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ORIGINAL ARTICLE

A method for predicting the probability of business network profitability

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Abstract In the design phase of business collaboration, it is desirable to be able to predict the profitability of the business-to-be. Therefore, techniques to assess qualities such as costs, revenues, risks, and profitability have been previously proposed. However, they do not allow the modeler to properly manage uncertainty with respect to the design of the considered business collaboration. In many real collaboration projects today, uncertainty regarding the business' present or future characteristics is so significant that ignoring it becomes problematic. In this paper, we propose an approach based on the predictive, probabilistic architecture modeling

The current paper is an extended version of a paper previously published in LNBIP 144. The paper includes a broader literature review, addressing data elicitation, and an analysis of a real life business proposition (Proceedings of the 5th International IFIP Working Conference on Enterprise Interoperability, IWEI 2013).

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framework (P^2AMF), capable of advanced and probabilistically sound reasoning about profitability risks. The P^2AMF-based approach for profitability risk prediction is also based on the e^3-value modeling language and on the object constraint language. The paper introduces the prediction and modeling approach, and a supporting software tool. The use of the approach is illustrated by means of a case study originated from the Stockholm Royal Seaport smart city project.

Keywords Value networks · Profitability · Risk analysis · Probabilistic inference · Goal interoperability

1 Introduction

A business model is critical for any new business venture, and especially for those that involve multiple organizations, due to the complexity of their relationships. In the literature of the last decade several authors have proposed different frameworks aimed at identifying the main ingredients of a business model (e.g., Osterwalder 2004; Gordijn 2002; for an overview, see Pateli and Giaglis 2004; Alberts et al. 2012). An important motivation behind business modeling is its ability to provide an overview of the relationships between the actors involved in a business collaboration and of the way they all aim to benefit from it, financially or otherwise.

In the design phase of a business collaboration, it is desirable to be able to predict the risks concerning profitability associated with the "business-to-be". This is particularly useful in electronic business, where the market conditions change rapidly and competition is fierce due to information transparency. As an alternative to the rather costly trial-and-error approach, it is desirable to understand the properties of the envisioned collaboration already in its early phases. Therefore some of the existing business modeling approaches not only model the business, but also propose some techniques to assess qualities such as costs and revenues (Osterwalder 2004), and profitability (Gordijn 2002). However, they do not allow the modeler to properly express uncertainty with respect to the considered business collaboration. In many real collaboration projects today, uncertainty regarding the business' present or future characteristics is so significant that ignoring it becomes problematic.

Our main contribution in this paper is an approach capable of advanced and probabilistically sound reasoning about profitability risks of a given business model expressed in the e^3-value modeling language (Gordijn 2002). Such predictions may guide business managers, allowing them to explore and compare collaboration scenario alternatives at a low cost. Profitability predictions do, in fact, constitute an important element in the strategic decision making process, and a critical part of the assessment of risks associated with a new business venture. Managers routinely argue for or against alternative business opportunities based on those opportunities' expected impact on, e.g., the company's future financial and business performance. However, experience/intuition-based predictions made by individual managers have serious drawbacks in terms of transparency, consistency, and ability to correctly evaluate costs and risks. Therefore, formal approaches to business model quality prediction are required. They not only allow us to anticipate the business-to-be, but they are also a means to achieve pragmatic and, goal interoperability (Asuncion and van Sinderen 2010) in multi-actor business collaborations. Our contribution is particularly useful for the strategic management of electronic business, where the market conditions change rapidly and competition is fierce due to information transparency. Moreover, the e-business setting is particularly suitable as application area, since the quantitative input required for the application of our method is relatively easy to obtain on one hand due to existing industry benchmarks, and on the other hand due to monitoring functionality offered by existing e-business technology platforms.

The proposed profitability prediction approach draws upon our earlier work concerning the predictive, probabilistic architecture modeling framework (P^2AMF) (Johnson et al. 2013) that, in turn, is based on the object constraint language (OCL) (OMG 2010). The process we follow to develop our profitability prediction approach is as follows. In the first step, starting from the original definition of the e^3-value ontology, we define the e^3-value extension in the P^2AMF, expressed as an OCL-annotated class diagram. Consequently, any e^3-value model can be instantiated from the e^3-value extension's class diagram in the form of an object diagram. Finally, we define and implement the underlying inference algorithm for the prediction of the attribute values associated with the model elements of the object model. Thus, the execution of the inference algorithm produces, for example, predictions about the net earnings attribute values for all actors participating in a business collaboration. Such profitability predictions of each of the actors involved, are determined taking into account given levels of uncertainty (expressed as probability distributions) at three levels: uncertainty regarding attribute values of objects in the object model, uncertainty related to objects (e.g., uncertainties regarding the actors' participation in the value network), and uncertainties regarding the (existence of) relationships between objects (e.g., uncertainties related to a value exchange). This represents an important advancement compared to Gordijn's work on profitability sheets and analysis (Gordijn 2002), since Gordijn's approach only considers deterministic values for attributes, and value network models are fixed. Furthermore, due to the fact that the P^2AMF and the Enterprise Architecture Analysis Tool (EAAT) allow us to incorporate uncertainty in e^3-value models, profitability predictions can be seen as risk assessments. To the best of our knowledge, this is the first time a formal business model-based profitability risk analysis method is proposed for business models. Work on how trust assumptions affect profitability in value networks has been reported (e.g., Fatemi et al. 2011). However, it should be noted that trust is just one specific source of risk.

The remainder of this paper is organized as follows. In Sect. 2 we give an overview of the related work and relevant literature. In Sect. 3 we briefly present the original e^3-value business model ontology (Gordijn 2002). Section 4 is devoted to the P^2AMF and tool. Section 5 describes the main contribution of this paper, the profitability prediction approach, which is illustrated in Sect. 7 by means of a case study that has been defined in the scope of the Stockholm Royal Seaport (SRS) smart city project (Exploateringskontoret Stockholms Stad 2010). Section 6 covers data elicitation. The paper ends with some conclusions and pointers to future work.

2 Related work on business modeling and risk/profitability analysis

In this section we discuss the extant literature in the areas of business modeling, risk modeling and management and we address the limitations of the papers that have proposed approaches that combine the two disciplines.

2.1 Risk and profitability

Since the nineties risk management has received a lot of attention from the academic and industrial communities, and has become an important control element in the governance and management of governmental organizations, banks, and large companies. Thus, risk management is a well-established discipline with applications in various areas such as economics and marketing (e.g. Hallikasa et al. 2004; Möller and Törrönen 2003; Cucchiella and Gastaldi 2006), finance, project management, physical security, healthcare, information security (Asnar and Giorgini 2006), etc. This is also confirmed by the body of standards (e.g., ISO 31000 2009; ISO 31010 2009; The Open Group 2009) addressing this issue. Risk is defined as: "the frequency and magnitude of loss that arises from a threat (whether human, animal, or natural event)." A comprehensive overview of risk types and discussion of risk definitions is given in (Cucchiella and Gastaldi 2006). The most common risk calculation formula is that of the threat's probability multiplied with the magnitude of its effect (i.e., the size of the value loss). This definition clearly indicates that a risk should be associated with some event (the occurrence of which could represent a threat) and with some value (loss) (The Open Group 2009), which makes it very easy to consider risk analysis as integral part of profitability analysis (Aaker and Jacobson 1987). Often such an analysis focuses on the trade-off between risk levels and expected profits in a given business situation. In terms of modeling several formalisms have been proposed that capture the risk concept. For example, Sousa et al. (2013), and Iacob et al. (2012) both argue the usefulness of risk modeling within enterprise architecture. In (Iacob et al. 2012) the inclusion of a risk concept and graphical notation for the enterprise architecture modeling language ArchiMate, while (Sousa et al. 2013) borrows from the field of information security the concept of attack-defense graphs (Asnar and Giorgini 2006) to elicit, capture and analyze risks. Finally, with respect to the methodological aspects of risk management in the context of business networks and supply chains we refer to Hallikasa et al. (2004), Cucchiella and Gastaldi (2006).

2.2 Business modeling

Many business model frameworks exist that aim at facilitating and guiding business modeling, e.g., *Activity system* (Zott and Amit 2010), *e^3-value* (Gordijn 2002), *VDML* (Zott and Amit 2010), *REA* (Geerts and McCarthy 2002), *RCOV* (Demil and Lecocq 2010), *The BM concept* (Hedman and Kalling 2003), *Entrepreneur's BM* (Morris et al. 2005), *The social BM* (Yunus et al. 2010), *The BM guide* (Kim and Mauborgne 2000), *4C* (Wirtz et al. 2010), *Internet BM* (Lumpkin and Dess 2004), and *BMO* (Osterwalder 2004). Some of them have a strong link to information systems, others are closely related to strategic management or industrial organization. Most of the business model frameworks mentioned above have been published in the top 25 MIS journals. However, a systematic literature review we carried out recently (Alberts et al. 2012) resulted in an initial set of 171 journal articles and conference papers relevant for the topic of business modeling. After filtering this set of publications, we ended up with 76 articles presenting some 43 different business model frameworks. Furthermore, five articles in the reviewed literature present a review of business model literature and aim to compare some existing frameworks: (Pateli and Giaglis 2004; Gordijn et al. 2005; Lambert 2008; Al-Debei and Avison 2010; Zott et al. 2011). A common trait of most of these frameworks is that they lack the level of formality which is necessary to relate a business model to its supporting enterprise architecture at the model level. However, of the reviewed frameworks, two stand out as having, from the modeling point of view, a sufficient formal foundation: e^3-value (Gordijn 2002) and BMO (Osterwalder 2004). An extensive comparison of these two formalisms is presented in (Gordijn et al. 2005). There are some significant differences between the two approaches. In terms of the scope covered, BMO is focused on a single element of a value chain and its direct relations with customers and suppliers, while e^3-value takes a network perspective in order to provide insight into value generation outside the formal boundary of a single organization. Also, at the conceptual level they are quite different: the BMO puts emphasis on resources needed to create a certain value proposition, while in e^3-value, the modeling of value streams in a business network is central. An approximate mapping between BMO and e^3-value concepts is proposed in (Gordijn et al. 2005), which clearly reveals these differences.

2.3 Business modeling and risk/profitability analysis and management

There have been attempts to enrich business models with risk/profitability analysis instruments existing (e.g., costs and revenues Osterwalder 2004, and profitability Gordijn 2002; Gordijn and Akkermans 2007). However, as mentioned in the introduction, these are fairly simple calculations that use at best some estimates of average values as quantitative input and do not allow the business modeler to capture uncertainty with respect to the outcomes of the business collaboration under analysis.

In the context of service value networks in cloud computing, in (Michalk et al. 2011) results have been reported that focus on the trade-off between risks and expected profit. The proposed approach uses the service provider's degree of risk-aversion as a proxy for preferences towards risk and expected profit and is essentially a multi-criteria decision making method.

A framework for dealing with uncertainties in supply chains in relation with minimization of firm risks based on the real option theory is presented in (Cucchiella and Gastaldi 2006).

Finally, an empirical study that investigates the relationship characteristics that have an impact on relationship profitability in business networks is proposed and tested in (Blankenburg Holm et al. 1996).

3 The e^3-value language and ontology

In this section we motivate our choice for the e^3-value modeling formalism and briefly present the e^3-value ontology (Gordijn 2002).

When considering the level of formality, although both e^3-value and BMO have been found to be "light weight" ontologies (Gordijn et al. 2005), e^3-value is more formal than BMO since it comes with a metamodel (Gordijn and Akkermans 2003) and a graphical notation, for which reason it is also a modeling language. The fact that BMO is widely accepted is partly due to its simplicity and ease of use, which come at the cost of formality. In this paper we choose for e^3-value, because of its higher level of formalism and because it provides a network perspective on business collaborations which makes it suitable for capturing network effects regarding value propagation. Moreover, Hacklin and Wallnöfer (2012) investigated business modeling in social practice and found that non formal business models might, due to linguistic barriers and high learning curve, be inferior to formal ones. Qualitative business models can create a collective lock in and trap organizations in their identity. This might lead to failing to actualize the potential of any innovative technology a company might have, because it is so hard to switch to any new business logic. We think that by not relying only on qualitative results and by using quantitative measurements and an approach like e^3-value, this lock in can be avoided.

In the remainder of this section we briefly summarize the e^3-value modeling constructs (for more details we refer to Gordijn 2002; Gordijn and Akkermans 2003). An e^3-value model essentially describes the value exchange relationships between two or more actors involved in a business collaboration, expressed as a value network model. The main concepts defined in the e^3-value business model ontology that capture these exchanges are: actor (with its specializations, market segment and composed actor), value exchange, value object, value port, and the value interface. Besides a structural specification of the elements of a business value network and of its value streams, an e^3-value model also captures behavioral aspects of such networks with respect to the flow of value. As such, concepts such as start stimulus and end stimulus, dependency path and value exchange are used to define a so-called use case map describing the business behavior of actor in the collaboration modeled by the e^3-value model. By using use case maps, one can specify a set of value exchanges that satisfy a need in the model. In essence a use case map shows which value objects have to be exchanged for a scenario to be complete. For example if a consumer would want to buy a book from a book store, the store would have to acquire it first from a wholesaler. These are two different scenario paths with their own start and end stimuli in a use case map.

In Table 1 we summarize the definition of all these concepts, and their graphical notation. Furthermore, in Fig. 3 an example of an e^3-value model can be seen.

4 The P^{2}AMF framework

As mentioned before, we use the P^{2}AMF framework (Johnson et al. 2013) and the EAAT (Johnson et al. 2007) tool to extend e^3-value to a probabilistic setting.

Table 1 e^3-value concepts

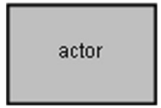
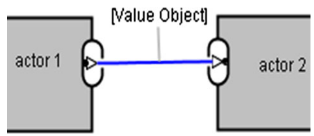
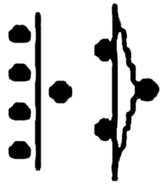
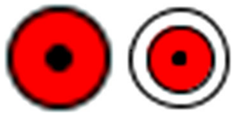
Concept	Definition	Notation
Actor	An economically independent (and often also legal) entity (Gordijn 2002)	
Market segment	Is a concept that breaks a market (consisting of actors) into segments that share common properties. It is often used to model that there is a large group of end-consumers who value objects similarly	
Value interface	Used to groups one or more value ports of one actor	
Value port	An actor uses a value port to provide or request value objects to or from his/her environment, consisting of other actors. Thus, a value port is used to interconnect actors so that they are able to exchange value objects (Gordijn 2002)	
Value exchange	Is used to connect two value ports with each other. It represents one or more potential trades of value object instances between value ports. As such, it is a prototype for actual trades between actors. […] It does not model actual exchanges of value object instances (Gordijn 2002)	
Value transaction	Concept that aggregates all value exchanges, which define the value exchange instances that must occur as consequence of how value exchanges are connected, via value interfaces to actors (Gordijn 2002)	No distinct notation is defined in the tool
Value object	A service, a product, or even an experience, which is of economic value for at least one of the actors involved in a value model (Gordijn 2002)	Is represented as a label on a value exchange relationship

Table 1 continued

Concept	Definition	Notation
Value activity	Collection of operational activities, which can be assigned as a whole to an actor and lead to creation of profit or economic value for the performing actor (Gordijn 2002)	
And/or fork and join	An AND fork connects a scenario element to one or more other elements, while the AND join connects one or more elements to one other element. An OR fork models a continuation of the scenario path into one direction, to be chosen from a number of alternatives. The OR join merges two or paths into one (Gordijn 2002)	
Start and end stimuli	Use case maps start with one or more start stimuli. A start stimulus represents an event, possibly caused by an actor. […] A use case map also has one or more end stimuli. They have no successors (Gordijn 2002)	

P^2AMF is based on the OCL (OMG 2010), which is a formal language used to describe expressions on models in the unified modeling language. OCL expressions typically specify invariant conditions that must hold for the system being modeled or queries over objects described in a model. The most prominent difference between P^2AMF and OCL is the probabilistic nature of P^2AMF. P^2AMF allows the user to capture uncertainties in both attribute values and model structure.

4.1 An introduction to P^2AMF

From the user perspective, P^2AMF has many similarities to OCL applied to class and object diagrams. As can be seen in the derivations in Sect. 5, P^2AMF statements generally appear identical to OCL statements. However, their interpretation differs because P^2AMF takes uncertainty into consideration.

In P^2AMF, two kinds of uncertainty are introduced. Firstly, attributes may be stochastic. For instance, when classes are instantiated, the initial values of their attributes may be expressed as probability distributions. To the attribute `Actor.expenses` in the following example,

```
context Actor::expenses:Real

init: Normal(3500,300)
```

a normal distribution with a mean of 3,500 and a standard deviation of 300 is assigned. The above expression determines the initial value of attribute instances. In the corresponding object diagrams, the values may be further specified in the form of *evidence*. Evidence, a term borrowed from the Bayesian theory of probabilistic inference, determines the attribute value of the instance, and may be either deterministic (hard evidence) or probabilistic (soft evidence).

Secondly, the existence of objects and links may be uncertain. It may, for instance, be the case that we do not know whether we will be able to generate solar energy next week. This can be represented as a case of object existence uncertainty (i.e., whether the generation activity will exist next week is not certain). Such uncertainty is specified using an *existence* attribute that is mandatory for all classes:

```
context GenerationActivity::existence:Boolean

init: Bernoulli(0.8)
```

where the Bernoulli probability distribution states that there is an 80 % chance that the activity in fact exists. Uncertainty with respect to the existence of links may be specified in a similar way.

The introduction of two mandatory existence attributes and the specification of attribute values by means of probability distributions thus constitute the only changes to OCL as perceived by the user. These changes, however, allow for a comprehensive probabilistic treatment of OCL-annotated class and object diagrams, including both attribute uncertainty and structural uncertainty. The mathematical approach and inference algorithms behind the approach are presented in (Johnson et al. 2013). In brief, object diagrams are subjected to Monte Carlo-based probabilistic inference with algorithms, e.g., Metropolis–Hastings (Osterwalder 2004) and rejection sampling (Walsh 2004). Attributes with previously unknown values are assigned probability distributions. Those with known probability distributions are updated in the light of their relations to neighboring attributes as well as in the light of evidence assigned to various attributes.

With the tool support presented in Sect. 4.2, the analyst can perform predictive inference on object diagrams with the click of a button. The results of the inference are new probability distributions assigned to the attributes. As these are often non-parametric, they are most easily presented in the form of histograms.

4.2 The EAAT tool

We have developed a software tool, the EAAT that allows both probabilistic class diagrams and probabilistic object diagrams to be modeled. It also performs inference as described in the previous subsection. The tool is presented in detail in (Johnson et al. 2007) and can be downloaded from (EAAT Tool Download). It is divided into two components, the CLASS MODELER, and the OBJECT MODELER, corresponding to two file types: class and object diagrams.

The CLASS MODELER is a graphical editing tool for probabilistic class diagrams. In addition to the basic editing functionality, the CLASS MODELER (1) allows attribute values to be defined either by probability distributions or by OCL expressions, (2) requires a value for the mandatory existence attributes of classes and associations, and (3) provides OCL syntax checking support.

The OBJECT MODELER has two components: (1) an editing tool for probabilistic object models, and (2) an inference engine. The editing tool (1) allows probabilistic attribute values, including the mandatory existence attributes, (2) displays histograms for all attributes representing their probability distributions after inference, and (3) offers an interface to different inference algorithms and parameters. With one click, the calculations described in Sect. 4.1 generate posterior probability distributions for all attributes. The graphical user interface of the OBJECT MODELER can be seen in Fig. 1

5 Predicting profitability risks using e^3-value models and P^2AMF

Due to the fact that the P^2AMF and the EAAT allow us to incorporate uncertainty in e^3-value models (at object, attribute and relationship levels), profitability predictions can be seen as risk assessments. Risk is generally defined as "the frequency and magnitude of loss that arises from a threat (whether human, animal, or natural

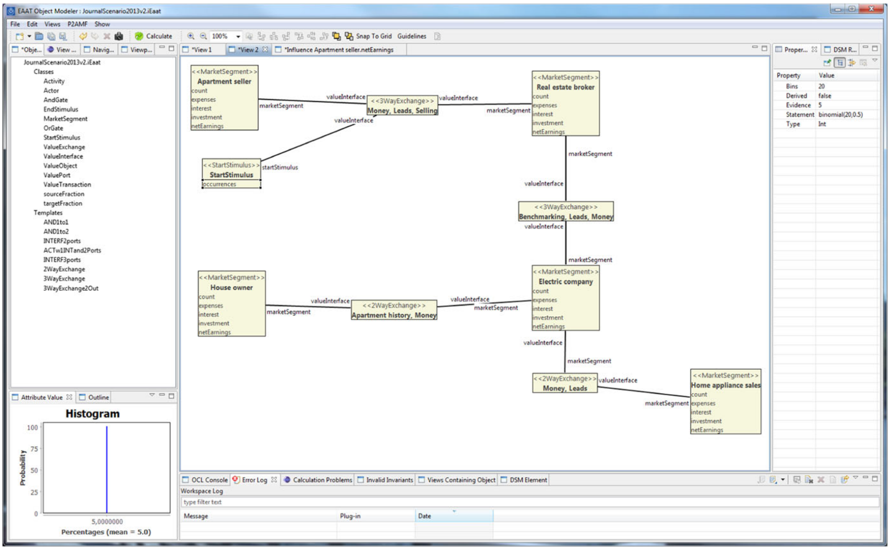


Fig. 1 EAAT object modeler's interface

event)" (The Open Group 2009) and calculated as the threat's probability multiplied by the magnitude of its effect (i.e., the size of the value loss). Thus, our profitability calculation fits in the above definition (i.e., of profitability risk) as it takes into account both uncertainty and magnitude of the net earnings. In this section we present our approach for risk prediction.

5.1 The P^2AMF e^3-value extension

As expressed in P^2AMF (Fig. 2), the e^3-value extension, sometimes also referred to as metamodel, is quite similar to the e^3-value ontology presented in (Gordijn 2002). All extension's entities and relations of the P^2AMF version can be found in the e^3-value ontology. For reasons of economy, a few concepts and relations in the e^3-value ontology have been omitted in the P^2AMF extension.

Currently, the P^2AMF version does not feature composite actors. It was also possible to omit a few elements from the use case maps of the e^3-value ontology without affecting the profitability algorithms. A few attributes and several operations have also been added in the P^2AMF-based extension. In this section, we will focus on these attributes and operations as these contain the OCL statements used to replicate the calculations of the e^3-value profitability sheet.

The graphical representation of e^3-value in EAAT is based on UML notation, which is designed for a wider usage than the original e^3-value modeling constructs. Therefore the visual side of the model is less intuitive. However, EAAT supports templates, which allows to improve visual comprehensibility. Templates are a way

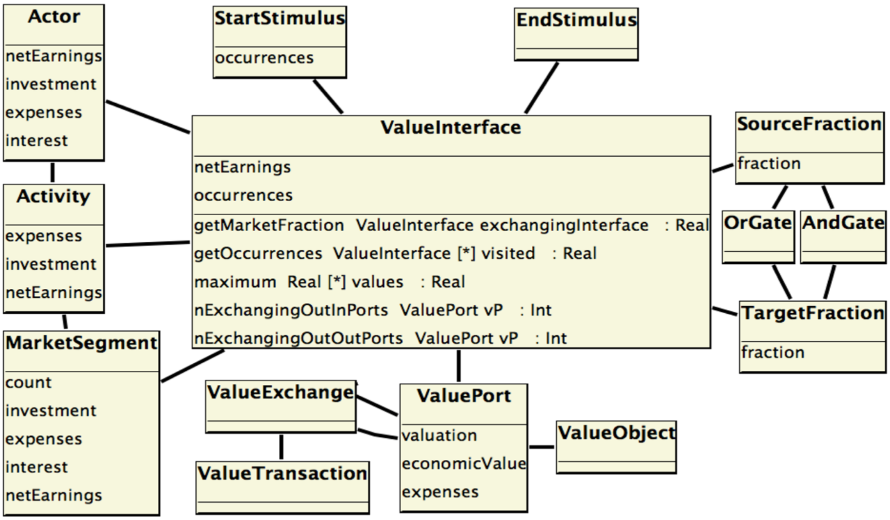


Fig. 2 P^2AMF e^3-value extension (metamodel)

of encapsulating EAAT objects, while the model retains its mathematical expressiveness.

5.2 The risk prediction approach

Predictive, probabilistic architecture modeling framework is able to include uncertainties in calculations. Using the Monte-Carlo sampling approach, nonparametric probability distributions can be generated for all attributes. The nonparametric distributions in our e^3-value calculation results express the influence that the amount of actors and occurrences has on earnings.

The main goal of the profitability analysis is to calculate the net earnings of each actor. While this attribute is not explicit in the e^3-value ontology or tool, it is calculated in the Excel profitability sheet generated by the tool. In the P^2AMF-based e^3-value extension, this attribute, `Actor.netEarnings`, is defined as follows:

```
context Actor::netEarnings: Real

derive:   self.valueInterface.netEarnings->sum()

          - self.investment - self.expenses

          - self.activity.investment->sum()

          - self.activity.expenses->sum()
```

The net earnings are thus the sum of all net earnings of the actor's value interfaces minus the actor's direct investments and expenses and the investments and expenses of the actor's activities. As noted in (Gordijn 2002), a proper net present value calculation requires a time series of e^3-value models. This is also the case for the P^{2}AMF-based version.

While investments and expenses are non-derived attributes, net earnings of value interfaces are derived.

```
context ValueInterface::netEarnings: Real

derive:   self.valuePort.economicValue->sum()
```

The net earnings of a value interface are thus the sum of the economic values of the value ports.

```
context ValuePort::economicValue: Real

derive:    if (self.valueExchangeIn->notEmpty())

           then self.valuation*self.valueInterface.getOccurrences(Set{})

           else - self.valuation*self.valueInterface.getOccurrences(Set{})

           endif
```

Each value port has a valuation attribute, specifying the value of the exchanged value object. If the value port is incoming, net earnings are increased by the product of the valuation attribute and the number of transactions. If the value port is outgoing, the net earnings are decreased by the corresponding amount. The occurrences, or number of transactions, originate from the attribute occurrence in the start stimulus. The value port occurrences are also affected by the structure of the use case map. For instance, if the scenario path from the start stimulus to the considered value port contains an OR fork with two branches, then the occurrences of the value port will be half those of the start stimulus.

In order to calculate the occurrences of a value port, a recursive algorithm (shown below) is employed. The algorithm searches through the use case map in order to find the start stimulus. The occurrence value is then propagated and transformed from value interface to value interface by various mechanisms. In many cases, the occurrence value is simply copied. In other cases, such as for the OR fork, the occurrence value is diminished by a factor equal to the number of downstream entities in the OR connection.

```
if visited->includes(self)
then 0.5
else     if (self.startStimulus->notEmpty())
         then self.startStimulus.occurrences
         else
                  let exchangingPorts1 : Collection(ValuePort)
             = self.valuePort.valueExchangeIn->excluding(null).valuePortOut in
                  let noPath1 : Boolean
             = exchangingPorts1->notEmpty() and
             self.maximum(exchangingPorts1.valueInterface.
             getOccurrences(visited->including(self))->asSet())<>0.5 in
                  let sumExchangingPortOccurrences1 : Real
             = exchangingPorts1->
             collect(eP : ValuePort | eP.valueInterface.
             getOccurrences(visited->including(self))/
             self.nExchangingOutInPorts(eP))->asSet()->sum() in
                  if noPath1
                  then sumExchangingPortOccurrences1
                  else
                           let exchangingPorts2 : Collection(ValuePort) =
                  self.valuePort.valueExchangeOut->excluding(null).valuePortOut->
                  asSet()-self.valuePort in
                           let noPath2 : Boolean =
                  exchangingPorts2->notEmpty() and
                  self.maximum(exchangingPorts2.valueInterface.
                  getOccurrences(visited->including(self))->asSet())<>0.5 in
                           let sumExchangingPortOccurrences2 : Real =
                  exchangingPorts2->collect(eP : ValuePort | eP.valueInterface.getOccurrences(visited->including(self))/
                  self.nExchangingOutOutPorts(eP))->asSet()->sum() in
                           if noPath2
                           then sumExchangingPortOccurrences2
                           else
                                    let andInterface : ValueInterface = self.andTarget.target in
                                    let andInterfaceOccurrences : Real =
                      andInterface.getOccurrences(visited->including(self)) in
                                    if not andInterface->oclIsInvalid() and andInterface->notEmpty() and
                      andInterfaceOccurrences<>0.5
                                    then andInterfaceOccurrences
                                    else
```

```
                                        let orInterface : ValueInterface = self.orTarget.target in
                                        let orInterfaceOccurrences : Real =
                           orInterface.getOccurrences(visited->including(self)) in
                                        if not orInterface->oclIsInvalid() and orInterface->notEmpty() and
                           orInterfaceOccurrences<>0.5
                                        then orInterfaceOccurrences/self.orTarget.source->size()
                                        else 0.5
                                        endif
                                endif
                        endif
                endif
        endif
endif
```

5.3 Validation of the extension

The validation of the extension has been limited to the comparison with the e^3-value software implementation. The EAAT tool (Johnson et al. 2007), where P^{2}AMF has been implemented, supports probabilistic and deterministic calculations. The deterministic calculations of the e^3-value P^{2}AMF extension give the same results as the e^3-value software tool does. This comparison with original e^3-value models allows us to claim that our extension implementation's calculations follow the e^3-value logic.

We have not tried to validate the probabilistic e^3-value approach itself. Such a validation could be possible by following a business scenario implementation, and comparing the results of the decisions taken, to the results from the P^{2}AMF e^3-value extension analysis that was done at the time of the decisions.

6 Data elicitation

The information underlying business models is often uncertain, irrespective of modeling approach. The difficulty of obtaining this data is therefore not particularly difficult for the proposed approach, but equally challenging for all business modeling methods. The alternative to attempting to obtain this information is, however, total ignorance, which, arguably, is worse.

In our data elicitation process we rely on the aforementioned e^3-value approach to identify variables with possible values and relationships between them. The more difficult part of the process is defining the inaccuracies by setting probabilities for the variables. Druzdzel and van der Gaag (2000) bring out that there are several problems associated with data collection. Most notable are biases and missing values. Their paper states that biases from data collection strategies are not easily detectable and have a definite influence to the final outcome. The end result of how precise the probabilities are depends on the domain knowledge of the people involved in the analysis. Missing values on the other hand occur mostly due to the error of omission, or measurement not making sense. Therefore it takes creativity and iterative work to elicit probabilities, which includes defining the accuracy of the values. The end result depends heavily on the beliefs of the modeler. Druzdzel and van der Gaag (2000) suggest that the most common sources for probabilistic information are statistical data, literature, and human experts. Haase et al. (2013) compare common formats for measuring subjective probability, among others visual analog scale and numeric measures. They find that numeric formats are more effective, but conclude that effectiveness of a method depends on the source and characteristics of the probability information.

Unless we completely abandon the idea of predicting business profit, we need to use incomplete data. We can fill this gap by specifying the uncertainty of data by using known methods.

7 Case study

The case study provided in this section analyzes a business proposition using the described approach. The goal of the analysis is to give scenario participants a better understanding of the profitability of the idea. Although it is a real life scenario, its only purpose here is to demonstrate the use of our approach.

7.1 Background

The SRS smart city project has a vision of becoming a world class environmental city district (Exploateringskontoret Stockholms Stad 2010). Many smart city initiatives are built upon the possibility for economic agents to make use of new available data.

One of the most exciting new possibilities within the smart city context in SRS is that it opens up ways for new types of data exchange between agents. This provides more opportunities, especially in terms of possible new business services—something that is delivered to customers and supports their needs. One idea that has recently been discussed within the project is an extension of an analytical business service that has a potential win–win situation for agents involved.

The owners of apartment buildings in SRS project have to install and manage a system for detailed energy measurement. They have to do this to be able to report levels of energy compliance along the different phases of the construction process. These systems are also used to bill the apartment owners, when the construction process has come to an end. Therefore they can be seen as mandatory, and the house owners are interested in finding ways to extend their use to fund the operation and maintenance of the measurement systems over time. This is where electric companies can help.

Electric companies, such as Fortum, have extensive knowledge about electricity usage patterns and performance indicators. They also have a vast amount of data which can be used for benchmarking or energy classification of different types. However, the companies lack data in the same granular level as the house owners, and that is why they are interested in obtaining this type of data. They need the data to be able to upgrade the quality of their analysis and thus construct new services. There are different types of customer segments, where an electric company can match their usage pattern analysis and use this for benchmarking purposes with the new data from the house owners. The company would want to do this in order to broaden its service portfolio and business possibilities. The service could give positive side effects for the electric company, such as making their brand greener.

7.2 Scenario

In our scenario an electric company wants to offer an analysis and benchmarking service of an apartment's energy consumption with recommendations to real estate brokers. The business development department of the electric company needs to analyze the scenario and come to a conclusion about its viability.

There are a number of actors involved in the scenario, which are besides the group electric companies, apartment owners, apartment buyers, real estate brokers, a group of house owners and home appliance sales stores. The motive for an apartment seller to participate is that the seller might want to be proactive before putting the apartment out on the market. In this scenario the seller has the possibility to order an extra service from the real estate broker. The service provided helps the apartment seller to understand the apartment's energy consumption, and also to identify possible energy guzzlers. That way the seller has information for improving the apartment's condition before selling it. For the example we assume that a change of appliances, to a much more energy efficient type, could make a difference in the final price of the apartment. We also assume that the electric company will offer this service to all real estate brokers. The real estate brokers are interested, since it adds value and quality to their broker services. The companies, with consent from the apartment owners, also sell leads to home appliance retailers. A lead in this case means contact information of a potential customer.

7.2.1 Data

In our analysis we elicit data for analysis from three expert interviews, SRS documentation (Exploateringskontoret Stockholms Stad 2010) and from other sources (Hemnet Service HNS AB 2013; Stockholm city 2012). The probabilities have been set according to the gathered information and the judgment of the modeler. Table 2 summarizes the data that is used in the analysis.

Our scenario takes place in the future over a 5 year period, after most of the construction work in the SRS region has completed, apartments have been sold, and some of the owners have decided to sell their apartments in the aftermarket. The scenario analysis is based on data from the current market situation, as this is in our opinion the best data available. Three experts were interviewed for this purpose, a real estate broker, a construction planner, and an electric company project manager.

Through expert interview we know that on average, midsize broker firms sell up to 300 apartments per year and that there are about 75 of such firms in Stockholm region. Considering that there are about 400,000 apartments that can be sold (Stockholm city

Table 2 Used data

Data	Mean value	Probabilistic value	Source
Apartment sales	720	B(720, 0.8)	Based on sales in Stockholm (Hemnet Service HNS AB 2013) and the amount of apartments
Cost of selling an apartment	2,500	N(2,500, 500)	Expert interview with a real estate broker
Duration of the scenario	5	–	Assumed
Electric companies	2	B(2, 0.5)	Assumed based on the amount of electric companies operating in the area
Home appliance companies	4	B(4, 0.5)	Assumed based on the amount of home appliance companies operating in the area
Investment to start the benchmarking service	100,000	N(100,000, 10,000)	Expert interview
Number of houses	200		Assumed based on SRS vision document (Exploateringskontoret Stockholms Stad 2010)
Price for a sales lead to electric company	1	B(200, 0.5) N(1, 0.1)	Assumed based on the average cost of an appliance from interview and possibility of false leads
Price for an apartment's history	50	N(50, 10)	Assumed based on the €33 maintenance cost per year
Price of the benchmarking service to the broker	120	N(120, 24)	Assumed based on the cost of providing the service
Price per lead to a home appliance store	2	N(2, 0.2)	Assumed
Profit from selling an apartment	6,000	N(6,000, 3,000)	Based on an expert interview and average real estate price from latest apartment sales in SRS (Hemnet Service HNS AB 2013)
Real estate brokers	5	B(5, 0.5)	Assumed
Value of a lead to a home appliance store	5	N(5, 0.5)	Assumed
Variable cost per benchmarking service	75	N(75, 15)	Assumed based on expert interview

2012), this makes about 6 % of sales during a year. Publicly available plans for SRS reveal that there will be altogether 12,000 apartments built in the region over a 10 year period (Exploateringskontoret Stockholms Stad 2010). The plans show that many of these apartments are located in houses of 40–50 apartments. The most commonly used remuneration model for selling apartments in the Stockholm area is a straight percentage of the purchase price. The levels are in between 1 and 3 % of the price. The expert interview also revealed that the fixed and variable costs vary around €2,500 ± 500 per apartment sale (where 2,500 is the mean and 500 is the standard deviation of a normal distribution). The average apartment price in this scenario is deducted from the known sales prices in the region (Hemnet Service HNS AB 2013) and is around €300,000, giving the broker a turnover of €6,000 ± 3,000 EUR per apartment. From the second expert interview we learned that an apartment house's owner has an approximate cost of €33 per apartment per year for billing and maintenance of measurement devices. To be able to create the benchmarking service, the electric company needs to invest about €100,000.

We assume that there are B(5, 0.5) real estate broker firms as customers during the first 5 years, where B is a binomial distribution (in this case with a mean value of 5). In case of normal distributions, letter N is used instead of B. We assume B(2, 0.5) electric companies want to take part. The electric companies need history data about the apartments to do the benchmarking. Based on the cost of yearly maintenance they charge the electric companies €50 ± 10 for an apartment's yearly consumption history. The variable cost for each benchmarking analysis is estimated to be about €75 ± 15, where the cost for the data from the house owners is included. The estimated price for the service to the broker is €120 ± 24 an analysis. The number of houses taking part in the service is assumed to be B(200, 0.5). We assume that B(4, 0.5) home appliance stores want to take part in this scheme and agree to pay €2 ± 0.2 EUR per lead, while valuing it to €5 ± 0.5, lead representing an interested customer. The electric companies pay €1 ± 0.1 for a lead to the real estate brokers. Because of the potential winnings, every apartment owner in our scenario has agreed to share their contact information with home appliance sales companies.

We're not interested in the profitability of the apartment sellers, and therefore only the cost of selling the apartment has been included in the calculations. Calculating the profitability of a sale to the seller would add unnecessary complexity to the scenario and would not help to estimate the profitability of the other agents that we're really interested in.

7.3 Results

The actors that we model are apartment seller, real estate broker, house owner, electric company and home appliance sales. The same actors are modeled using P^2AMF e^3-value extension. The aim of the analysis is to see the economic viability of the set up based on the gathered values, as a support for decision making. The results of both of the calculation approaches show profitability per actor and market segment.

7.3.1 e^3-value

The original e^3-value net value flow calculations are based on mean economic values. However, given that perfect information is rarely available, this influences the quality of results.

The profitability in e^3-value is calculated by subtracting costs and outgoing values from incoming values, multiplied by occurrences and adopted to the number of actors in a path. The strong side of the original e^3-value approach compared to the P^2AMF extension is the intuitive visual representation. The semantics of it were explained earlier. The visual model of the e^3-value model is shown in Fig. 3.

The e^3-value calculation shows that taking the high investment cost into account, the electric company loses €17,200 in 5 years, while a house owner's profit is €900, home appliance sales company's €2,700 EUR. Note that we're not interested in profits that come from apartment sales, as it is not in the focus of the current analysis.

The analysis shows that the set investment costs and pricing are not favorable for electric companies in the scenario. Given that only mean values were used here, the results give a very rough approximation. To obtain more precise results, the original e^3-value analysis would have to be conducted with different set of inputs several times, which is time consuming to do. In addition, it will be time consuming to compare these results with each other.

7.3.2 P^2AMF e^3-value

P^2AMF e^3-value extension is able to incorporate probabilistic evidence and show variability (also known as spread) of results. The graphical representation in EAAT tool can be customized using templates that are explained in Sect. 5.1. The P^2AMF e^3-value extension based model can be seen in Fig. 4. In comparison to e^3-value, the UML based P^2AMF e^3-value extension is highly customizable. Figure 4 shows single objects like MarketSegments, as well as groups of objects like 3WayExchange. For both of these object types one can hide, or unhide the attributes that they comprise, such as netEarnings.

Unlike e^3-value, P^2AMF is able to include uncertainties in calculations. The probability distributions of net earnings that were generated using Monte-Carlo sampling approach are shown in Figs. 5, 6, 7 and 8 as histograms. We exclude the distribution of the net earnings for the apartment seller, because it is not important for our analysis.

Let's consider our calculation results. While the deterministic calculations of the extension give equal results to e^3-value, the ones incorporating uncertainty differ considerably. The reason is that the mean values of the nearest integer have been replaced with binomial distributions in the extension calculations, adding the uncertainty defined by the modeler. An example of that would be that the modeler has set the amount of electric companies in the analysis to be 2 with the probability of 50 %, which gives us a mean value that is close to 1.

Predictive, probabilistic architecture modeling framework implementation generates a probability distribution for each result, which can be non-parametric. These

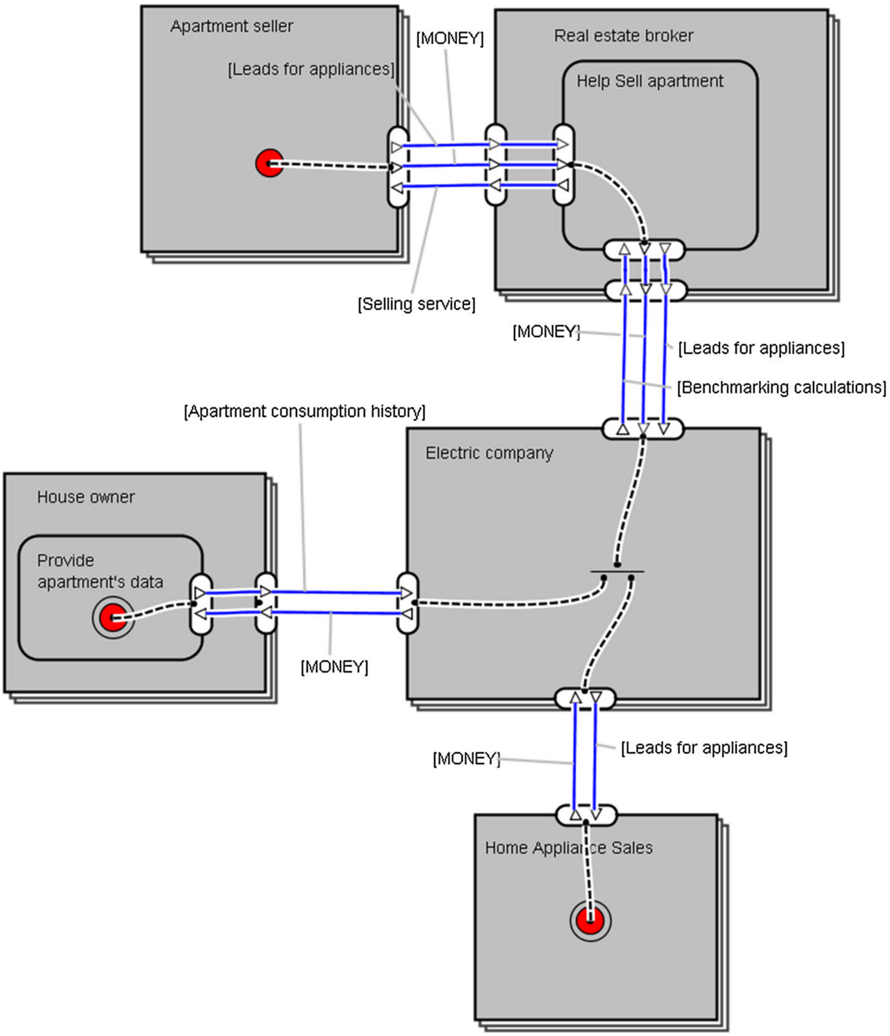


Fig. 3 e^3-value model of the scenario

distributions give us a much better understanding than just the mean values. A mean value might not reflect the real risk that a stakeholder might be taking if implementing an idea. This is apparent in our scenario analysis.

Figures 5 and 6 show us highly distributed normal distributions. One can clearly see how the uncertainty of the collected data propagates to here. The original e^3-value model predicted loss for each electric company, but the P^2AMF calculations show that it is possible to make a profit, if the circumstances are favorable. In our scenario, the number of competitors has a strong influence to the profitability of each electric company. As the market size is limited, then having more than one participant prolongs the time of getting investment money back and making a profit.

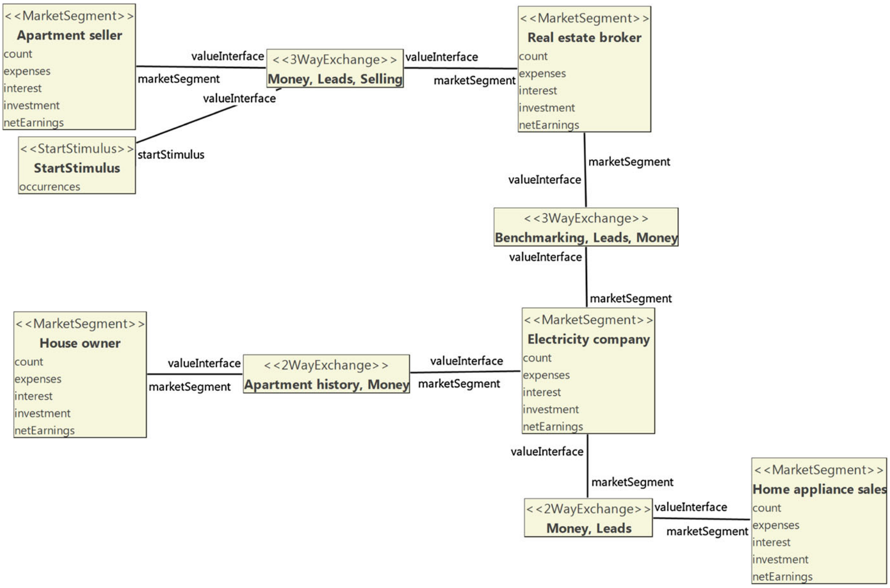


Fig. 4 P^2AMF e^3-value extension based scenario model

From an electric company perspective, this kind of scenario could fit a risk prone entrepreneur. For a more certain profit, either the price of the service, or the size of the investment will have to be reconsidered. The situation for the house owners looks also better than the mean value based e^3-value approach predicted. The house owners earn money each time an apartment in their house gets benchmarked. Therefore the number of apartments benchmarked in a house is important. It is not possible to know exactly how many of these will change owners in a single house, and that is why the spread is high in Fig. 6. The profits are higher than the mean value approach showed most likely for the same reason, as we set in our P^2AMF e^3-value extension analysis that there is only 50 % probability that apartments from all houses will be sold. The reason for steady profits here is probably that no cost was specified in the model for gathering the historic data, as the regulations require it to be gathered anyway. The income from this scenario would be pure winnings.

In Fig. 7 we see a non-parametric distribution. Non-parametric distributions give a completely different understanding of the situation than merely the mean and standard deviation of an assumed normal distribution. The mean value of the e^3-value extension is again bigger than of the original approach. Like previously, this can be attributed to the probability of existence of market participants. Although the mean value for the extension analysis is bigger, Fig. 7 shows that there is a threat for a much lower profit. If predicted based on the extension's mean value, the expectations for profit would not be met easily. This could be dangerous, if investment was considered based on mean values. The actual earnings could make the whole venture unprofitable. Therefore it is important to look at the probability distribution figures. The potential earnings differ more than 5 times.

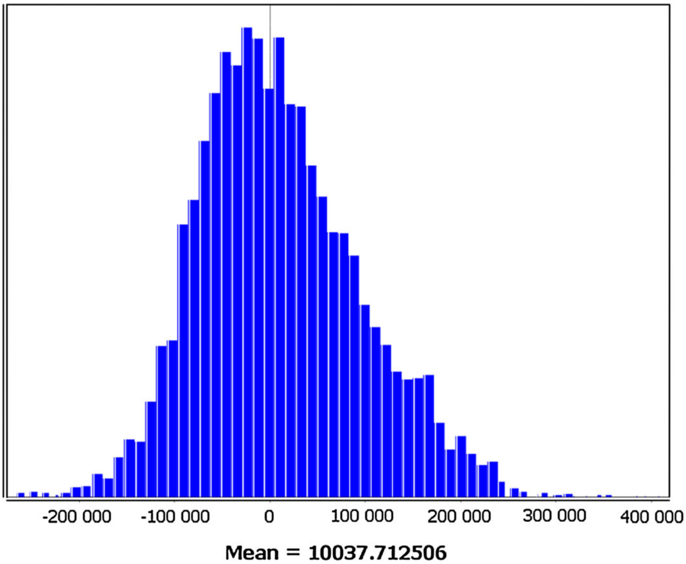


Fig. 5 Net earnings of the electric company

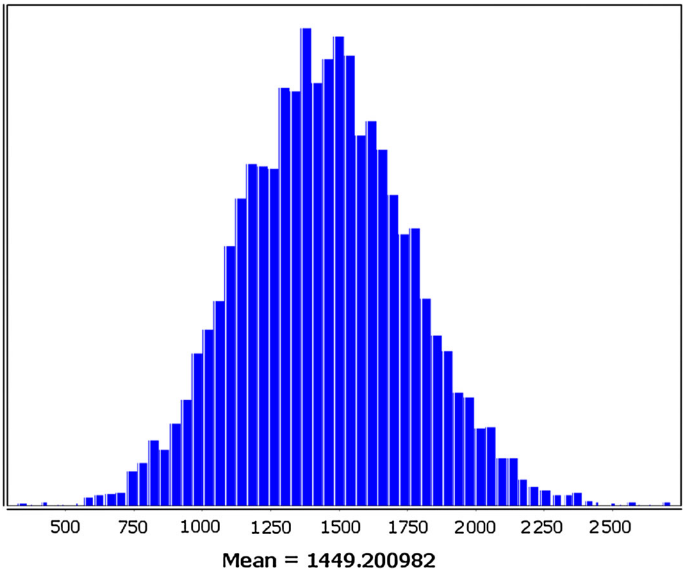


Fig. 6 Net earnings of a house owner

Lastly, we analyse the net earnings of the real estate broker. The histogram in Fig. 8 shows a normal distribution with a relatively low spread around the mean value. This means that out of the actors analyzed so far, the real estate broker has the

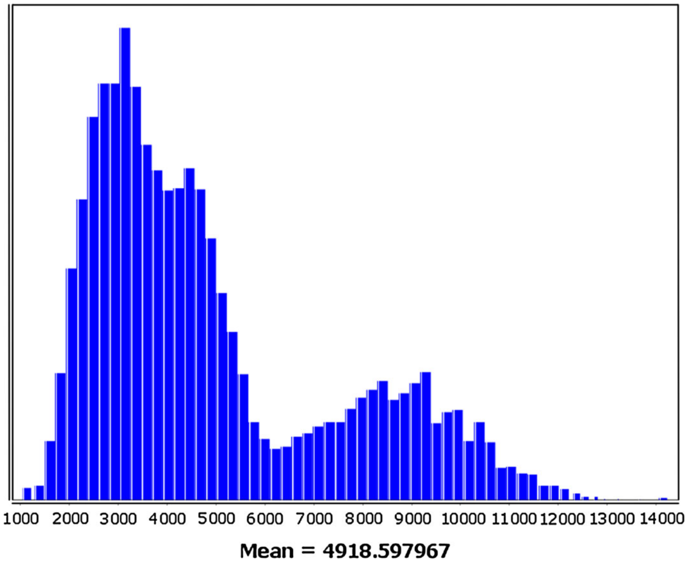


Fig. 7 Net earnings of a home appliance company

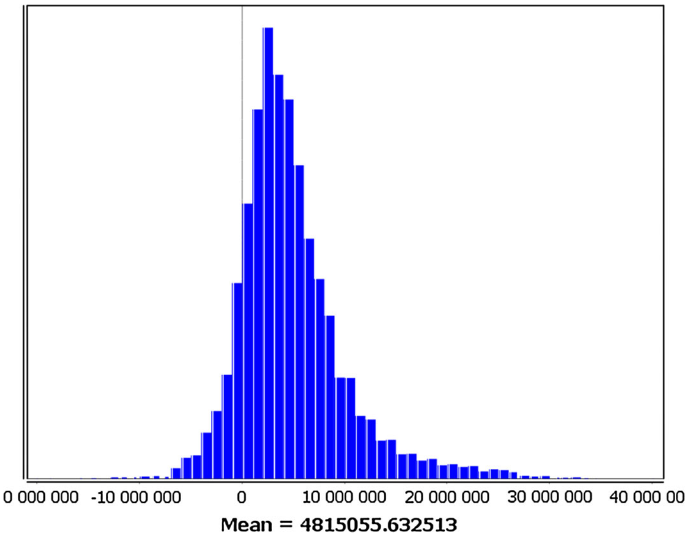


Fig. 8 Net earnings of a real estate broker

most certain income. Although the graph also shows a chance for a loss, it is a very small one, and most obviously caused by the situation where the expenses for selling an apartment exceed the profits. Should the real estate broker stick to the expenditure limits based on the apartment's price, and keep charging on the upper limit of the spectrum, the income would be certain.

We find with our results that mean value based calculation is a serious limitation to the original e^3-value methodology. By implementing the original e^3-value logic in our EAAT tool, we are able to improve the methodology's analysis capabilities significantly by bringing in the missing uncertainty and improving understandability. Our tool allows to generate probability distributions based on stochastic attributes and analyse uncertainty of existence, both of which give a clearer picture of the risks involved in a business model. However, our tool provides only decision support and the final decision to accept or reject a business scenario, will have to be made by each stakeholder independently, considering the quality of the analysis data and other factors in play.

8 Discussion and conclusions

Prediction and assessment of the expected profitability and behavior of a new business venture already in the early planning phase is a desirable capability, especially in support of strategic decision making. As the business venture becomes more complex and involves more partners, the sources of risks also proliferate, which increases the criticality of analyses taking uncertainty into consideration. In this paper, we have reported on an approach and a tool for probabilistic prediction and assessment of profitability risks. The proposed formalism is based on the e^3-value business modeling language and the P^2AMF framework, and supports automated probabilistic reasoning based on set theory, first-order logic and algebra. Our approach allows us to anticipate profitability levels expressed as probability distributions assigned to the model elements' attributes. The proposed approach assumes that the value network model is enriched with realistic probability distributions. In our paper we demonstrated that our approach is a viable alternative to mean value based analysis.

The lack of knowledge may have a negative impact on the quality of the analysis outcomes. To a very large extent this is due to the fact that value networks abstract from the internal details of the actors involved in the business collaboration. We argue that such quantitative input (of sufficient accuracy) can be obtained if one takes these internal details into account, and relates value network models to enterprise architecture models. Therefore, one direction in which we foresee a possible extension of our approach is that of chaining existing enterprise architecture cost analysis (Iacob and Jonkers 2007) and prediction techniques with the value network profitability prediction technique proposed in this study.

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