A Study on Developing Autonomous Procurement System (APS)

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Abstract—**This paper provides a full disclosure of a pending patent that was filed with the United States Patent and Trademark Office (USPTO) in March 2020. The proposed patent provides an autonomous solution conducting a procurement process for services and materials. However, the authors believe that there could be some challenges in building APS where AI is possibly immature in certain areas. However, building a prototype could be the first and correct step to have a fully reliable autonomous solution in procurement. This could also inspire others to have autonomous solutions in other fields that require cogitative capabilities. The paper also provides a brief description of a typical procurement process for services as a background.**

Keywords: *Procurement; Artificial intelligence; Machine learning; Natural language processing*

1. INTRODUCTION

Researchers have attempted since the 1980s to apply some AI algorithms in the procurement process [3,4,5,6,7,8,9,10]. Most previous research that attempted to employ AI algorithms in the procurement process were more theoretical and academic in nature, and they were difficult to implement in industry. In addition, the attempts to develop friendly solutions based on AI to augment procurement are fragmented. The recent advancement in algorithms, data availability, and affordable computational power (GPUs) provided new paradigms for employing AI in the procurement process. In fact, it became possible to develop an AI solution that could conduct the procurement process autonomously [1,2,3].

In this paper, a full disclosure of the Autonomous Procurement System (APS) (patent pending) is presented. The proposed invention is to execute the entire procurement process mainly for services autonomously without any human intervention. Although traditional programming is incapable of performing this task, natural language processing (NLP) and machine learning could conduct the procurement process of a similar, if not superior, quality to that processed by a human being. Prior to this paper two papers were presented in conferences where some functionalities of APS, namely: Pro forma development and bidder selection were disclosed [1].

2. PROCUREMENT PROCESS

The procurement process, especially for services, consists of several activities that are governed by certain procedures and regulations to maintain the integrity of the process. The procurement process is typically initiated due to a need. The principles of the procurement process are generally the same, with minor differences based on the procedures and rules that could vary from one organization (buyer) to another.

Figure 1 depicts the typical procurement process activities, where highlighted marks optional activities.

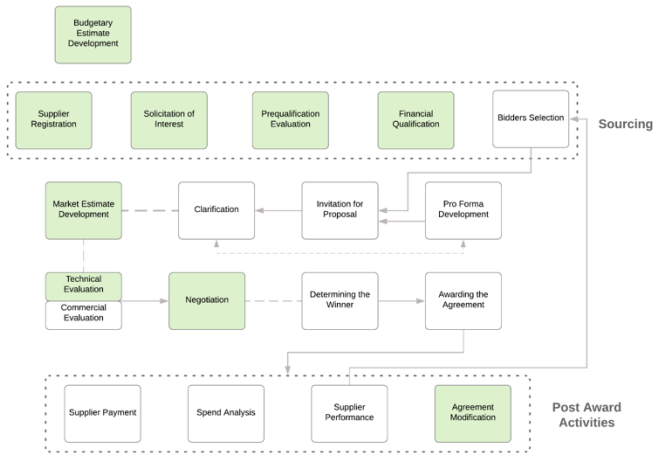

Figure 1 Traditional Procurement Process

The following 12 activities represent the typical core steps in the procurement process. However, there could be some variation from one organization to another

1) *Supplier Registration*
2) *Solicitation of Interest*
3) *Prequalification Evaluation*
4) *Financial Qualification Evaluation*
5) *Bidders Selection*
6) *Pro Forma Development*
7) *Invitation for Proposals*
8) Clarification:
9) *Commercial and Technical Evaluation*
10) *Negotiations*
11) *Estimate Development*
12) *Agreement Award*

In addition, there are other essential processes related to the contract administration, such as supplier payment processing, supplier performance evaluation, and strategic processes, such as spend analysis

During the execution of any agreement, it is always possible that some terms and conditions or requirements will need to

be modified. The modification of the agreement could be in different formats, such as a change order or amendment.

3. DESCRPITION OF APS

The procurement activities are to be fully automated and synchronized with one another. The invention is to execute the entire procurement process for services autonomously without any human intervention. The service requestor can create a procurement request in the system either verbally or in writing. The system will perform all the activities of the procurement process, including selecting bidders, issuing solicitations of interest, producing appropriate contracts pro forma, issuing invitations for proposals, receiving commercial and technical proposals, performing technical and commercial evaluation, selecting the winner supplier, and obtaining the signatures of both parties. The system is configured by assembling various applications and technologies, including blockchain, NLP, machine learning, and advanced analytics techniques to discover deeper insights, make predictions, and provide recommendations in all procurement aspects. The integration of the various applications could be built on a special platform using a suitable programming language (e.g., Python) as a back-end and a more user-friendly application as a front-end. Figure 2 depicts a general schematic of the APS.

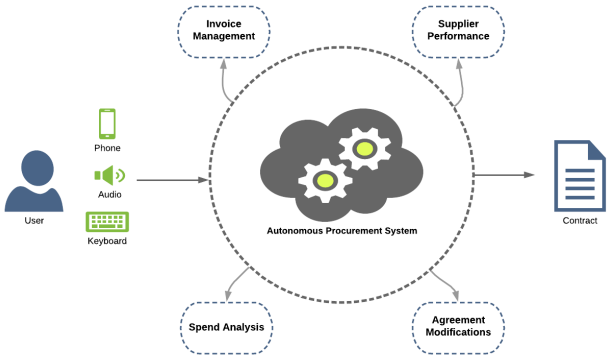

Figure 2 Autonomous Procurement System

3.1 System Configuration

The system can be unlocked using several recognition options, including biometric identification, such as finger prints, iris, facial, or voice recognition, or traditional passwords. These authentication methods will protect the system from unauthorized requests or modifications. After the system is unlocked, the user can start feeding the request and required parameters to the system through vocal or written statements.

The system must be initially configured with some default policies to determine the underlying logic for certain modules (Table1). The default initial policies will represent the best market practices. The user can make changes to the default settings to accommodate special cases or to reflect their own policies and procedures.

TABLE 1 BUYER POLICY MATRIX

Buyer Policy	Affected Module	Default Conditions
Financial Qualification	Financial Qualification	Mandatory for lump sum construction procurements with a value of more than $1MM
SOI	SOI	Mandatory for Selective Bidding and Ad Hoc Bidding
SOI Duration	SOI	10 days as a default condition
Prequalification	Prequalification Evaluation	Mandatory for all new registered suppliers with procurement estimates of more than $1MM
Bidding Strategy	Bidders' Selection	Open Bidding
Performance Bond	Financial Qualification	When performance bond is mandatory, financial qualification is not needed
Estimate Development	Estimate Development	There is no need to prepare estimates when the bidding type is competitive
Supplier Access to Estimated Quantities	Hypothetical Quantities Module	Estimated quantities are not shared with the supplier and shall be used for the sake of evaluation only
Consumer Indices	Estimate Development	Extract consumer indices from the Department of Commerce webpage
Award Strategy	Technical and Commercial Evaluation Agreement Award	Weighted evaluation formula for technical and commercial scores

3.2 Pro forma Development

It is the first activity to be executed by the system when a user initiates a procurement request as it will be a key input to many other modules of the system.

Under the proposed invention, pro forma development is linked to the initiation of the procurement request. In order to initiate a procurement process, the user can either verbally or in writing instruct the system to begin the sourcing activities. If the request is verbal, the system will convert it to text using speech recognition algorithms (e.g. Linux Speech recognition software–open source).

There are many open-source software applications that can be used to conduct NLP analysis, such as Bidirectional Encoder Representation from Transformers (BERT). One advantage of using BERT is the attention block feature, which puts more emphasis on keywords in the text to recognize request parameters more easily. This information is fed to Python, one of the main programming languages for the proposed invention, to fill a matrix with certain variables that are necessary to initiate pro forma development. These variables generally include the following:

1. The general category of the scope of work (e.g., janitorial services, software licenses, consultancy services, etc.)

2. The duration of the contract
3. The location of work
4. The contract type (replacement or new)

The user can specify additional variables in the matrix to emphasize their preferences. If the user fails to provide any of the mandatory variables, such as the commencement date of the contract, the system will ask the requestor to complete all mandatory fields. An example matrix is provided in the following table (Table 2):

TABLE 2. PROCUREMENT REQUEST VARIABLE MATRIX

Variable	Variable Type	Input
Contract Type	Mandatory	Replacement or New
Scope Category	Mandatory	Operation/ Project/General Service/ Software/ Consultancy
Location	The Scope Category will determine if the location is optional or mandatory. The default setting is that the location is mandatory, but it can be optional, as in the case of software licensing.	GPS Coordinates
Contract Duration	Mandatory	The duration of the contract in years, months or days
Commencement Date	Mandatory	The effective date of the contract
Procurement Type	Mandatory	Sole Source/Selective Competitive/Open Bid
Payment Method	Mandatory	Lump Sum/Cost Plus/ Time Unit Rate/Work Unit Rate
Scope Details	Optional	Any additional details related to the nature of work
Bidder list	Optional	The user can specify open bidding strategy preferences or a specific list of bidders. If no input is given, the system will determine the list based on the bidder selection module
Evaluation Criteria	Optional	Weighted Evaluation/ Lowest Bidder If no input is given, the system will determine the best strategy
Solicitation of Interest	Optional	The user will be able to deactivate the SOI module based on his or her preference
Prequalification Requirement	Optional	The user will be able to specify whether prequalification is needed and may provide a technical questionnaire if available.
Financial Qualification	Optional	The user will specify whether the financial qualification module shall be executed or not.
Bidding Strategy	Optional	Open Bidding Selective Bidding Ad Hoc Bidding
Hypothetical Quantities	Optional	Specified by the user

The input of the above matrix will trigger a decision tree algorithm (Figure 3. The system will have a repository of all procured agreements in Word format. Once the relevant agreement is identified, special requirements or changes will be processed.

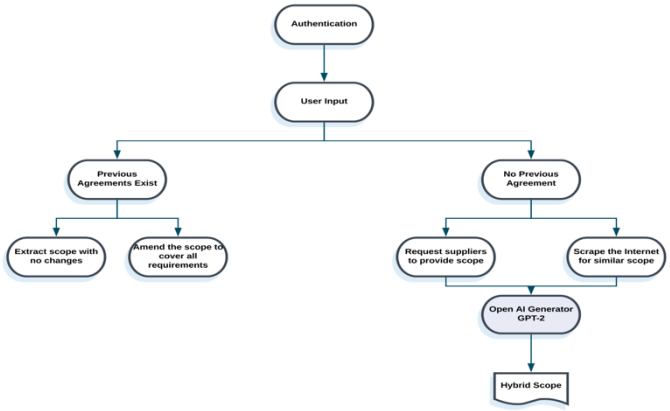

Figure 3 Scope of Work Development

The existing agreement may have been developed by the APS system or procured by a professional (legacy). When the original agreement is generated by APS, scope changes will be immediately implemented. On the other hand, when the contract is procured by a professional, the system will find a suitable location to add the new requirement using unsupervised machine learning techniques. This technique will allow the algorithm to act on the information without prior guidance.

The structure of the pro forma generated by the system will follow a specific outline, where the general terms and conditions are segregated from the specific scope of work. The general terms and conditions will be uploaded in a library where standard templates are stored based on the relevant category of product or service (Figure 4).

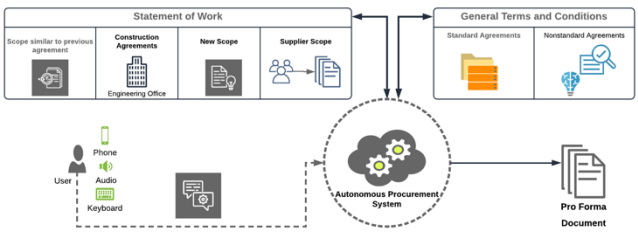

Figure 4 Pro Forma Development Module

There are cases where the procured service or product are new in nature, and previous similar agreements do not exist in the repository. In these cases, the system will scrape the internet and find similar scopes of work to the user's requirements. The collected information will be used as training data to be fed into AI Text Generator GPT-2 or GPT-3 to process and generate a relevant statement of work. Finally, the system will generate a suitable scope of work along with the relevant terms and conditions (Figure 5). As the system is deployed by more organizations, the database will have a wider range of agreement types and scopes of work that can be utilized across multiple organizations. This feature will be applicable when the notion of e-market place is well established. More details will be provided in the supplier registration section.

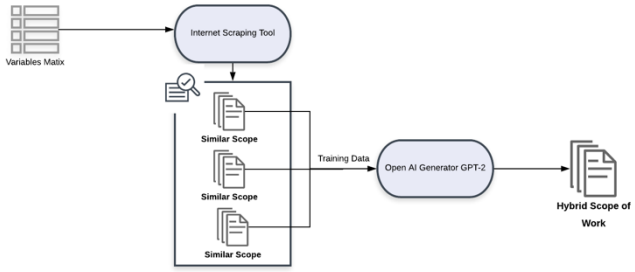

Figure 5 Developing New Scope

In some cases, the system may not be able to find similar scopes of work on the internet, such as in the case of new technologies. The user may have a brief idea about the scope requirements but lack the technical details. In this case, the system will solicit the scope of work from potential bidders. Unlike the usual sequence of the procurement process in APS, the system will first identify potential bidders. Then, it will begin acquiring the technical details for the scope of work. When the bidders send the scope of work, it will be fed into Open AI Text Generator GPT-2 or GPT-3 as training data to produce a hybrid scope of work based on the market input. For construction projects, the design and specifications that constitute the statement of work will be provided by the engineering office (Figure 6).

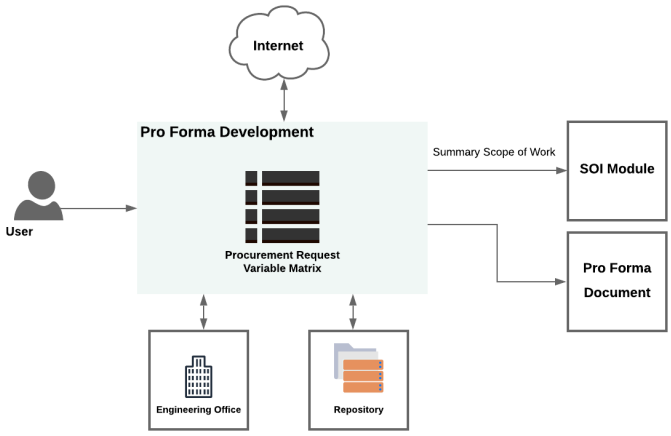

Figure 6 Pro Forma Development Module

The system will generate the commercial form based on the user's input. The payment method could be lump sum, time unit rate, work unit rate, or cost plus. Deep learning algorithms or BERT will be employed to extract the commercial form from unstructured text. This will include tagging the scope of work document by extracting noun phrases and building trees representing their relationships. The decomposition of the scope results in a number of phrases that could end up being a pay item. Subsequently, the model will analyze whether the phrases shall be considered as a pay item or not by applying deep learning architecture that was trained on a labeled training set. The resulting commercial form will be in a spread sheet format and will be used later to conduct the commercial evaluation and payment process.

3.3 Supplier Registration

Supplier registration is the process of creating supplier accounts. To register, the supplier visits the buyer's webpage and initiates the registration process (Figure7). Supplier databases will keep records of registered suppliers as well as invited ones.

The process will be autonomous, and the supplier number will be assigned to the supplier without human intervention.

After the supplier's account is created, the supplier will have a designated webpage through which all communications with the buyer will take place. This includes receiving solicitation of interest requests, invitations for proposals, and clarifications to queries.

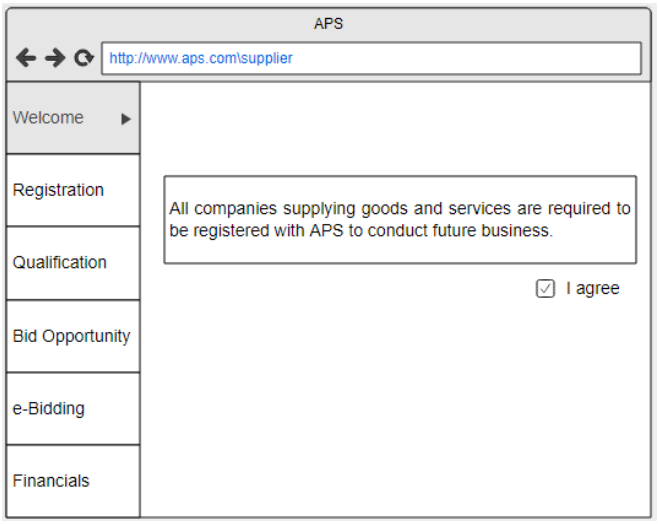

Figure 7 New Supplier Webpage

However, data verification is essential to ensure that the supplier's records are valid. Supplier data may contain inconsistencies, errors, and out-of-date information, which may ultimately result in exposing the organization to additional risk.

The system allows for supplier input to be verified by sending requests to the applicable government agency. A machine learning algorithm will extract and classify the data

that need verification and send a request to the corresponding agency to verify this information (Figure 8)

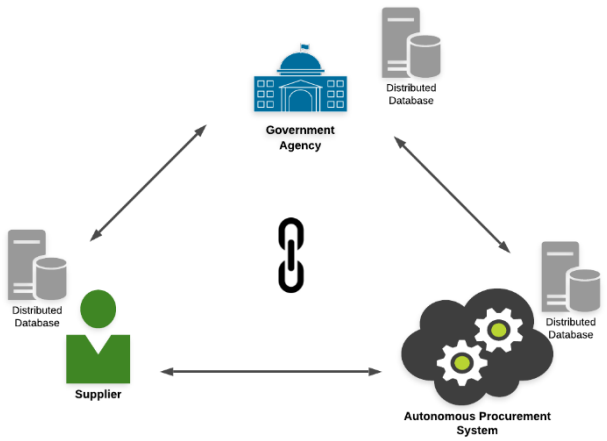

Figure 8 Supplier Registration and Blockchain

3.4 Bidder Selection

There are three basic strategies that can be used for determining bidders: open bidding, selective bidding, and ad hoc bidding. Ad hoc bidding is when the potential bidders are determined by surveying the market. This occurs when there are no known bidders who are capable of delivering the requirements of the procurement. One of the variables of the initial procurement request variable matrix is the procurement type, which is essentially the bidding strategy. For each strategy, a different scenario shall take place, as described in the following:

3.4.1) Open Bidding:

If the procurement request specifies that the procurement should occur through open bidding, the system shall post an announcement on the buyer's webpage with a public invitation to those who are interested in participating in the bidding. The announcement will be generated by the system using a standard template into which certain variables will be exported from the procurement request, such as the location, effective date, and duration of the bidding. It is also important that a summary of the scope of work is visible to potential bidders.

In addition, some general instructions, such as the registration of the supplier's requirements, will be published with the announcement on the web page. For any supplier who is interested in the bidding, registration will be required. A supplier number and access account will be created. The supplier registration will provide the supplier with an access account. All communications between the system and the supplier would take place via the supplier account. The suppliers who are interested in participating in the bidding would go to their account, click on the "Bid Opportunity" button, and select the procurement that the supplier is interested in bidding on (Figure 9).

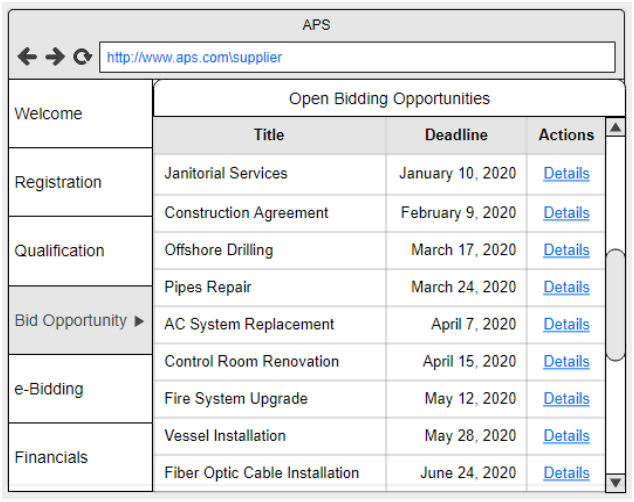

Figure 9 Open Bidding, Supplier's View

3.4.2) Selective Bidding:

In selective bidding, the bidders have to be identified by the system. The system will go to the registered suppliers list and select bidders whose registration reflects the services relevant to the scope of work. To automate this task, the system will review the scope of work and use a machine learning algorithm to identify the applicable field of services.

3.4.3) Ad Hoc Bidding:

The last strategy is used when no registered suppliers have been identified for a certain scope. In this case, the system will scrape the internet using scraping software to identify potential bidders. It will then make predictions based on its search and recommend potential bidders that could participate in tendering. A suitable machine learning tool will be used to set up the internet-scraping process. An invitation will be sent to potential bidders to complete their registration and obtain a supplier account.

3.4 Bidder Risk Analysis

Before finalizing the bidder list, a risk analysis will be conducted by the system. The module will perform a comprehensive search using internet scraping for negative phrases that could be associated with risks, such as bankruptcy, court orders, lost cases, debt, etc., to determine the supplier's overall risk status (Figure 10). Natural language processing and web scraping technologies will be applied for this task.

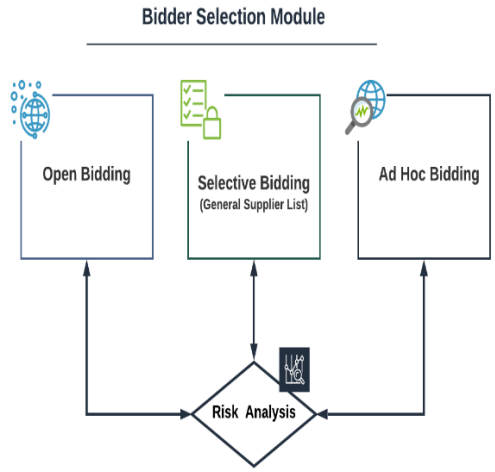

Figure 10 Bidder Selection Module

3.6 Financial Qualification Evaluation

This task will be triggered for certain procurements based on predefined criteria. This activity could be skipped for certain procurements, especially when the financial risk is minimal. The criteria for mandating the financial qualification evaluation as a default requirement will depend on the buyer's procurement policies.

When a financial qualification evaluation is required, a message will be sent to the suppliers of the bidder list requesting them to fill out a financial evaluation form. The financial qualification evaluation form is a spreadsheet where the supplier will input various elements, such as assets, liabilities, operating earnings, and revenues. Once those variables are entered, the financial qualification evaluation module will run calculations based on predefined financial ratios, such as profitability, liquidity, efficiency, and debt ratios. Predefined criteria will determine, based on the financial ratios, whether the supplier is financially qualified or not. If the supplier is not financially qualified, the supplier will be excluded from the bidder list.

The system permits suppliers to authenticate their financial inputs by submitting a PDF copy of their formal financial statement through their supplier account. The submitted financial statement will be analyzed using a machine learning algorithm, such as BERT, to extract the essential variables and calculate the ratios. The same standard qualification evaluation form that is supposed to be filled out by the supplier will be filled out instead by the trained machine learning algorithm.

3.7 Solicitation of Interest

This task will be triggered based on predefined criteria during the configuration of the system. Also, the user can deactivate this task by instructing the system not to issue SOI. The Procurement Request Variable Matrix has SOI element as one of its variables. This variable will be applicable by default in case of selective bidding and ad hoc while it is going to be not applicable in case of open bidding. If the requestor wishes not to issue SOI, the requestor could state during the initiation of the request that SOI is not needed and this will deactivate SOI task. The system will be configured so this task takes place after completing the Bidder List.

SOI can take two forms: simple SOI and SOI with prequalification evaluation. The purpose of simple SOI is merely to solicit the supplier interest and those who respond positively will remain in the Bidder List and those who do not respond or respond negatively will be excluded from the Bidder List. Another scenario is to request from the interested Bidders to submit a prequalification proposal. The criteria for selecting the applicable SOI form will be based on the predefined Buyer policies and procedures. As a default criteria for the system, Ad Hoc Bid Slate will always trigger SOI with a prequalification request for services procurement. There could be some exceptions such as in the case of acquiring standard material where technical prequalification is not required. Conversely, Selective Bidding will be at the requestor discretionary to request a prequalification or not.

The SOI message will be in a standard letter format that provides basic information about the proposed procurement including the effective date, the duration and summary of the scope of work. The information to be inserted in the SOI will be from the Procurement Request Variable Matrix and a summary of scope of the work will be imported form the Pro Forma Development module. It will also specify a deadline for the reply. The deadline could be predefined duration (e.g. 10 days) or some longer duration such as in the case of technical prequalification requirement. The supplier allowable duration to respond is a variable set in the Procurement Request Variable Matrix.

The SOI will be sent to the suppliers though their accounts and an email notification will be triggered. If the supplier is not registered in the system such as in the case of Ad Hoc Bid Slate, instructions will be sent to the supplier's available contact information to complete his registration and respond later through his designated account. General description of the scope will be presented to the suppliers and a timeframe to solicit his interest in the bidding. The SOI will be in a smart form in which responses will be captured against each question separately. The interested supplier could respond by clicking a button indicating interest or another button indicating declination. If the button indicating declination is selected, the supplier will be excluded from the Bidder List. In case that prequalification is required, the prequalification questionnaire along with the instructions will be available to the supplier to respond. Accordingly, the exclusion form the Bidder List will be subject to the prequalification evaluation which takes place under Prequalification Evaluation Module. The SOI module could be developed with Python or any other compatible programming language (Figure 11**Error! Reference source not found.**).

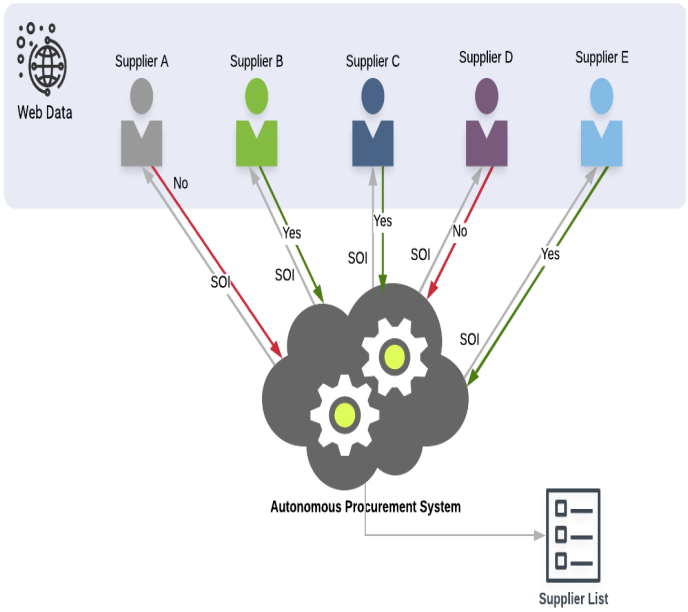

Figure 11 Solicitation of Interest Prequalification Evaluation

The prequalification evaluation is necessary to reassure that the supplier has the minimum capacity and capability levels and thus may be a potential bidder. This task will be triggered for certain procurements by default or at the requestor discretionary if specified. In the Procurement Request Variable Matrix, one of the variables is the prequalification evaluation requirement. If the Prequalification evaluation is set to required, the system will trigger this task. The task could also be triggered as a result of issuing the SOI.

Most prequalification data are general information about the supplier which could be captured once during the Registration process and updated by the supplier when needed (instead of filling the same information for every procurement requiring an SOI). This information includes Company's Scope, Human Resources, Equipment, Facilities, Experience List, in addition to Safety and Quality Management (Figure 12).

Figure 12 Supplier Qualification Profile

Various versions of predefined prequalification questionnaire will be loaded in the system in smart form format, so the supplier could fill the responses in the same form. The different templates will be relevant to the theme or the scope of work and the system will automatically pick the most relevant version. The versions of the prequalification questionnaire types could be these as a minimum: Operation Services, Construction Services and Material Procurement. Based on the scope of work, the applicable version of the prequalification will be selected.

The prequalification questionnaire will be entirely quantitative which simplify the solution and where there is a weighting point system to conduct the evaluation. Predefined response categorization will be established along with the questionnaire development in which scoring will be associated with a certain response range. Some of the evaluation criteria will be based on Procurement Request variables such as the estimated proposed procurement value and the Supplier previous agreements or manpower. A minimum predefined passing score shall determine successful and non-successful suppliers. In the case of Ad Hoc Bidder List, relative evaluation will be applicable where suppliers will be ranked against each other rather than having a perfect score.

The prequalification questionnaire will be sent to the supplier via Supplier Account where the supplier has to fill in the prequalification questionnaire and submit it to the Prequalification Evaluation Module. The result of the evaluation will exclude failed suppliers from the Bidder List. In a more advanced version of the Prequalification Evaluation, the Buyer will be provided with the flexibility to amend the prequalification questionnaire to include special questions. Some questions will highlight necessary requirements in which pass or fail scoring will be assigned against such questions.

These questions will be captured in the Procurement Request Variable Matrix. The system will prompt the user with the prequalification requirement options. If the user elects to proceed with prequalification version of the process, the most relative template will be provided to the user and he will be given the option to add additional questionnaire. The questions inserted by the user will append the standard prequalification questionnaire. More sophisticated scenario could be developed within the same concept depending on the Buyer's procurement policies and procedures. Supervised learning algorithms is the most suitable technique for this process due to its ability to provide the correct output based on a previously-analyzed dataset.

Authenticating the responses could be simply by confirming the accuracy of the submittal and assigning legal accountability on the supplier in the case of submitting invalid data. However, since the system is built with Blockchain network principles, using Hyperledger algorithm for example, the authentication among various suppliers' records is automated (Figure 13). Previous experience or awarded contracts could easily be verified in the case of e-market place.

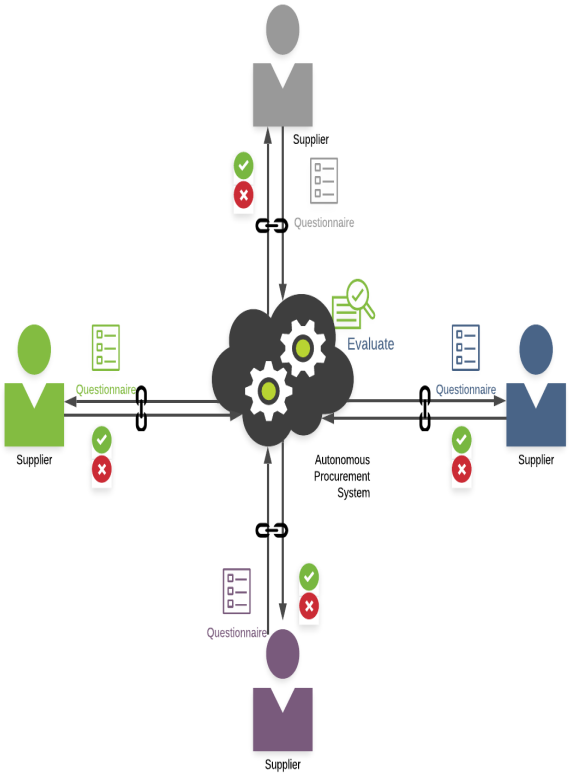

Figure 13 Prequalification Evaluation Module

3.8 Invitation for Proposals:

After the deadline of the SOI (if required), prequalification proposal (if required) and the financial qualification submittal (if required), the Bidder List will be finalized and will point out those who responded and passed the prequalification evaluation and/or financial qualification. The system will be ready to send to the Bidders the invitation though the Supplier Account (Figure 14). The invitation will be a standard letter with some instructions such as the bid closing date. The Pro forma and the Commercial Forms developed by the Pro Forma Development Module will be accessible to the Bidder in his account. The general information about the procurement such as the duration and the effective date will also be available to the supplier and will be exported from the Procurement Request Variable Matrix. If technical evaluation is required, the technical evaluation form produced by the Technical Evaluation Module, will be also sent to the Bidder.

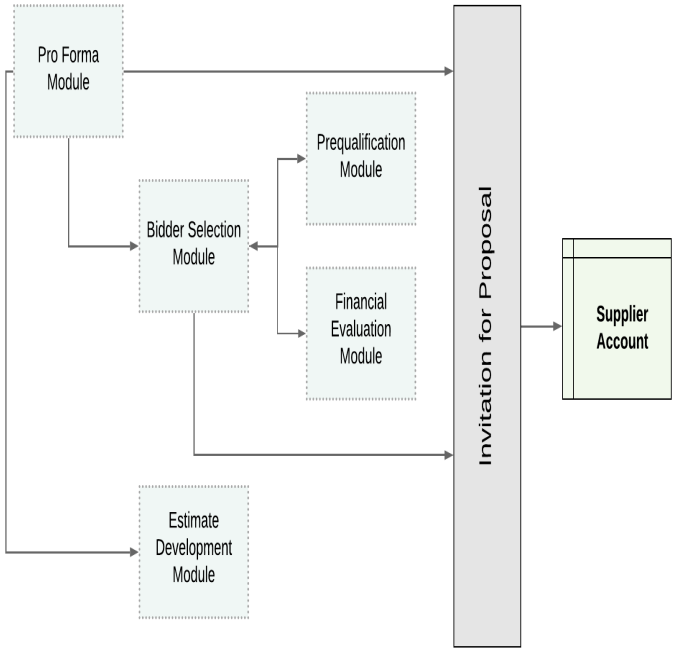

Figure 14 Invitation for Proposal

Depending on the scope complexity, the system will determine the most applicable bidding period and will assign a bid closing date in which the system will not accept any bid from the suppliers after this date. When the user initiates the request, the system will prompt him with the proposed bidding period and the user will be allowed to change this parameter in the Procurement Request Variable Matrix. A timer will be shown in the supplier account under the prospective procurement section.

3.9 Clarification:

After receiving the invitation and before the bid closing data, the bidder could submit a question though his supplier account for clarification. The question will be submitted and the system will run a Natural Language Process algorithm such as BERT to answer the question. The module will use linguistic keys to find the answers to the suppliers' queries. This module should become more mature by utilization since unsupervised Machine Learning algorithm will be used.

If the answer is not satisfactory and in exceptional cases, the question will be sent to the Procurement Requestor and based on his reply, the Pro forma may change and the suppliers will be informed accordingly. This could occur due to wrong input by the Procurement Requestor or unrealistic requirements. The response of the Requestor will be processed by the Modification Module. This task will provide quality assurance of the Pro Forma generated by the system.

3.10 Estimate Development:

Usually two estimates are developed namely: budgetary estimate and detailed estimate. The budgetary estimate is used to provide the buyer with a rough estimated value of the proposed procurement while detailed estimate provides higher accuracy estimates used in sitting the negotiation parameters. The reason for having two different estimates is because the detailed estimate cannot be developed unless the final pro forma is completed and usually it takes long time to develop a pro forma. However, with APS capability to generate pro forma contract autonomously and instantly in most cases, except when the suppliers are requested to submit their proposal of the scope of work, defeats the need to have a budgetary estimate. In other words, both budgetary and detailed estimates could be combined in one estimate.

The system will have different scenarios to develop the estimate depending on the variables provided by the requestor in the Procurement Request.

If the procurement type as indicated in the Procurement Request Variable Matrix is a replacement procurement, the system will take the existing prices and use them as bases for developing the estimate. The prices will be adjusted by applying inflation factors using the consumer indices. The indices could be imported from the internet directly. A certain web site for example, the site of the Department of Commerce in some jurisdictions, where historical consumer indices are available could be used as a source to import the indices to the Estimating Module. Extracting from the web site could be done by any suitable web scraping software. Accordingly, the system will generate a spreadsheet that will include the existing rates from the line items of the commercial form and the rates will be adjusted by calculating the inflation rates. The inflation calculation algorithm will consider the old rates as well as the future forecast of the inflation rates for the duration of the agreement. This method could even be enhanced by considering external factors that could affect the estimate such as the demand or certain fundamental incidents. This will entail to scrape the news from the internet using an open source scraping tools such as Beautiful Soup or Scrappy which are supported by Python and run the relevant news by Machine Learning to extract relevant variables and convert those variables to weight and adjust the estimate accordingly.

If the procurement is a new Time Unit Rate or Work Unit rate procurement, the estimate will be generated by scraping the internet and extracting relevant estimate. The estimates could be developed by finding time unit rate or work unit rates from the internet and then the rates are to be filtered and adjusted by taking into the consideration the inflation, the location and currency of similar service providers. For standard material items the accuracy of the estimate could be very accurate since the rates are available in most cases in the public domain and published in the internet.

The real challenge is to develop realistic estimates for lump sum project contracts when the work has never been done before. For this procurement type, parametric estimate will be applied in the proposed system where the internet scraping will be employed to determine the prices of similar projects and then prorating the price proportionally to the size of the proposed project. For example, if the proposed procurement is to build a hospital of 400 beds, the system will scrape the internet to find out the cost of building hospitals. Scraping the net will provide large mix of hospital projects with different capacities (different number of beds) at different locations globally and different project construction time. Accordingly, the system will tabulate the data points and filter them based on predefined rules such as excluding projects from third world countries or projects that are more than 10 years old. The data will also be adjusted by converting the lump sum to cost per bed since different projects might have different hospital capacities (number of beds). Each lump sum price will also be adjusted to reflect the inflation. Finally, various statistical analysis will be conducted and an average, as the simplest form, will determine the estimate.

The proposed solution does not provide detailed estimate that entails breaking the scope of work into its elements (e.g. Material, Manpower or Equipment); although it is possible to add this option within the proposed invention since the tools and the technology are available. However, the accuracy of such estimate might be challenging for some procurements since the range of assumptions is so wide. For example, to develop a detailed estimate for building a hospital will entail breaking the entire project into materials, manpower and equipment. The quantity estimate of the materials require breaking down the design and specifications to produce the bill of quantities. To be able to do this task, the design shall be presented in a systemic manner that will make the autonomous quantitate take off doable. Such autonomous detailed estimate solution is more important to the bidder when the supplier is developing the commercial proposal than to the buyer.

The detailed estimate for construction projects could be provided by the Engineering Office as an input along with the corresponding pro forma.

For cost plus procurement methods, the estimate will be based on the actual cost plus the mark up. The estimate of the actual cost will follow the above estimate scenarios. In this case, the negotiation will focus only on the supplier mark up.

The system will mark procurements with a special flag where estimate cannot be generated after scraping the net. Also, some acquisitions such as artistic items (e.g., painting) will be flagged that estimate cannot be generated. Those cases will be predefined and linked to the Procurement Request Variable Matrix.

3.11 Generating the Hypothetical Quantities:

Hypothetical Quantities (Estimated Quantities) are essential to conduct the commercial evaluation especially for time unit rate and work unit rate contracts. In some cases, the contract could have combination of lump sum, time unit rates and work unit rates. While the quantity for lump sum is always one, the quantities for time unit rates and work unit rates have to be determined. There are different scenarios for determining the estimated quantities for work unit and time unit rates and each scenario shall be processed differently:

1. For a replacement agreement, the quantities of time unit rate or work unit rate of the old agreement will be used unless the Requestor instructed the system during the initiation of the request to make some changes. This could be by stating something like "increase the quantities by 10%" in this case the old quantities will be adjusted. Another approach is to take the actual utilization of the quantities of the replaced contract. Each contract will have a spreadsheet of all line items, estimated quantities, rates and actual utilization which is useful for analysis and for determining future hypothetical quantities.
2. For contract generated for the first time, the system will ask the requestor to provide the estimated quantities while filling the initial procurement request. The commercial form will be generated by the Pro Forma Module and the requester will be presented with the line items to specify the estimated quantities at once.
3. If the distribution of the quantities is unknown, the system will generate hypothetical quantities by taking the procurement estimated value provided by the requestor in the Procurement Request Variable Matrix and use the Estimate Development Module to generate balanced quantities distribution. Various distribution sets will be generated and will be fed to a sensitivity analysis module to determine the apt set. This is useful approach for frame agreements where the utilization is unknown.
4. For Time Unit contract and where the payment is monthly payment or function of any time period the total contract duration will be converted to quantities such as in the case of lease agreements.

3.12 Commercial and Technical Evaluation

In traditional procurement process, some organizations may elect to perform the technical evaluation prior to the commercial evaluation to avoid being influenced by suppliers who proposed lower prices on the account of the quality of the service. However, this is not the case in the APS system, where there is no human intervention, and therefore these two activities can be executed simultaneously. In fact, each supplier will be assigned a technical score in addition to a commercial score. The bid ranking will be a weighted average of the two scores.

The technical evaluation questionnaire assesses the supplier's ability to deliver the work and will be linked to the scope of work and other elements from the Procurement Request Variable Matrix. There are some standard sections that will be part of the questionnaire such as supplier mobilization, allocated resources, manpower qualifications and equipment specifications. These will be evaluated and authenticated in a similar way as the prequalification evaluation underlying principles. The other section of the questionnaire will be scope dependent and will rely heavily on Machine Learning algorithms. The system will be loaded with previous technical questionnaire which will be fed into AI Text Generator GPT to process the training data and generate a relevant questionnaire. Scoring the supplier responses will be executed by Machine Learning where the most adhering supplier response will be given the highest score and other responses will be ranked accordingly. However, some elements of the questionnaire will be evaluated as pass or fail in which suppliers will be excluded from the evaluation when not meeting such requirement.

The Technical Evaluation of the technical proposal questionnaire will produce a score and based on predefined minimum passing score (e.g., 70%), suppliers who achieve the minimum passing score will remain under consideration while those fail will be excluded.

The Commercial Evaluation will be either based on rate in case of a lump sum, or the result of the multiplication of the quantities by the rates. The system will either share the quantities even if they are only estimated quantities with the bidders or have them in the system for sake of evaluation only. Estimated quantities will be generated from Hypothetical Quantities Module. The total value for each commercial proposal will be generated. The calculation algorithms will take into consideration any discounts offered by the supplier, distance factor, penalties or other factors affecting the total cost of a bid. More complex commercial evaluation methodology can be configured by the organization. However, the simple total value commercial evaluation is the most common approach widely used.

A spread sheet will be generated after the technical (if applicable) and commercial evaluations are completed and the bidders will be ranked in ascending order either based on their weighted combined technical and commercial scores. Another column will have suppliers ranked based on their technical scores and a third one will be based on their commercial scores only.

The purpose of conducting the technical and commercial evaluation is to determine the winner bidder. However, there is a variation among organizations (buyers) on how to determine the winner bidder (awarded supplier). Some Buyers embrace the simplest method which is the lowest commercial proposal from any technically qualified bidder regardless of the technical score. In this case, the lowest bidder in the evaluation spreadsheet will be the awarded supplier. This method of

evaluation is the most common for acquiring standard material items.

Another approach in determining the winner bidder is to have weighted evaluation formula that assign weight for both commercial and technical evaluation score. In this case, a weighted evaluation formula will be applied to determine the awarded supplier.

A third common approach is to negotiate with the lowest three bidders where the determination of the three lowest bidders could be based on the simplest method or weighted evaluation method. In this case, simultaneous negotiation will take place with the lowest three bidders. The Negotiation Module in this case will determine the lowest bidder. Other protocols on determining the winner bidders could be included with ease such as reserve bidding. Alternative proposal process can be accommodated as well.

3.13 Negotiations:

Using the APS System to handle negotiations will eliminate the psychological influence that humans may encounter in any negotiation process. A key element in successful negotiations is the holistic knowledge of the industry and the technical details of the given contract. Therefore, developing a system that uses artificially intelligent algorithms and has access to an all-inclusive database to navigate through the buyer's requirements considering the suppliers' level of flexibility will ensure that the results of the negotiation are optimal for both parties. Such algorithms can detect if a change in one term of the contract will result in changes in its monetary value or not. The system will always look for a win-win outcome considering the organization's preferences based on historical data. Reinforcement learning algorithms will enable the system to evaluate many different scenarios and all possible outcomes. The dialogue between the supplier and buyer will be automated using Natural Language Processing where the system will play the role of the Buyer.

The system will conduct the negotiations on more structured approach rather than intuitive approach which could be advantageous. The negotiation will not be conducted in all procurements unless the buyer's contracting polices mandate having negotiations for all procurement. The cases where the negotiations should be mandatory will be predefined.

The negotiation could be limited to the commercial aspect of the proposal. In this case, the Estimate that is developed by the system will be used as a basis for the negotiation. The system will use the Estimate as a benchmark. A spreadsheet will be generated that includes the commercial proposal and estimate. A comparison between the commercial proposal and the estimate for each line item (rates) will calculate the differences. If the Estimate is higher than the commercial proposal the system will still send the supplier a request via the Supplier Account to lower their commercial proposal by certain reasonable percentage (e.g. 10%). If the commercial proposal is higher than the estimate the system will send the estimate as a counter offer. The bidder could reject the counter offer, and in this case the system will send another higher offer with a percentage lower than a certain cap (e.g. 10 % higher than the estimate). With each offer the system will send a message. A repository of messages could be predefined where the system will select a relevant message with a justification for the offer. The bidder could also enter a justification for the offer which will be processed by NPL using suitable algorithm such as BERT and a response will be generated form the repository where unsupervised Machine Learning will be employed to develop the response.

Allowing the Bidder to negotiate the terms and conditions along with the price is more challenging. In this case the changes to the terms and conditions will be translated into monetary value. Using Artificial Intelligence in general and deep learning algorithms in particular will allow the system to predict economic value of legal terms based on previous data. The system will update its learning data as new contracts are awarded. The monetary value will be treated as a base for the negotiations and the system will run iterations of negotiation similar to the commercial negotiation process.

3.14 Agreement Award

The results of Commercial and Technical Evaluation module are a key input in determining the winning bid. The award criteria could either be based on commercial evaluation for those who are technically qualified, or weighted evaluation where both technical and commercial aspects are considered to determine the best bid. Organizations can choose from a wide range of preconfigured award scenarios and algorithms to enable the platform to determine the winning bidder autonomously.

The final agreement package will be sent the supplier through his secured supplier account. Digital signature technologies could be utilized to legally sign the final agreement.

In addition to the above core activities, there are other essential processes related to the contract administration that will be developed and integrated with the core system at future releases. The following is a brief description of those processes:

3.15 Supplier Payment

The commercial form of each contract where the line items (rates) reside will be exported to the accounting system once the contract becomes active. The supplier will submit the invoices through the Supplier Account. The invoice can only be created against the line items of the commercial form. This means that the APS will be used by the supplier to produce the invoice. In case of cost-plus agreements and where the line items are not defined the supplier will have the flexibility to enter the line items. Once the invoice is submitted a workflow will be sent directly to the Contract Administrator to certify the invoice and the payment subsequently could be triggered and the amount will be transferred to the supplier bank account. For materials the process could even skip the certification process where human intervention is required and the certification could be replaced by RFID barcode reader receipt which is a legacy technology.

A module that is built using Blockchain and smart contract technologies could be applied for the supplier payment process (Figure 15). Once the service is certified or goods are received, the system will automatically initiate the payment process. In particular, smart contract technology will be utilized to make payments to suppliers in a decentralized network. Transactions on the Blockchain network are easy to track and monitor raising the efficiency and accuracy level of the whole system.

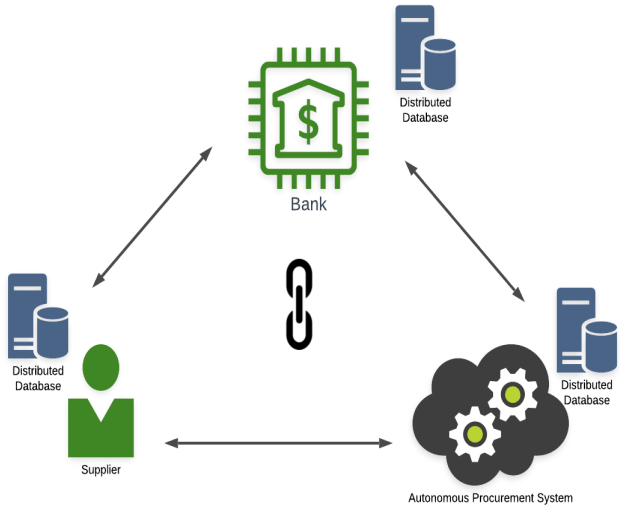

Figure 15 Supplier Payment

The APS could still be developed without Blockchain technology to handle supplier payments for the time being since the implementation of fully autonomous solution entails adoption of Blockchain technology by all stakeholders by developing the e-Market Place solution. Going with this approach, the process will require more verification steps between the supplier and the system and payments to the suppliers will be placed once the service is verified.

3.16 Spend Analysis

All line items will have a service master which is basically a code. The system will retrieve the line items form all commercial forms and arrange them in a manner that shows the rates of the same line item under various agreements. It will also retrieve the utilization of each line item across various agreements form the Supplier Payment. Without having a service master, this task could also be achieved via Machine Learning where the various line items with common description could be clustered and collected in order to use the data points in the spend analysis. Once the data points are available, various statistical analysis could be conducted such as the disparity in the prices and possible correlations due to sources, location or timing. Trend of the prices and the future forecast can be predicted. These are simple examples of the analysis once the data points are available. This feature could be useful to states where they have multiple agencies who have similar agreements where such analysis could provide optimal spend strategy.

If the organization has a known output layout, training data will be used to construct the model and classify the input. It can also suggest new categories based on pattern recognition. Unsupervised learning will be used if the output is not known and the algorithm will use clustering analysis to group the data and find similarities within the database.

3.17 Supplier Performance

Once the contract is effective, a Supplier Performance Form will be sent automatically to the contract administrator periodically. The evaluation will be maintained under the contract and in the Supplier record. The user will provide information on the performance of a supplier based on predefined criteria. The system will then process these comments using Natural Language Processing and translate them into a score. Using Artificial Intelligence techniques, the system will later use this information to classify the supplier and determine the overall performance status. This module will be fed into the Bidder Selection process.

3.18 Agreement Modifications

There are two sources for agreement modifications, either based on user demand or supplier request. When the user requests a change in the agreement, only a subset of the system will be triggered for the applicable modules. This modification will result in amending the agreement document.

Additionally, a supplier may request a change in the agreement based on new developments. In such cases, Natural Language Processing systems will scan legal contracts for relevant terms such as termination clauses, re-negotiation rights as well as scope details. Extracting such critical data gives the system the ability to identify risks and opportunities and decide whether or not to accept the supplier's request. If the change is favorable, the system will go over the procurement process again to accommodate the change. A smaller set of the core modules will be executed to process the modification. Pro Forma Development, Estimate Development, Invitation for Proposals, Commercial and Technical Evaluation in addition to Negotiation modules will be executed by the system to determine the changes to the original agreement. This modification will result in revising the agreement document that was awarded to this supplier.

4 CONCLUSIONS

This paper provided a full disclosure of APS (patent pending). The paper demonstrated that the tools and algorithms to develop an autonomous procurement system are feasible. However, the authors believe that there could be some challenges in building APS where AI is possibly immature in certain areas. However, building a prototype could be the first and correct step to have a fully reliable autonomous solution in procurement. This could also inspire others to have autonomous solutions in other fields that require cogitative capabilities. The first prototype version of an autonomous procurement system might not outperform experienced procurement professionals in certain aspects, and there might initially be a need for minimal human intervention. But as we progress in this era of AI revolution, we will be able to create autonomous procurement systems that will outperform experienced procurement professionals. This will be a major

game changer, and our current procurement process will become a legacy.

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