. Analogies between financial and engineering option scenarios

Figure 4 depicts the basic finance option scenario. The seller of the option offers the buyer the right but not the obligation to buy a certain paper at a certain time and at a certain price. The buyer in return pays the Option Price (OP) to the seller. In a fair setting the Option Price equals the Option Value at the day of trade.

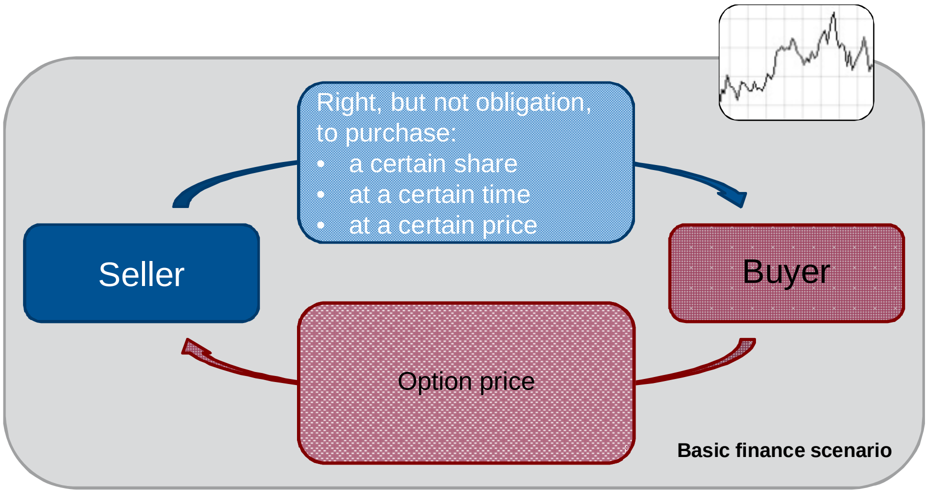

Figure 4. Basic finance option scenario

An analogous setting in engineering is depicted in figure 5. It considers a producer of an engineering system and a buyer of the same. The option in this case is a component upgrade. In this case the seller of the option is the manufacturer of a technical system, here an unmanned vehicle, who offers the buyer the right but not the obligation to upgrade the navigation system at a certain time (expiration day) and at a certain price (upgrade cost). This results in additional engineering effort for the producer and additional value for the buyer, who in return pays the Option Price.

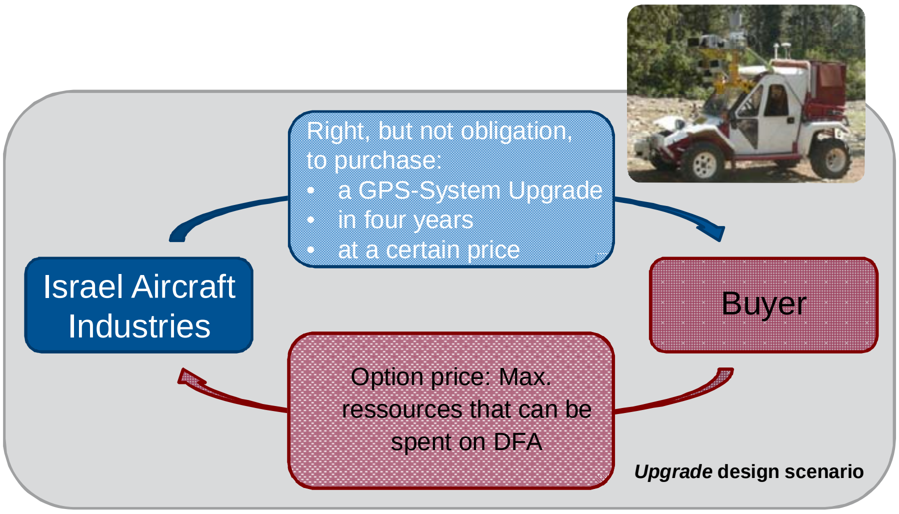

Figure 5. Upgrade design option scenario

The Option Price represents the value created by the option for the buyer and at the same time the maximum amount of money the system developer is allowed to spend on technically making that option possible. That includes all engineering effort needed to develop and physically incorporate the option into the system and is defined as Option Cost (OC). It is reflected by the delta of the cost of the system that is designed for adaptability (System A) in comparison to the initial system not designed for adaptability (System 0).

$$OC = \text{Delta (Cost System A} - \text{Cost System 0)} \quad (2)$$

The option cost shall be lower than the Option Price in order to be economically interesting to the system producer. In a fair setting the Option Price – the amount a buyer is willing to pay for having the option – equals the option value at the day of trade as well. Where Option Cost and Option Price are considered to be equal in a financial setting, it is substantial in an engineering setting that they are not. Otherwise the additional effort for the producer, which usually also results in a more complex technical system, is not justified.

$$OP >! OC \tag{3}$$

Calculation model for option value

Different calculation models for the calculation of option value, namely the Black-Scholes formula, Binomial lattice models and Monte Carlo Simulation, were discussed in the state of the art. Whereas the Black-Scholes formula is a closed analytical equation that is suitable for European type options only, Binomial lattice models as well as the Monte Carlo simulation are numerical approaches that can be used either for European or American type of options. European and American type of options differ only in the way, that latter allows the exercise of the option at any time up to the expiration day where European options can only be exercised at maturity. American options offer more flexibility and are thus more valuable [Rieger 2009].

In the basic engineering setting a component within a system is designed to be interchanged, so that the buyer of the system can conduct a system upgrade when desired. Usually the buyer of the system is not bound as to when to upgrade. Should there be rapid evolution of the components performance parameters a quick update would be just as possible as a late update in case of slow development, which is analogue to the American type options that can be activated at any time. Fundamentally, architecture options would not have an expiration day in many cases. Influence factors might be the business models or certain technical boundary conditions (i.e. obsolesce of certain interface type). As described before, American type options are generally more valuable than European type options.

The conclusion that the Black-Scholes formula, representing European type options, is unsuited for the assessment of engineering option could be drawn. But since it is sensible from an engineering point of view from to have extra security, it is proposed to take advantage of the simplicity of the calculatory model all the same. However, a sensitivity analysis as to the influence of the calculatory model is recommended as future research. Since the Binomial lattice model and the Monte Carlo simulation require equal input parameters as the Black-Scholes approach, the analogies established in the following part are valid for those also. The fact that Engineering options often do not have an expiration day furthermore adds to the safety factor of the calculation.

For the establishment of an analogue setup the Black Scholes formula is most suited though, especially because it is a closed formula and an understanding and interpretation of the equations terms is substantial.

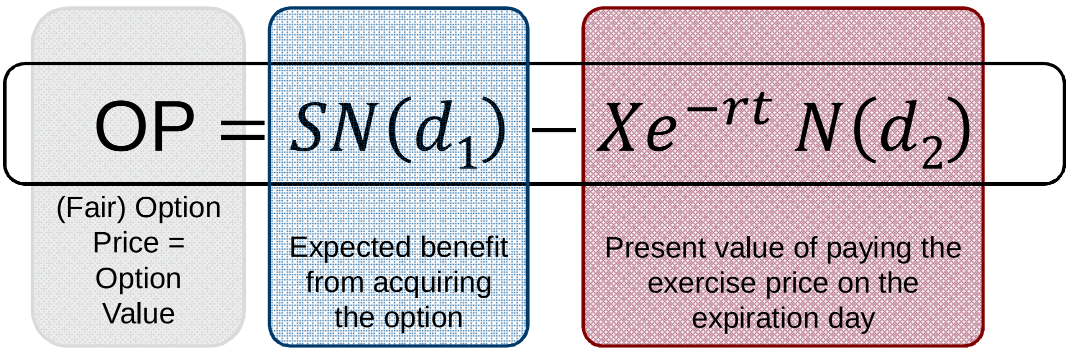

Figure 6. Black Scholes formula – main terms

The Option Price is determined by two terms as shown in Figure 6. The first term $SN(d_1)$ describes the expected benefit from acquiring the option. To obtain the option value, the present value of paying the exercise price on expiration day, described in the second term, is subtracted from the first term [Hull 2007]. The equation can be rearranged so that the expected benefit equals the Option Price plus the (present value) of the exercise price, which helps for an understanding of the formula.

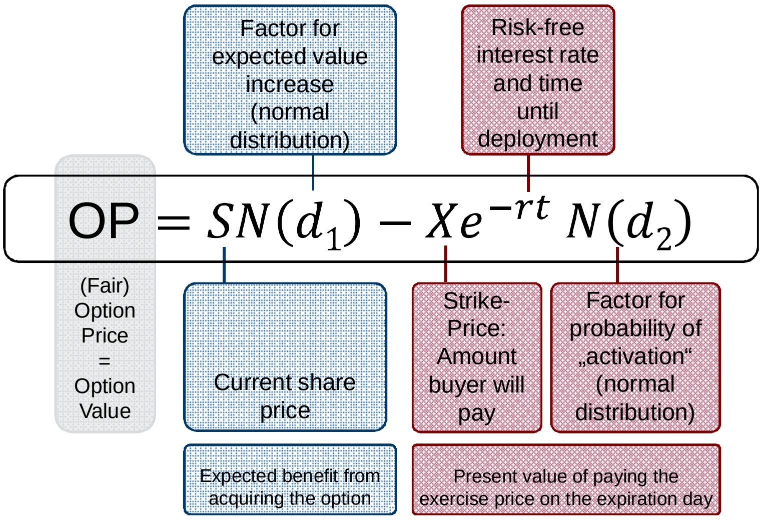

Figure 7. Black Scholes formula – singular parameters

Figure 7 depicts the terms in more detail. The term describing the expected benefit is made up of the current stock price times a factor $N(d_1)$ which is the factor by which the present value of contingent receipt of the stock exceeds the current stock price taking into account uncertainty by using risk-adjusted probabilities [Nielsen 1992].
The term describing the present value of the exercise price consists of the Strike price times a discountation factor (taking into account time until deployment and risk-free interest rate) times $N(d_2)$, the risk-adjusted probability that the option will be exercised. This is only the case if the Stock price at expiration day exceeds the strike price [Nielsen 1992].

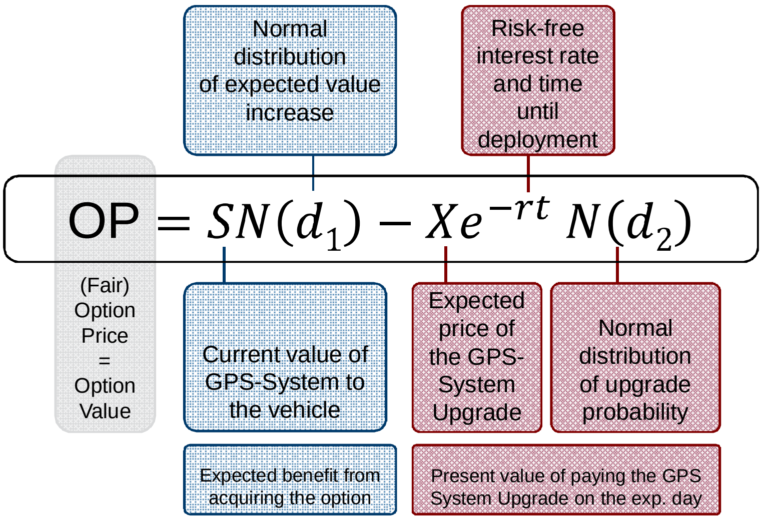

Figure 8. Black-Scholes formula – analogies in upgrade design scenario

Figure 8 shows the analogous setup of the Black Scholes equation in the basic upgrade scenario. The option under examination is that of a possible navigation system upgrade. The Option Price (in a fair scenario equal to Option Value) is defined by the estimated benefit from acquiring the option minus the present value of paying the exercise price on expiration day, as in the financial scenario. The current value of the component to the system is defined by its performance parameters. In the case of a navigation system this could be accuracy and reliability for instance. The benefit results from positive development of the components performance parameters that result in additional System Value. As in finance, that development includes uncertainties and therefore the factor $N(d_1)$ is used accordingly. The strike price in case of a component upgrade is the price that the buyer will have to pay to replace

the component and therefore coined as Upgrade Price. Discount factor and $N(d_2)$, the risk-adjusted probability that the option will be exercised, remain unchanged.
As described in the state of the art, the uncertainty factors $N(d_1)$ and $N(d_2)$ necessitate volatility as an input parameter. It is a statistical measure of the dispersion of returns for a given market index. Volatility can either be measured by using the standard deviation or variance between returns from that same market index. Commonly, the higher the volatility, the higher the Option Price. This is due to the asymmetric pay-off inherent to options. Volatility refers to the amount of uncertainty or risk about the size of changes in a security's value. A higher volatility means that a security's value can potentially be spread out over a larger range of values. A lower volatility means that a security's value does not fluctuate dramatically, but changes in value at a steady pace over a period of time.

6. Input parameters: Commonalities and restrictions

In the following commonalities and discrepancies for the input parameters between finance and engineering are discussed in more detail.

(Current) Stock price/ Component value "S"
Where the share price is clearly visible and historical data is easy to acquire, the component value of the to be adapted component to the system has to be determined. A means of doing so is to define performance parameters and associate a incremental unit for each parameter with a monetary value. In order to determine future value, both the development of the performance parameters as well as the monetary value of each incremental unit to the system, which may also change, have to be taken into account and therefore there are two sources of uncertainty. It is proposed to incorporate this factor into the volatility.

Strike price/Upgrade price "X"

The Upgrade Price, being the amount of money the buyer has to invest in case of activating the option and the strike price are analog. In the upgrade scenario, however, the Upgrade Price is mainly defined by two factors: the price of the new component and the price of the upgrade process. Both factors are related to other parameters of the formula. The price of the new component will be dependent on its performance parameters, which have an influence on the component value. A high performance component will be more expensive than a low performance one. The price of the upgrade process will be dependent on the degree the system is prepared for the adaption. This ranges from a plug and play interface, which may result in high effort in engineering but offers most easy and convenient interchange and thus minimal Upgrade Price, to mere reservation of space. In latter case the initial effort is low but the upgrade price will be high due to major changes within the system. So there can be a shift of effort between initial system design and the upgrade process and thus between Option Cost and Upgrade Price. It can be made use of to act most suitably to uncertainty situation. Another difference is that the replaced component may have a market value and can thus be subtracted from the upgrade price.

Volatility "v"

Volatility generally refers to the amount of uncertainty or risk about the size of changes in market values. Where, in finance, volatility can be measured by using the standard deviation or variance between stock-prices, data acquisition in engineering is far more critical. If the value of a component is defined by its performance parameters and the monetary value each increment of those parameters can be assigned with, volatility may be derived by tracking those historically or by accounting the standard deviation of (expert) estimations of future development.
One criticism about the Black-Scholes model is the lognormal distribution used, which does not account for volatility clusters and disruptive events [Scherer 2010]. Alternative approaches in that area have been developed and analogously the inhomogeneous development of technology can be taken into account by evolutionary forecasting and technology screening. The value is to some degree predictable due to technological evolution and expected rapid development which can be taken

advantage of. Furthermore it is to be expected that the performance of components will develop strictly positively, as depicted in the following figure [Orloff 2005].

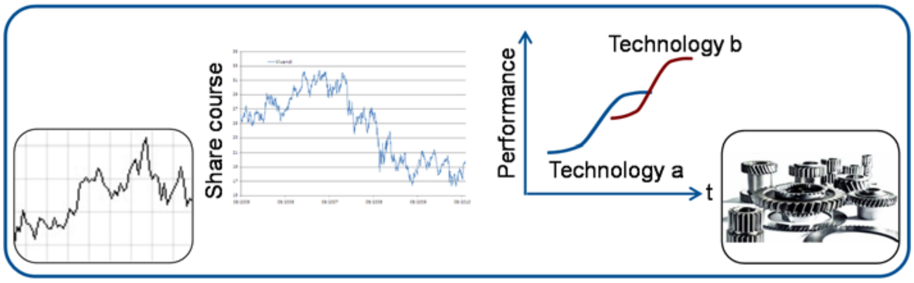

Figure 9. Comparison of volatility in finance and engineering

Payback function

Like financial options, architecture options offer an asymmetric payback function, the loss being limited to the Option Price. The unlimited payback opportunity potential due to stock price development is not realistic in architecture options, though. Realistically, there would be a limit at approximately the level of system value plus Option and Upgrade Price, since customers would prefer to buy a whole new system instead of performing an update. Advantages resulting from quicker deployment in the case of adaption in comparison to redesigning and rebuilding the system might turn the balance towards adaption still, but will probably only be relevant for major modifications in big systems.

7. Conclusions

This paper discusses the use of option theory on an architectural level of technical products or systems. The assessment of the value of possible future adaptions is identified as prerequisite for decision support on which adaptabilities to design into a technical system at an early product development phase. After presenting option theory for financial and for real options the establishment and examination of analogies of scenarios, calculatory models and input parameters for architectural options are conducted.

Analogies and discrepancies are outlined and discussed using the Black-Scholes equation and an industry example from the AMISA project context. The general set-up of financial and engineering settings is assessed in a top-down approach, with the overall idea defining the top- and the singular input parameters for the Calculation of Option Value defining the bottom-level.

Major discrepancies are identified in the definition of value, the composition of the Upgrade price as well as the pay-off function of architecture options. The input parameters need to be adjusted in order to fit the financial equation requiring a profound understanding of option theory. Those adjustments are proposed and need to be validated by conducting Option Value Assessments for different technical Systems in different industry cases. That will be performed in the course of the AMISA research project.

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