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Deciding on the Appropriateness of B2B Reverse Auction Technology Adoption: An AHP Approach Combined with Integer Programming

**Tobias Schoenherr
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ABSTRACT

Although Business-to-Business online reverse auctions have emerged as a promising purchasing tool, no research has been found that provides a model to assess the reverse auction decision in a systematic way. This paper fills this gap by presenting an integrated approach, utilizing Analytic Hierarchy Process techniques and an Integer Programming Formulation, to decide whether Reverse Auction Technology (RAT) adoption is cost-effective and appropriate. The model developed is a practical decision support tool that allows for the consideration of both qualitative and quantitative decision factors, and for the adoption of multiple modes of RATs, which are contrasted to traditional purchasing.

INTRODUCTION

The exponential growth of the Internet and the rise of online commerce are creating an entirely new environment for businesses. The Internet affects the purchasing and marketing functions of products and services tremendously, especially through technologies such as Business-to-Business (B2B) e-procurement, including reverse auctions. With the diffusion of the Internet gaining momentum and the number of Internet users constantly rising, a proliferation of electronic markets, especially electronic auctions, can be observed (Klein, 1997). Deciding which auction platform, if any, to choose may thus become a challenging task. This paper facilitates and provides guidance in the selection process for the most appropriate reverse auction technology.

A reverse auction is a special type of auction. It is a real-time online competitive bidding event where the buyer sends out a request for quotation and suppliers bid on the business, decreasing their selling prices until optimally a true market price has been reached. However, not only price, but also other factors, such as quality, delivery, reliability, reputation, proximity, buyer-supplier relationship etc. may be taken into consideration. These factors, some of them more qualitative in nature, may be of greater importance than to simply obtain a lowest price.

B2B online reverse auctions have emerged as a promising and important purchasing tool. Forrester Research estimates the value of the 2002 auction market at \$52.6 billion and numerous industry and trade publications advertise the tremendous savings that can be obtained in the first few bidding events. However, it is easy to get carried away in the B2B auction hype. This new form of doing business provides not only opportunities, but also challenges, and it is crucial that a buyer considers the implications of his or her choice of purchasing mode. The current paper brings light into this area and establishes a practical decision support tool for deciding whether the adoption of Reverse Auction Technology (RAT) is cost-effective and appropriate, i.e. beneficial for the company. This model allows for the consideration of both qualitative and quantitative decision factors, and for the simultaneous adoption of multiple modes of RATs, which are contrasted to traditional purchasing.

The paper proceeds as follows. After a brief review of past research in reverse auctions, crucial decisions and considerations regarding Reverse Auction Technology adoption are explored. This forms the underlying framework for the proposed model. A discussion of the methodology, comprised of the Analytic Hierarchy Process (AHP) and an Integer Programming Formulation, follows. In the subsequent section the approach is illustrated by an example. As such, aspects influencing the various decisions are listed and substantiated, followed by an evaluation of these factors using AHP. After the Integer Programming Formulation is presented, AHP weights are integrated into it to combine quantitative and qualitative decision elements. Implications are discussed. The last section concludes.

Reverse Auctions

Although reverse auctions have been used extensively by Fortune 1,000 companies, specific academic

research in online reverse auctions has emerged only in the recent past. For example, types of terms and conditions that typically accompany purchasing contracts resulting from online reverse auctions for industrial components are discussed (Emiliani & Stec, 2001), and it is suggested that reverse auctions are especially useful as a strategic tool to procure indirect items (Gebauer & Segev, 2001). However, depending on the situation, there can be savings resulting from online reverse auctions also for non-standard products (Emiliani & Stec, 2002a). In either case, experience is crucial for success (Mabert & Skeels, 2002).

There are positive and negative views of reverse auctions in academic literature. Kinney, co-founder and executive vice president of FreeMarkets, describes how seller-bidding reverse auctions are conducted, illustrates cost savings that are possible for the buyers, and discusses implications of this new type of commerce (Kinney, 2000). However, not all accounts of reverse auctions are that positive and supportive. For instance, some (Emiliani & Stec, 2002a, 2002b; Ruzicka, 2000) paint a rather negative picture of reverse auctions and justify their assessment for example with the perpetuation of divisive business practices generated by these tools.

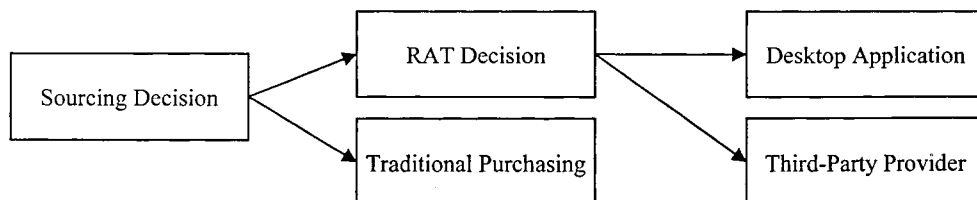
It is apparent that online reverse auctions have opportunities as well as challenges. Therefore it is important to assess carefully whether to engage in such activities or not. Electronic reverse auctions are efficient, but they may alienate the buyer's best suppliers (Jap, 2000). A decision maker must look beyond all the hype that is present in this area at the moment and consider the implications of his purchasing method decision. The following sections outline a model which facilitates this process and provides decision support.

Crucial Decisions Concerning RAT Adoption

The appropriateness of RAT adoption is to some extent similar to the Information Technology (IT) selection process. Selecting the right IT and making and justifying associated investment decisions is a difficult and cumbersome process, as was illustrated in various works (e.g., Beach, Muhlmann, Price, Paterson, & Sharp, 2000). Similar difficulties may be encountered when deciding on the appropriateness of RAT adoption.

The present study considers three major alternatives the buyer may decide on in terms of RAT adoption. First, he may decide to stick with traditional purchasing initiatives, i.e. not change anything in his procurement practices. This option is named "Traditional Purchasing." Second, he may decide to implement RAT on his desktop and conduct the auctions, mostly independently, by himself or by the company's internal procurement team, via an in-house developed system or a software application purchased from an application provider. Set-up and administration of the auction event is completely in the hands of the buying company, and minimal, if any, service assistance is provided by the auction application provider. This alternative is called "Desktop Application." And third, the buyer may opt for RAT provided by a third party, such as FreeMarkets, where this outside company conducts and manages as an intermediary (cf. Buxmann, Rose, & König, 1998) most of the auction process; this choice is labeled "Third-Party Provider." The same decision alternatives were the basis for Schoenherr's (2002) model for the adoption of B2B Reverse Auction Technology, which used an Integer Programming Formulation, however without the use of AHP. The underlying decision process is depicted in Figure 1.

Figure 1. Decision Process



METHODOLOGY

Liberatore, Monahan, and Stout (1992) criticize the exclusive use of objective measures as part of discounted cash flow capital budgeting models because of their inability to handle qualitative or intangible benefits, and tie the capital budgeting decision formally to organizational strategy. Similarly, Sangari, Mattson, and Beheshti (1999) argue that traditional cost-justification techniques associated with technology acquisition do not capture the intangible and long-term. It is therefore necessary to consider both objective and subjective criteria when deciding on IT investments and, specifically, on the appropriateness of RAT adoption. For example, the potential lower purchase price obtained in a reverse auction must be weighted against a possible alienation (Jap, 2000) of suppliers due to this approach. Such an assessment provides challenges for the decision maker, especially if numerous potential alternatives and multiple measures are involved.

The Analytic Hierarchy Process (AHP) tries to overcome the difficulty of multi-attribute decision making and facilitates the process for managers. Because of this rationale the AHP is utilized, combined with an Integer Programming Formulation. The latter accounts for objective cost criteria, whereas the former considers subjective judgments and evaluations of the alternatives, by assigning a weight to each. Similar approaches were taken by Ramanathan and Ganesh (1995) and Kearns (2001).

Analytic Hierarchy Process

The Analytic Hierarchy Process, a powerful and flexible decision making tool to prioritize alternatives and their characteristics, was developed by Saaty (1980). It was a response to the need in corporate and military contingency planning, decision making, the allocation of scarce resources, and to political participation in negotiated agreements (Vargas & Whittaker, 1990). The methodology reduces complex multi-criteria decisions to a series of pairwise comparisons and helps decision makers arrive at the best alternative (Pearson, 2001). The AHP process can be summarized with the basic four steps that need to be followed through: construct the decision hierarchy, determine the relative importance of attributes and sub-attributes, evaluate each alternative and calculate its overall weight with respect to each attribute, and check the consistency of the subjective evaluations. In the first step, the decision is decomposed into its independent elements and represented in a hierarchy diagram, which must have at least three levels (goal, attributes, alternatives). Second, the user is asked to subjectively evaluate pairs of attributes on a nine-point scale (Table 1). In a third step, a weight is calculated for each attribute (and sub-attribute), based on the pairwise comparisons. Since judgments were given subjectively by the user, the logical consistency of these evaluations is tested in a last step. The ultimate outcome of the Analytic Hierarchy Process is a relative weight for each decision alternative. For an introduction, overview and application of the technique, the special issue by the European Journal of Operational Research on "Decision Making by the Analytic Hierarchy Process: Theory and Applications" (Vol. 48, No. 1, 1990) provides an excellent reference. Details and proof of the mathematics underlying AHP can be found in Saaty (1980). Although smaller AHP problems can easily be calculated by hand, there are several commercial software packages available that facilitate the evaluation process of more complex decisions. Past research frequently employed the Expert Choice software (e.g., Cheung & Suen, 2002; Byun, 2001; Udo, 2000; McIntyre et al., 1999; Min, 1992), which is also utilized in this study (Expert Choice 2000, trial version 10.1, build 903.05, database version 2.04).

Table 1. Nine-Point Pairwise Comparison Scale (adapted from Saaty, 1980)

Numerical Value	Verbal Meaning
1	Equally important
2	Equally to moderately more important
3	Moderately more important
4	Moderately to strongly more important
5	Strongly more important
6	Strongly to very strongly more important
7	Very strongly more important
8	Very strongly to extremely more important
9	Extremely more important

Integer Programming Formulation

When the AHP step is completed, the different decision alternatives have been ranked. Nevertheless, this ranking does not necessarily reflect associated costs with each decision. Kearns (2001) cautions that no attempt should be made to incorporate costs into the AHP scheme, because they are not easily represented using a system of relative rankings. Rather, the problem should be converted into a linear or integer programming maximization problem, which is an effective approach to solving multi-criteria resource allocation problems. In the formulation, decision alternatives are used as variables, and the via AHP developed priority weights are used as the variable coefficients in the model's objective function (Ramanathan & Ganesh, 1995). Following this suggestion, an Integer Programming Formulation is developed, combined with AHP weights, for the decision concerning the appropriateness of RAT adoption.

Illustration and Discussion of the Approach

This section outlines specific factors that may influence the two crucial decisions this paper deals with, the Sourcing Decision and the RAT Decision (Figure 1). The factors were included based on previous observations (Mabert & Schoenherr, 2001a, 2001b) and several additional interviews with companies that had already implemented, were in the process of implementing, or were contemplating to implement, Reverse Auction Technology. Interviews were conducted with key purchasing professionals and e-commerce / e-procurement tool administrators. While open-ended questions were asked, one goal of the interviews was to identify factors that influence the two decisions this paper focuses on. The aspects, described in the following paragraphs, were evaluated using AHP to generate priority weights for each decision alternative. These values then serve as input parameters for the Integer Programming Formulation. How the AHP results can be integrated into the formulation is presented in detail at the end of this section.

Sourcing Decision: Traditional Purchasing or Reverse Auction Technology

The possibly significant lower purchase price achievable through RAT, often advertised in the popular press, may lure many buyers into deciding in favor of RAT adoption. However, price should not be the only reason to opt for RAT. Whether a company uses reverse auctions or continues with Traditional Purchasing should depend on several company-specific aspects, including the type of product to be procured, the importance of price, and company internal issues. As such, a major determinant may be whether the product is a direct or an indirect material, a commodity, a custom-manufactured product, or a service. Further aspects influencing the Sourcing Decision could be internal human factors, which may include issues such as knowledge and training level of employees, human resources, and the employees' support for this new technology. Some may very well be reluctant at first and resist the change to move to RAT.

On-time delivery and quality is crucial, especially in a Just-In-Time environment. With an incumbent supplier the buyer already has experience about its delivery and quality performance. Going with a new supplier is thus always risky, as its performance may not be known in advance. In reverse auctions, although suppliers have generally been qualified, this risk is emphasized. Many suppliers may participate that purchasing has not done any business with in the past, adding some degree of complexity. The same uncertainty can be seen in regard to the supplier's amount of delivery flexibility, enabling him to respond to unusual demand and emergency deliveries.

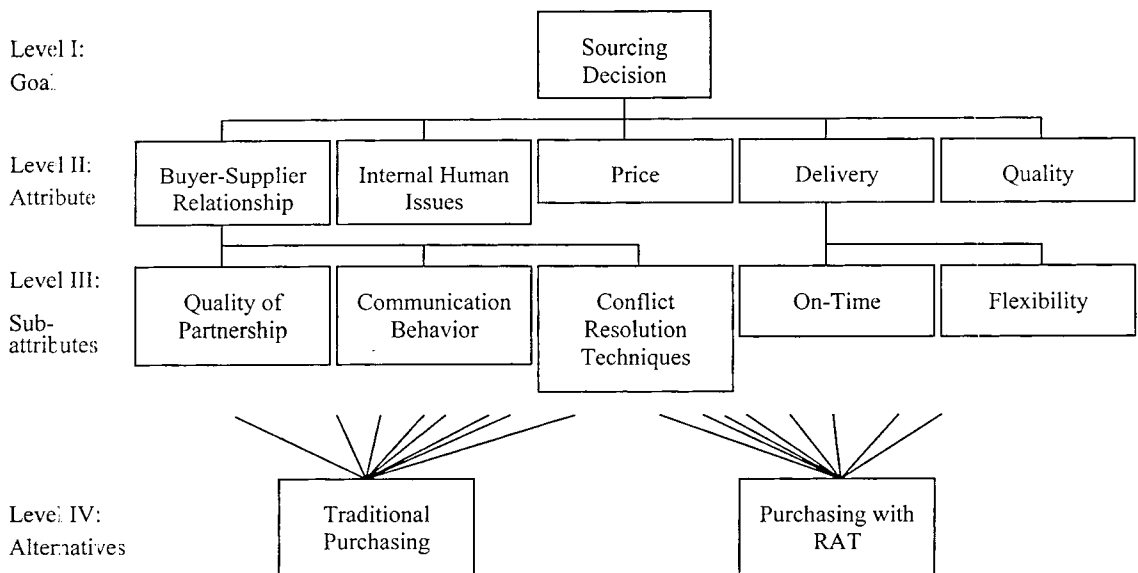
Another key concern when making the Sourcing Decision is the development of the relationship to suppliers, which can be seen as consisting of aspects such as general quality of the partnership (characterized by the degree of commitment, coordination, interdependence and trust), communication behavior (characterized by the degree of communication quality, information sharing and participation), and conflict resolution techniques (characterized by the degree of joint problem solving, persuasion, smoothing, domination, harsh words and arbitration) (Mohr & Spekman, 1994). As such, many purchasing professionals, that were interviewed for this study, are afraid that the relationship to suppliers will be negatively affected by the reverse auction process, and thus categorically refrain from engaging in online bidding events. Even once purchasing has been convinced to use RAT, reluctance to participate will most likely still be present on the supplier side. This can especially be true for incumbent suppliers, who often view reverse auctions as an adversarial way of conducting business, leading to disappointment in the buyer. Such considerations have led purchasing leaders to firmly oppose any form of RAT.

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Recognizing this fear, e-procurement providers have recently started to offer reverse auction packages that incorporate these crucial aspects, e.g. a good relationship quality to suppliers, into the decision process (Verga, 2002). The interviews conducted also revealed that purchasing often assigns weights to suppliers, indicating their standing in regard to quality, delivery, reputation, technology, attitude and administration. Submitted bids in a reverse auction are then weighted according to these additional assessment criteria, so that cost is not the only measure considered. However this issue is approached, purchasing should make every effort to educate itself and its suppliers about the process, in order to not let irrational fear prevent the parties to objectively evaluate the possibility of conducting business via RAT.

The above discussed factors are examples of indicators that could facilitate the Sourcing Decision. Figure 2 presents these in an AHP hierarchy diagram. Additional decision determinants, also more company-specific ones, may be found via brainstorming activities among multifunctional teams within the company. The list presented here merely serves as an illustration.

Figure 2. AHP Hierarchy for the Sourcing Decision



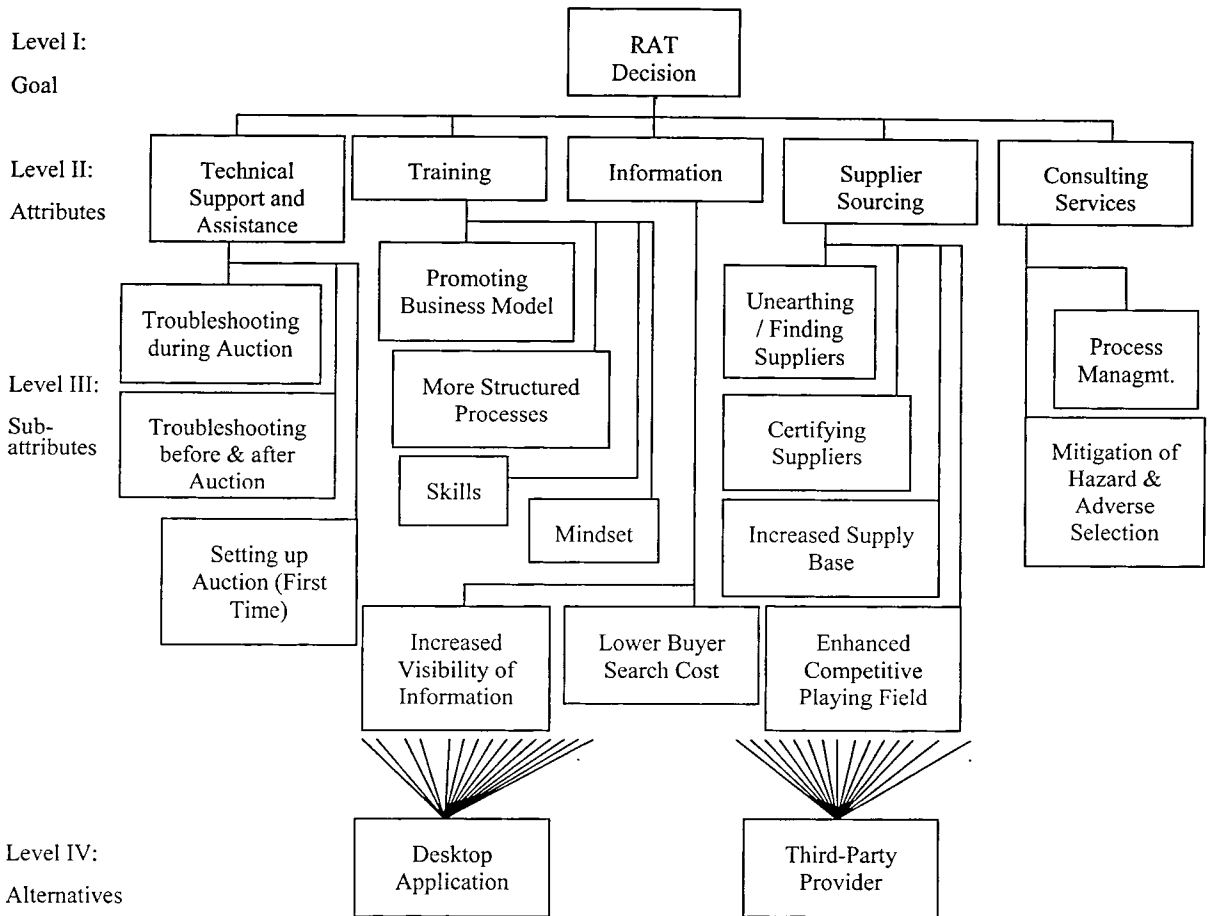
RAT Decision: Desktop Application or Third-Party Provider

Once the decision is made to engage in RAT, it has to be decided whether a desktop application should be used or whether a third-party provider should be consulted (Figure 1). The following factors, that are also presented in an AHP hierarchy diagram in Figure 3, may be influential. This list, which is presented for illustrative purposes, is exemplary and may again be extended by criteria discovered in brainstorming activities within the company.

Technical Support and Assistance. Includes setting up an auction for the first time and troubleshooting before, during and after an auction. The third-party provider is likely to provide all three of those services, whereas the desktop software provider may only support assistance for setting up the auction for the first time.

Training. Includes promotion of the business model, its alignment with company culture, establishment of more structured processes, provision of skills needed to conduct the reverse auction, and help in changing employees' mindsets so that they support the changes, which are especially in the procurement area. Here again, the third-party provider is more likely to offer most, if not all of these services, which may be crucial for the sustainability of the software and its use within the firm (cf. Vedder, Van Dyke, & Prybutok, 2002). On the other hand, in most cases the desktop application provider only supplies the software or auction platform.

Figure 3. AHP Hierarchy for the AHP Decision



Information. Includes aspects such as lower buyer-search costs and increased visibility of information. Through the third party the buyer often can get to know many more potential suppliers, which have been identified by the third party. As before, the desktop application provider is less likely to offer such services.

Supplier Sourcing. Includes activities such as unearthing, finding and certifying suppliers, and outcomes such as an increased supply base and an enhanced competitive playing field. All these value-added activities are again more likely to be supplied by the third-party provider of reverse auctions.

Consulting Services. Includes mitigation of moral hazard and adverse selection, as well as process management. Here again it is more probable that the third-party provider offers these services.

Evaluation of Decision Factors Using AHP

The factors influencing the Sourcing Decision, as discussed above, were analyzed using the AHP model Expert Choice 2000, trial version 10.1, build 903.05, database version 2.04. In the example presented here, the summarized final ratings for the individual factors are listed in Table 2 (the intermediate results are omitted for brevity). These ratings, which were obtained by pairwise comparisons, signify the relative importance the user

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assigns to each attribute. As such, quality is more important than buyer-supplier relationship, which is followed by price, delivery, and internal human issues. In other words, these values signify that if the buyer has a total of 100 minutes to devote to all of these aspects, he works 44 minutes on quality-related issues, 22.2 minutes on buyer-supplier relationship-issues, and so on. Each decision alternative, i.e. Traditional Purchasing and Reverse Auction Technology, was then also evaluated by pairwise comparisons on how well it is able to fulfill each of these attributes. With this information the overall rating for the two Sourcing Decision alternatives can now be computed (for more detail regarding the AHP approach in general please see Saaty, 1980). Traditional Purchasing received an overall weight of 0.739, and sourcing via RAT an overall weight of 0.261. In other words, based on the information obtained in previous steps, the potential user is to approximately 74% in favor of Traditional Purchasing, and to approximately 26% in favor of sourcing via RAT.

Table 2. Final Ratings of Sourcing Decision Factors

Proposed Characteristic	Rank	Overall Rating
Quality	1	0.440
Buyer-Supplier Relationship	2	0.222
Price	3	0.121
Delivery	4	0.120
Internal Human Issues	5	0.097
<i>Total All Ratings</i>		1.000

Next, the factors influencing the RAT Decision, as discussed above, were analyzed using the same AHP software. The summarized final individual factor ratings are depicted in Table 3 (the intermediate results are again omitted here for brevity). These results were obtained and can be interpreted in a similar fashion than the answers for the Sourcing Decision. The overall rating for the two RAT Decision alternatives was 0.724 for RAT provided by a third party, and 0.276 for RAT on a desktop application basis. In other words, based on the information obtained in previous steps for the RAT Decision, the potential user is to approximately 72% in favor of RAT provided by a third party, and to approximately 28% in favor of RAT via a desktop application.

It should be noted that the evaluation of attributes and sub-attributes is a subjective process, and the results may vary from person to person, and from company to company, depending on the importance assigned to each attribute and sub-attribute. This is the very nature of AHP. The calculations of hard numbers in this paper serve thus only as an illustration of the approach. However, to ensure that the rating of an individual user is internally consistent, a critical ratio value is computed (for details of this procedure see Saaty, 1980). In this paper's evaluation of the decision alternatives, for both the Sourcing Decision and the RAT Decision, the critical ratio was smaller than 0.10, which is an indication of sufficient consistency in the rankings.

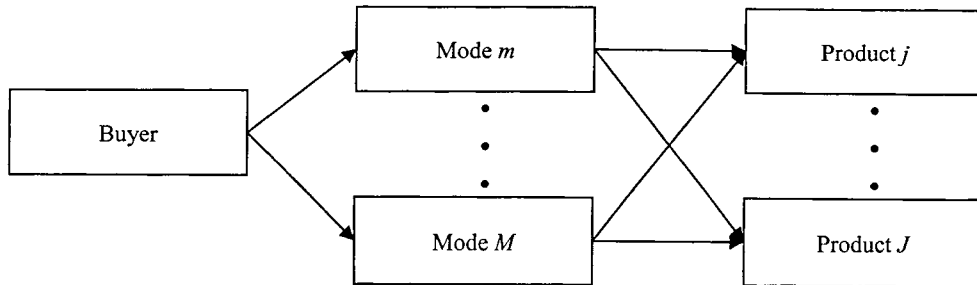
Table 3. Final Ratings of RAT Decision Factors

Proposed Characteristic	Rank	Overall Rating
Supplier Sourcing	1	0.387
Consulting Services	2	0.281
Information	3	0.213
Training	4	0.073
Technical Support & Assistance	5	0.046
<i>Total All Ratings</i>		1.000

Integer Programming Formulation

The RAT adoption problem is modeled as a binary integer program, and is examined in the context of a single buyer. Procurement of products out of set J is conducted by M possible purchasing modes (Figure 4).

Figure 4. Single-Buyer, Multi-Mode, Multi-Product Problem Structure



In the case considered in this paper there are three purchasing modes, as already outlined in previous sections (Figure 1): Traditional Purchasing ($m=1$), use of a desktop reverse auction application (“Desktop Application,” $m=2$), and use of a third party that conducts the reverse auction (“Third-Party Provider,” $m=3$). A buyer may purchase one or multiple products with the same purchasing mode. Also, the same product may be procured by the buyer via one or multiple purchasing modes. However, for a product j only one purchasing mode may be used in a given time period t , i.e. the same product in the same time period cannot be procured via multiple modes. The direction of the arrows in Figure 4 indicates that the buyer is the party who initiates the actions, first and foremost by putting up a request for quotation and inviting suppliers to the auction event. The Integer Programming Formulation can then be modeled as follows, with the notation summarized in Table 4.

$$\text{Max } \sum_{j=1}^J \sum_{t=1}^T \left[0.739 \cdot \text{NetGain}_{jt1} \cdot E_1 \cdot x_{jt1} + 0.072036 \cdot \text{NetGain}_{jt2} \cdot E_2 \cdot x_{jt2} + 0.188964 \cdot \text{NetGain}_{jt3} \cdot E_3 \cdot x_{jt3} \right] - \sum_{m=1}^3 (F_m \cdot E_m) \quad \forall j \in J, \forall t \in T \quad (1)$$

$$\text{s.t. } \sum_{m=1}^M x_{jtm} = 1 \quad \forall j \in J, \forall t \in T \quad (2)$$

$$x_{jtm} \leq E_m \quad \forall j \in J, \forall t \in T, \forall m \in K_{jt} \cap M_{\text{RAT}} \quad (3)$$

$$\sum_{j=1}^J \sum_{t=1}^T \sum_{m=1}^M x_{jtm} \cdot E_m \cdot \text{NetGain}_{jtm} - \sum_{m=1}^M (F_m \cdot E_m) \geq 0 \quad \forall j \in J, \forall t \in T, \forall m \in M \quad (4)$$

$$E_m = 1 \quad \forall m \in M_{\text{non-RAT}} \quad (5)$$

$$x_{jtm} \in \{0,1\} \quad \forall j \in J, \forall t \in T, \forall m \in K_{jt} \quad (6)$$

$$E_m \in \{0,1\} \quad \forall m \in M \quad (7)$$

The optimal solution maximizes the objective function (1) value and provides insight in how one should make decisions regarding the adoption of RAT. The objective is to select those purchasing modes that maximize the profit of the organization. Profit is represented by the term *NetGain*, which corresponds to a value for the monetary net amount gained or lost when purchasing product j in period t via method m , compared to period X , where X is a typical period before having made the RAT adoption decision. In other words, the average historic purchase price for a particular product j is compared to the new actual or potential purchase price achieved for that product at time t , given that the product is sourced via purchasing mode m . *NetGain* provides then the amount of money saved or

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lost in the new or potential purchase transaction, compared to an average historic transaction involving product j procured via mode m . For brevity, a further elaboration on and detailed calculation of *NetGain* is omitted here, but can be found in Schoenherr (2002).

Table 4. Summary of Model Notation

$NetGain_{jtm}$	=	net amount of monetary value gained when purchasing product j in period t via method m , compared to a typical period before having made the reverse auction adoption decision
J	=	index set of all products that need to be purchased
T	=	index set of time periods in planning horizon
M	=	index set of purchasing methods available
x_{jtm}	=	1 if product j is purchased in period t via method m 0 otherwise
E_m	=	1 if RAT m is used, $m \in M_{RAT}$ where $M_{RAT} = \{2, 3\}$ = enablement variable 0 otherwise
F_m	=	fixed one-time setup and training cost, where $m \in M_{RAT}$
K_{jt}	=	index set of modes by which the buyer can purchase product j in period t

The binary decision variable is x_{jtm} , and E_m is a binary purchasing mode enablement variable, indicating whether the purchasing mode has been enabled ($E_m=1$) or not ($E_m=0$). Constraints (6) restrict the decision variables to 0 or 1, and constraints (7) restrict the enablement variables to 0 or 1.

Constraints (2) ensure that only one mode of purchasing is used to source product j in period t . Using two modes to procure the same product in the same period is likely to be inefficient. Constraints (2) also ascertain that a purchasing mode is used, i.e. that products are purchased to fulfill demand. A purchasing mode must be enabled before it can be used, i.e. Reverse Auction Technology has to be implemented and people must have received training. Constraints (3) impose this stipulation. The enablement decision is made at the very beginning, i.e. if a certain RAT is used at all in any time period during the planning horizon, it is enabled for the entire time horizon. Enablement includes the one-time fixed setup and training costs associated with enabling the respective alternative. For the RAT options this can be quite significant. The last term in the objective function, after the square brackets, takes this into account. Constraints (4) ensure that at the end of the time horizon the firm should at least break even. Traditional Purchasing is already enabled at the start ($E_1=1$), since this is the mode the company uses before making the RAT Decision. Therefore there is no start-up cost in continuing with Traditional Purchasing ($F_1=0$). This condition is enforced with constraint (5).

Integration of AHP Results into Integer Programming Formulation

This section illustrates how the AHP weights for the decision alternatives can be integrated in the Integer Programming Formulation. All expressions in the formulation have been explained, except the three numerical values in front of the *NetGain* terms in the objective function (1). These values come from the AHP computations above and serve as weighting factors for the *NetGain* terms. How the AHP results are used in the Integer Programming Formulation is discussed in the following.

Use of Traditional Procurement Methods (not Reverse Auctions). Analysis with the AHP found that this option, when compared to the alternative of conducting reverse auctions, has an importance weight or preference value of 0.739. The first *NetGain* term in the objective function, $NetGain_{j1t}$, refers to the net amount saved or lost if mode 1 ("Traditional Purchasing") is used to procure product j in time period t . This *NetGain* term is now weighted by the preference for Traditional Purchasing, which is 0.739. The binary variable x_{j1t} then determines whether this method, i.e. Traditional Purchasing, is used to procure product j in period t (x_{j1t} has a value of 1) or not (x_{j1t} has a value of 0). As discussed above, Traditional Purchasing is already enabled from the beginning, i.e. $E_1=1$.

Use of Reverse Auctions. The first AHP analysis (Sourcing Decision) found that the use of reverse auctions in general, when compared to the alternative of doing purchasing the traditional way, has an importance of 0.261. If it is decided to use reverse auctions, it must further be differentiated whether to conduct the auctions with a desktop application or a third-party provider (Figure 1). This decision was labeled the RAT Decision. With the second AHP

analysis above attributes and sub-attributes for the RAT Decision were evaluated, resulting in relative preference values for both RAT alternatives. It was found that choosing a desktop application has an importance of 0.276, when compared to the alternative of having a third-party provider, which consequently has an importance of 0.724. In the previous paragraph the first *NetGain* term in the objective function was explained. The second *NetGain* term, $NetGain_{j,t,2}$, refers to the net amount saved or lost if mode 2 ("Desktop Application"), i.e. reverse auctions via a desktop application, is used to purchase product j in time period t . The third *NetGain* term, $NetGain_{j,t,3}$, refers to the net amount saved or lost if mode 3 ("Third-Party Provider"), i.e. reverse auction services supplied by a third party, is used to procure product j in time period t .

Use of Reverse Auctions via a Desktop Application. To compute the weighting factor for $NetGain_{j,t,2}$, the importance value for reverse auctions in general (0.261; determined in the AHP evaluation of the Sourcing Decision) must be multiplied by the importance value for reverse auctions conducted on a desktop application (0.276; determined in the AHP evaluation of the RAT Decision). This results in a value of 0.072036, with which $NetGain_{j,t,2}$ is weighted. The binary variable $x_{j,t,2}$ then determines whether this method, i.e. reverse auctions conducted on a desktop application, is used to procure product j in period t ($x_{j,t,2}$ has a value of 1) or not ($x_{j,t,2}$ has a value of 0). Before it can be used however, mode 2 must be enabled ($E_2=1$), taking into consideration the fixed costs associated with engagement in this type of RAT (fixed costs due to enablement of a mode are considered in the last term of the objective function).

Use of Reverse Auctions via a Third-Party Provider. Similar as above, a weighting factor for $NetGain_{j,t,3}$, the net amount saved or lost if product j in time period t is purchased with Reverse Auction Technology provided by a third party, must be determined. To get this factor, the importance value for reverse auctions in general (0.261; determined in the AHP evaluation of the Sourcing Decision) must be multiplied by the importance value for reverse auctions conducted via a third-party provider (0.724; determined in the AHP evaluation of the RAT Decision). The resulting weighting factor for $NetGain_{j,t,3}$ is 0.188964. The binary variable $x_{j,t,3}$ then determines whether this method, i.e. reverse auctions via a third-party provider, is used to procure product j in period t ($x_{j,t,3}$ has a value of 1) or not ($x_{j,t,3}$ has a value of 0). Before it can be used however, mode 3 must be enabled ($E_3=1$), taking into account the fixed costs associated with engagement in this type of RAT (again, fixed costs due to enablement of a mode are considered in the last term of the objective function).

The weighting factors for all three *NetGain* terms have now been obtained. Since the weights are relative, they all add up to 1. With these values in place, the Integer Programming Formulation combines both quantitative and qualitative decision aspects to evaluate the appropriateness of Reverse Auction Technology adoption.

CONCLUSION

A practical decision support tool for evaluating if the adoption of RAT is beneficial for a company was developed in this paper. The approach integrated the Analytic Hierarchy Process with an Integer Programming Formulation, thus combining subjective, non-monetary factors with objective, monetary criteria. This methodology and its two components were illustrated and discussed in detail.

The model allows for the consideration of both qualitative and quantitative decision factors, and for the adoption of multiple modes of RATs, which are contrasted to Traditional Purchasing. Several attributes were listed that may influence the decisions. With the proposed approach decision makers can determine whether to invest in Reverse Auction Technology to procure a specific product in a specific time period, or whether to stay with traditional purchasing practices. If the decision is made to engage in reverse auctions, the model gives decision support whether to utilize a desktop application to conduct the auction or whether to contract with a third party that administers the auction for the buyer. Overall, the decision support tool provides an opportunity to assess, whether the adoption of Reverse Auction Technology is cost-effective and appropriate for the company.

B2B reverse online auctions are a dynamic and fast-evolving area. Much work remains to be done and much is still to be learned. The Analytic Hierarchy Process combined with integer programming is just one way of approaching this issue. Schoenherr (2002) proposes an alternate way of solving the problem, utilizing integer programming and suggesting several structural measures. Nevertheless, whatever the future of procurement may look like, it is crucial that purchasing remains flexible and adapts to developments and changes in this dynamic

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market. Purchasing needs to anticipate change and, alluding to Spencer Johnson's (1998) famous parable, purchasing needs to "move with the cheese." Or like Charles Darwin commented on evolution, it is not the strongest of the species that survive, nor the most intelligent, but those that are most responsive to change. It is hoped that this paper provides a starting point for further exploration of this fascinating and fast-evolving area.

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