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Simple fuzzy input scorecard for intellectual property rights evaluation

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Abstract. Scorecards are an often used, structured, reporting method for the analysis and assessment of performance. In this paper we show how an advanced, but simple IPR scorecard that uses fuzzy numbers as inputs can be built and used in the analysis, evaluation, and the management of IPR resources. The scorecard has an intuitively understandable graphical presentation of the scorecard information and the final score - a triangular fuzzy number that is a distribution able to show estimation imprecision. Meaningful and intuitively understandable single number information can be extracted from the resulting distribution. As a result the scorecard offers enhanced decision support for the IPR manager for IPR resources that may be very hard to analyze in light of vague cash-flow information.

Keywords: balanced scorecard; fuzzy numbers; scenarios; valuation

Introduction

Making decisions with regards to intellectual property rights (IPR) is sometimes as much of an art as it is science. This is especially true for IPR that is strategic in nature, that is, intellectual property rights (like patents) that may become relevant sometime in the future, but that at the moment do not necessarily hold any operational, or intrinsic value. For such IPR the information available is often imprecise and inaccurate, and having such information or the sheer lack of any relevant information, makes decisions more difficult. Yet we must often make decisions based on such incomplete, vague, and imprecise information.

IPR is commonly understood as being an enabling class of assets, that is IPR can be seen as a key for firms to new (technology based) markets, or as a supporting asset for ongoing operations. In either case the relevant information about IPR is most often contingent on the markets in which the firm holding the IPR operates and on the expectations about the future of these markets, that is, on issues like the other market players, customers, and technological advances.

The more strategic the IPR is, that is the further away in the future the expected benefit from a given IPR will take place the more and the deeper the uncertainty with regards to it is, and the more inaccurate and incomplete the information about the IPR may be. When classifying the role of uncertainty with regards to IPR we can talk about different categories of uncertainty depending on the how deep the knowledge (or the lack of) is (Reilly and Schweihs, 1998, Smith and Parr, 2000): we can speak about *parametric uncertainty,* when a decision maker has an exhaustive list of all the possible future states of the world and he/she knows the consequences of these states, that is, there is certain knowledge about the structure the future (markets). Parametric uncertainty is what typically faces the decision-maker with regards to IPR assets that will soon be or already are in operational use.

A decision maker typically faces a situation characterized by *structural uncertainty,* when the structure the future can take is uncertain, that is, the agents do not know the set of all the possible future states and/or consequences of these states; this is a deeper type of uncertainty. There are many reasons for structural uncertainty, for example, the unknown actions of the (other present market) players, unintended and/or emergent (not yet existing) consequences, and there may be game-theoretic, or endogenous and exogenous uncertainties depending on the acts of existing or forthcoming rivals. Under structural uncertainty traditional analysis and valuation methods often fail. Structural uncertainty is what most often faces the decision maker when strategic IPR assets are concerned.

As potential is usually connected to uncertainty, that is, where there is uncertainty about the future outcomes there may be a possibility that the asset experiences a more positive than expected outcome, it is important from the point of view of the decision maker to highlight the potential connected to IPR assets. If the IPR assets characteristics are depicted with "averages" or other single number (crisp) descriptive the information about potential may be lost.

This paper describes how the analysis of IPR assets, facing parametric or structural uncertainty that manifest themselves as vague and/or imprecise information can be aided with a special scorecard that uses fuzzy numbers as inputs. The paper goes first through a short introduction of issues relevant for IPR evaluation and analysis. Then scorecards are shortly discussed as a management tool, and then fuzzy logic and fuzzy numbers are discussed. The paper continues with a presentation of a stylized numerical example that illustrates an application of the discussed ideas and a fuzzy IPR scorecard.

IPR analysis

Analysis of IPR is a tricky business and there is no one established only way of IPR evaluation and qualitative methods seem to be prevailing. This is clearly visible in the volume of, for example, different methods for patent valuation: out of twenty-five observed valuation and measurement methods most are qualitative measures of patent "goodness" and the ones that include valuation in terms of money rely on the conventional discounted cash-flow (Andriesen, 2004). The reason for the prevalence of qualitative methods is perhaps caused by the uncertainty and low availability of precise information that surrounds IPR assets.

In practical IPR management, the evaluation / analysis of (existing) patents takes place on a regular basis, usually once every year. During the evaluation the managers adjust their evaluation of IPR assets (for example, patent families) according to the available new data. IPR asset data can be collected in a structured way, but it is our experience that in many organization the data regarding valuation of patents and other IPR resources is more often than not, seldom methodically gathered; the analysis of IPR and the decision-making regarding IPR is most often done based on qualitative (often normative) assessments alone. There are, however also examples of how qualitative and quantitative information collection about IPR assets can be done and even of systems dedicated to the task (Camus and Brancaleon, 2003); many of the general information gathering is notably perhaps more interested in the "patent landscape" or about gathering information about if certain innovations are patentable or not, than the actual analysis of individual IPR assets held by a given company.

Since new information about the IPR assets may imply changes in assessment, it is important that these changes can be made visible to the decision makers, who determine the future of individual IPR assets and the company IPR portfolio. For this purpose, it is essential that the gathered data is processed and stored systematically and presented to the decision-makers in a coherent way that facilitates decision-making. That is, the causal logic of how a change in information affects the analysis result should be made as clear as possible. Understanding the change in information is likely to be easily conveyed by a graphical presentation. When decisions about IPR is made and analysis results are available graphically, the managers can compare the updated results to the results of previous years, and trace reasons for the change in the results; perhaps even back to individual "variables". This facilitates decision-making – it is easier to decide to continue/discontinue an IPR asset, when information about the "direction" the asset goodness (for example value) is taking, is available. The managers have also a possibility to reflect the consequences of their previous decisions and pave way for new, better informed decisions. In any case what remains is that as information about IPR assets is most often qualitative (and normative) and the type of uncertainty facing the IPR decision maker is structural, or at best parametric, the information about IPR assets is uncertain, vague, and/or incomplete.

Scorecards

Perhaps the best known management scorecard, the "balanced scorecard" was created by Arthur Schneiderman in 1987 (Schneiderman, 2006) and the method was brought to fame by articles by Kaplan and Norton (Kaplan and Norton, 1992, 1993). The balanced scorecard has mostly been used in managing and controlling the holistic performance of organizations with a focus also to non-financial measures of performance. The measuring tool that the balanced score card is, has also been used to "fuel" organizational management systems. Scorecards have been used in analysis of IPR assets, see for example (Edvinsson, 1997).

From a decision-making science - point of view the basic form of a scorecard is a rather simple multiple criteria decision analysis (MCDA) tool, an elementary non-weighted scoring system that uses a numerical scale in ranking. Indeed, when a numerical scale is used in scoring the ranking of alternatives or measurement of performance is simple – "the higher the score the better the outcome". The commonly used scorecards most often have usually been constructed by including as measurable factors issues that have a (past, observable) performance and that can be measured accurately and the given scores are based on the measuring results. In some cases, for example when IPR is concerned, the information available may be vague and imprecise and no precise measurement is possible. In fact, in forward looking analyses precise measurement is often impossible and the scorecard in its original format is a poor match. If a scorecard is used as a base for decision support that uses estimates of future values as a base it should undergo some changes; specifically as there is uncertainty connected to the future the scorecard should be enhanced so that it can take the uncertainty and vagueness (Bobillo, et al., 2009) into consideration.

A non trivial observation is that it is very likely that it is the simplicity of the scorecard that has made it such a widespread tool in management – this is an indication of intuitively understandable systems having an advantage over less intuitive, even though more scientifically mature systems.

Fuzzy numbers

Using fuzzy logic (Zadeh, 1965, 1975, 1978) and fuzzy numbers, a subset of fuzzy sets, in giving an exact representation of vague or imprecise information is widespread in many areas and used in many applications. For a good overview on applications of fuzzy sets, see for example, the Springer book series "Studies on Fuzziness and Soft Computing" with more than 150 volumes on the subject.

Triangular fuzzy numbers, a subset of fuzzy numbers and of fuzzy sets, can be defined with three values; a, α (alpha), and β (beta) where "a" is the peak (or center) of the fuzzy number and alpha and beta the left and the right width of the number. When α,β > 0 the membership function of the triangular fuzzy number has the following form:

$$\begin{cases} 1-\frac{a-t}{\alpha} & if\ a-\alpha \le t \le a \\ 1-\frac{t-a}{\beta} & if\ a \le t \le a+\beta \\ 0 & otherwise \end{cases}$$

And we use the notation (a, α, β). This kind of simplicity is well in line with how managers are accustomed to think, that is, it is compatible with thinking in (three) scenarios. Mapping three different scenarios (best expectation, a low, and a high expectation) for an input variable with a, a- α, and a+β allows us to "create fuzzy number inputs for our IPR analysis. It is clear that the relationship with the three scenarios is most likely different from the linear relationship of the triangular fuzzy number, however, for the purposes of a simple analysis it is most likely not so different that it could not be used, and is such that it does not jeopardize the reliability of the results that will most often remain at a "good enough" level.

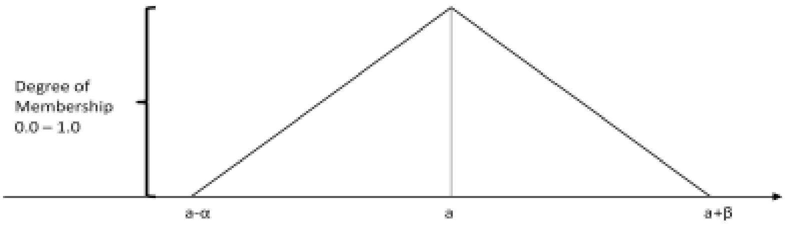

Fig. 1. Definition of a triangular fuzzy number with graphical presentation

Fuzzy logic and fuzzy numbers have been used for the analysis and valuation of IPR resources, exactly because it is a framework that can handle inaccurate "fuzzy" inputs, the kind that we now information that can be found about IPR assets can be used for. There are examples about using fuzzy logic for framing the analysis of strategic patents (Collan and Kyläheiko, 2012) and for enhancing the valuation and analysis of patents (Collan, et al., 2011, Collan and Heikkilä, 2011, Wang, 2011). Fuzzy logic has also been used, on some occasions with the balanced scorecard, for example, in expert systems based on the balanced scorecard (Amiran, et al., 2011, Bobillo, et al., 2009, Su, et al., 2011).

IPR scorecard with fuzzy inputs: numerical example

In this section we present a scorecard with fuzzy inputs through an illustration of a numerical example a selected piece, including five factors, from an IPR scorecard that is used for patent evaluation, visible in Figure 2. The structure of the scorecard is the same as of any scorecard, but for each factor three values (for three "scenarios") are given. The procedure for using the scorecard is shortly the following:

Firstly, the managers or experts are asked to give their rating of the five factors on a scale from one to ten, where one represents the minimum possible and ten the maximum possible score of "goodness" for a given factor. The scores or bundles of scores can be given a linguistic or even a numerical meaning to help in the evaluation, such as "1-2 is equal to very low" and so forth. Giving such context based meaning to the scores will help in introducing similarity of rankings if multiple experts are giving scores – if different assets are evaluated by different experts their evaluation may be based on dissimilar understanding of asset goodness if they are not directed to understand the context by linguistic or numerical specification. In other words, specifying what a score of, say "7" means is to help "normalize" the scores given by different experts. Multiple experts can be used in the valuation of a single asset, and an average or a consensus valuation can be reached, this issue is however, outside the scope of this paper. The scale of scores for the five factors is therefore between five and fifty. Three values are given for each factor score: minimum (possible), most likely, and maximum (possible) values. This "spread" or rather the width of the estimation can be used to represent the inaccuracy in the factor value estimation; each factor will have a "different" inaccuracy and this will also be reflected in the width; the more there is uncertainty the wider the width of the "scenario" values.

Motivation of patent application - score: scale 1-10	**min**	**most likely**	**max**	**weight**
Value added in the market (market share, price)	1	3	4	1
To protect own activity (against IPR of others)	7	7	8	1
Licensing (Out/Cross)	1	4	5	1
Disturbs competitor's activities (maintained due to "strategic" reasons)	6	8	9	1
Preparation for the future ("mining the landscape")	9	9	10	1
SUM	**24**	**31**	**36**	

Fig. 2. Scorecard part with three input "scenarios" for considering the vagueness/imprecision

Secondly, all the minimum, best guess, and maximum scores are aggregated to yield minimum, most likely, and maximum scenarios for the evaluated patent (IPR asset). This is done by adding up the scores for each of these alternatives, just like the scores would be added up for a scorecard using a single scenario. We can also input a weight for each factor, according to how important the factor is in relation to the other factors; this is helpful if the considered factors have unequal importance, in Figure 2 all the factors have been given the same weight.

Thirdly, using the aggregate scores we create a triangular fuzzy number from the three scorecard scores, according to the simple procedure outlined shortly above: We do this by observing that the most likely scenario is the most possible one and assign it full membership in the set of possible outcomes. We decide that the maximum and minimum scenarios are the upper and lower bounds of the distribution. We make a simplifying assumption and consider values higher than the maximum scenario and lower than the minimum scenario so unlikely that they need not be taken into consideration. After creating the triangular fuzzy score it can be used in analysis.

The company has made a decision to accept projects with a total score of more than 30; the cut-off is visible in Figure 3. and is shown in relation to the score distribution of the project under analysis. As the distribution includes information about estimation inaccuracy of the score, we can intuitively understand something about the risk of ending up with a score below the cut-off score (30, shown with a solid vertical line in figure 3 left and right) – such information is valuable for the decision-maker.

If there are more than one potential IPR assets competing for a scarce resource (money), then it is a common practice, when scorecards are used in aiding selection, to select the assets with the highest score up until the budget is fulfilled. In situations where two assets have the same or very similar single score this may create problems, because with multiple criteria considered it may be difficult to determine which alternative is better. This is when having a distribution may be highly advantageous; by comparing the distributions two assets with the same "most likely" value are easier to compare. Two competing assets' distributions are shown in figure 3 (left). Both assets have the same most likely score (31), but the other is clearly inferior, with a lower minimum and maximum values (18,31,35) vs. (24,31,36). Knowledge about the width and shape of the distribution is relevant.

Sometimes we are faced with situations where an asset offers high potential, however the most likely expectation (score) is below the acceptable level. In these cases managers sometimes override policy (cut-off) and declare the asset "strategically important", and accept it based on "gut feeling". Such decisions may be based on intuitive understanding of the value of potential, but suffer from a lack of structured support for the decision. Using fuzzy numbers can help; we can calculate a "smart" mean value, a possibilistic mean value (Carlsson and Fullér, 2001), for the asset score that takes into consideration the downside and the asset potential, defined in Definition 1.

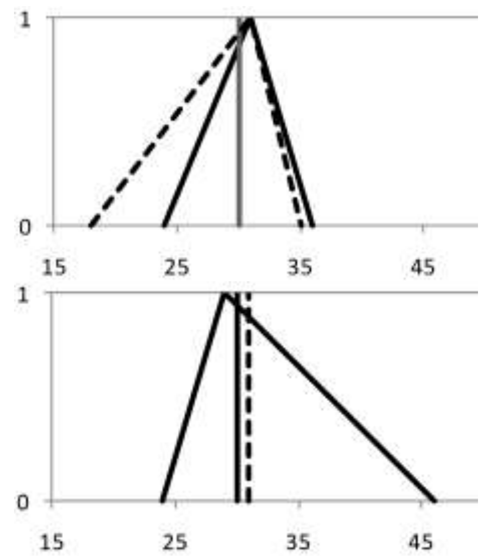

Fig. 3. Triangular fuzzy numbers based on the scorecard results ready for analysis

Definition 1. *The possibilistic mean value of a triangular fuzzy number* $E(A) = a + \frac{\beta - \alpha}{6}$.

The fuzzy score of a patent with the most likely expected value under the cut-off value of 30, but with the possibilistic mean higher than the cut-off is shown in Figure 3 (right). By calculating the mean value we get 31, which is enough to "justify" accepting the asset, and not having to rely on the gut feeling. Obviously if the potential is not large enough the asset will not be accepted, and this will be reflected also in the value of the possibilistic mean. It is possible to calculate also other crisp descriptive numbers from the triangular fuzzy numbers that can further be used to aid the decision- making, for example the real option value (Collan, et al., 2009). Simplicity of the method allows also for the use of more complex systems to be easily built, for example systems that can aid in the portfolio optimization of IPR assets, similar to for example (Hassanzadeh, et al., 2011).

Discussion and conclusions

We have shown how trapezoidal fuzzy numbers can be used as input in IPR analysis and how the analysis can benefit from using them. The ability to represent vagueness and imprecision in an IPR setting is important as information about IPR is often not precise (crisp). Use of a simple scorecard with regards to IPR analysis is also a rather new approach. We illustrated that analysis can be performed with a simple fuzzy scorecard and discussed some possible benefits of such an approach. Simplicity of the methods depicted is an asset when analysis has to be performed on a large number of separate IPR assets, for example, for portfolio analysis purposes. If a single asset requires a very complicated and/or time-consuming procedure the analysis may become prohibitively expensive; thus a simple method allows for mass analysis of IPR assets. The suitability of the fuzzy methodology for evaluating IPR characteristics, be they qualitative or quantitative, seems to be rather good.

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