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DESIGN AND IMPLEMENTATION OF SEMANTIC DECISION SUPPORT SYSTEM FOR SUPPLIER PERFORMANCE CONTRACT MONITORING AND EXECUTION

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Abstract

Business contracts are the key governing mechanism for inter-organizational collaboration and they are increasingly taking a central role in e-commerce, e-business and extended enterprise governance related to key process integration, exchange of knowledge and information and as drivers for performance. This research is motivated by the critical problem of stark incompatibility between the contractual clauses (typically buried in legal documents) and the myriad of performance measures used to evaluate and reward (or penalize) supply participants in the extended enterprise. This difference between what is contractually expected and what is actually performed in addition to the lack of transparency of what is measured and how those measures relate to the contractual obligations make it difficult, error prone and confusing for different partner organizations. To address this critical issue, in this paper, we present a supplier performance contract monitoring and execution decision support architecture and its prototype implementation using a real business case study. In this research, we use OWL DL Knowledge Representation formalism and the Protégé 3.2.1 Ontology Development Environment to develop the Extended Enterprise Supplier Performance Contract Ontology. OWL DL has been extended with Horn Rules like formalism to express Semantic Rules that make use of the concepts and roles defined in an OWL DL ontology. We use the SWRL extension of OWL-DL to represent contract conditions and rules as part of the ontology and then use the Jess Rule Reasoner to execute the contract rules integrating with Service Oriented Computing to provide decision support to managers in the extended enterprise.

Keywords: Contract, Semantic Architecture, Description Logics, SWRL, Supplier Performance, Extended Enterprise
Extended Enterprise and Contracts

The key to governing and improving performance in an extended enterprise is to create a new set of organizing principles and measures of performance that allow companies to drive performance across their extended enterprise (IBM Executive Brief-http://www.ibm.com). Performance improvement in the extended enterprise should include the correct set of performance measures and incentives (or penalties) that help motivate the correct set of actions across an extended value chain or network (Dyer, 2000). Business contracts are the key governing mechanism for inter-organizational collaboration and they are increasingly taking a central role in e-commerce, e-business and extended enterprise governance related to key process integration, exchange of knowledge and information and as drivers for performance (Governatori and Milosevic, 2006; Governorati and Hoang, 2005; Governoratori, Milosevic, Sadiq, 2006; Grosof and Poon, 2004).

Despite the importance of the role of contracts in the extended enterprise, Governoratori and Hoang (2005) and Governoratori, Milosevic and Sadiq (2006) and Nelore (2004) emphasize the limited awareness, among extended enterprise participants, regarding the constraints imposed on business processes and performance by business contracts. The most typical scenario today is in which extended enterprise participants still treat contracts as legal documents typically detached from their governance role for cross-organizational business processes and performance.

It has been recognized in the literature that communication, coordination and other problems arise due to the use of different terms and concepts (and their underlying lack of common semantics or meaning or incompatibility) used in the description of the contracts and those terms and concepts used in the description of business processes and performance. These problems obviously lead to the “undesired consequences of inability to fulfill organizational obligations” (Governatori and Milosevic, 2006 and Nelore, 2004) arising out of contractual agreements. This is no where more true than in the case of supplier contracts governing supplier performance obligations, as required by the contractual clauses, and the supplier performance criteria used by the focal firm in measuring supplier performance in the extended enterprise (Grosof and Poon, 2004; Governoratori and Milosevic, 2006 and Nelore, 2004). This research is motivated by this critical problem of stark incompatibility between the contractual clauses (typically buried in legal documents) and the myriad of performance measures used to evaluate and reward (or penalize) supply participants in the extended enterprise. This difference between what is contractually expected and what is actually performed in addition to the lack of transparency of what is measured and how those measures relate to the contractual obligations make it difficult and confusing for different partner organizations. If the unit of competition is no longer the individual firm but the extended enterprise (Dyer, 2000) then it is critical to address this research issue of developing a contractual mechanism that lays out the contractual obligations of the participating partners as well as direct and transparent measures of performance that are based on the same contractual clauses. Hult, Ketchen, and Slater (2005) point out the need for meaningful knowledge sharing to improve supplier performance. They are basically pointing towards the need for a common ontology for sharing knowledge and information across the supply chain for improving supplier performance. Ontology is defined as a shared conceptualization of a phenomenon (Guarino, 1995).

Although recently scholars (Grosof and Poon, 2004; Governaroi and Milosevic, 2006 and Nelore, 2004; Karacapilidis, N., and Moraitis, 2001) have began to address and emphasize the link between contracts and business processes, little or no work has been done (to the author’s knowledge) in developing either contract languages or architectures specifically for composing contracts based upon agreed and widely accepted measures of supplier performance, and then using such measures as part of information or knowledge-based systems to monitor and execute contracts based on ongoing and real-time supplier performance information through integrated service-oriented computing architecture. This paper addresses this critical research area.

The paper is organized as follows: First we provide a brief literature review of relevant research on contract languages and architectures and then present a conceptual representation of our architecture. We then discuss OWL DL and its Rule based extension. In the next section, we present OWL DL supplier performance contract ontology using Protégé 3.2.1. Then we present SWRL contract rules and its representation in Jess Rule Reasoner. Then we present the business case study with prototype implementation as proof of concept.

Literature Review And Related Research on Contract Languages And Architectures

Governarorti and Milosevic (2005) proposed the Business Contract Language including notions of deontic concepts of obligation, permission and prohibition. They also included the logic of violation as part of their proposed contract language. Our research incorporates these important and critical deontic concepts and operationalizes those using the Semantic Web
Rules Language (SWRL, Grosof and Horrocks, 2003) contract rules that are effected should any of the deontic concepts are violated thus implicitly incorporating the notion of violation. Additionally, this research addresses an issue not addressed previously in most contract literature that is the notion of positive incentives or rewards. In an extended enterprise there needs to be incorporation of positive incentives and rewards to address the idea of conforming to obligation and of carrying out that obligation to the satisfaction of the beneficiary. This notion is new in this research and has not been that well covered in the literature explicitly and at least not in terms of an implemented architecture.

Grosof and Poon (2004) considers the monitoring of contracts, exceptions and process descriptions and includes the treatment of violations, but they do not use deontic modalities (Governaroi and Milosevic, 2006). We must concede with Governaroi and Milosevic (2006) that deontic concepts and modalities should be a required part of contract ontology to clearly set the conceptual parameters of obligation, permission and prohibition.

In this research, we present the Supplier Performance Contract Monitoring and Execution and Decision Support Architecture using the Supplier Performance Contract Ontology based on Web Ontology Language (OWL) and Description Logics (DL) and extension of OWL DL using SWRL. We demonstrate using a real case study approach and a prototype implementation how OWL DL and SWRL can be used for representing Supplier Performance Contract concepts and roles including deontic concepts of obligation, permission and prohibition. Additionally, we show how the conditions or rules from the contract can be expressed using SWRL. According to the author’s knowledge, this is one of the first attempts at applying this novel approach in the context of supplier performance within the context of the extended enterprise supplier performance and contracts. This research has brought together two disparate worlds: namely (1) the world of supplier performance measures, supplier selection and supplier retention decisions typically made by supply chain managers and, (2) supply chain contracts that are typically treated as legal (most often hardcopy) documents under the purview of lawyers and legal professionals. But as Governatori and Milosevic (2006) and Nellore (2004) and others have pointed out that these are not to be treated as different worlds but should be treated as an integral component of the same extended enterprise.

**OWL DL Supplier Performance Contract Ontology For The Extended Enterprise**

The supplier performance contract ontology presented in this research is based on the Description Logics (DL) formalism (Baader, Calvanese, McGuinness, Nardi, and Patel-Schneider, 2003). Contracts are defined as legal agreements between two or more parties (Nelore, 2004). Typically contracts are treated as legal hard copy documents by most businesses. In this research, we are concerned with Electronic Contract Documents and specifically Electronic Extended Enterprise Supply Contract and therefore we conceptualize electronic contracts as being subsumed by the concept LegalElectronicDocument which is subsumed by ElectronicDocument. We present this conceptualization as part of our contract ontology in Figure 1.

![Figure 1. ExtendedEnterpriseSupplyContract concept and its parent and its Relationships (Roles) with other Concepts in the Supplier Performance Contract Ontology](image)

The primary purpose of contracts are to legally bind two or more business enterprises for a set of mutually responsible set of activities. In this context, the ExtendedEnterpriseSupplyContract has the hasBounded property to bind Individuals of Class BusinessEnterprise. Since it is through contracts that a set of Activities in terms of Roles are made available to business partners. ExtendedEnterpriseSupplyContract (see Figure above) has the hasEnabledSupplierRole property that enables certain Supplier_Role to be performed by a Supplier Business Enterprise as signatory to the contract. The complete Supplier Performance Contract Ontology in Protégé 3.2.1 is shown in Figure 2.
In this ontology, ExtendedEnterpriseSupplyContract has the isComposedOfContractClause property that relates to ContractClause concept. Contracts are typically signed by some Agent of the participating Business Enterprises. So the ExtendedEnterpriseSupplyContract has the isSignedBy property that is signed by some Supplier Agent.
It is assumed here that the other party is always the Focal Firm in all of these contracts. ContractedSupplierCompany is subsumed by the SupplierCompany concept. In the full supplier performance contract ontology (see Figure 2 above), SupplierCompany is subsumed by the BusinessEnterprise concept. This means that all ContractedSupplierCompany individuals are also by definition BusinessEnterprises. Additionally, since we are concerned with Supplier Performance in the Extended Enterprise, the ContractedSupplierCompany has the hasCustomer property which has at most one customer that is the FocalFirm.

Contracts are typically composed of Contract Clauses or conditions that parties agree to fulfill as part of their contractual agreement. In this sense, ContractClause concept has the hasComposedContract property to indicate that some ExtendedEnterpriseSupply Contract can be composed using this concept. ContractClause concept also has the hasContractualPerformanceMetrics property that points to some Contractual Performance Metrics concept.

The Supplier_Role concept is central to this contract ontology as it captures and provides the critical performance link between what is contractually obligated what actually transpires for an entity that takes up this Role. Supplier_Role concept is subsumed by the Role Concept. In this research, Role is conceptualized as a collection of behaviour or activities. We have two properties of the Supplier_Role concept (1) hasContractualPerformanceMetrics and (2) hasActualPerformanceMetrics. These two properties relate to the Concepts ContractualPerformance and ActualPerformance respectively in the Contract Ontology (see Figure 2 above). This contractual foundation of the Supplier_Role also provides the deontic foundation of Obligation, Permission and Prohibition for this Role. Thus, we have three properties namely, hasModalityObligation, hasModalityPermission and hasModalityProhibition as deontic properties of the Supplier_Role. Each deontic property relates to its respective concept of Obligation, Permission and Prohibition.
Supply Chain Council (SCC) constructed a descriptive framework called the Supply Chain Operations Reference (SCOR) model. The SCOR model aims to enable companies to communicate supply chain issues, measure their performance objectively, identify performance improvement objectives, and influence future SCM software development (Stephens, 2001). Since the SCOR model is intended to be an industrial standard and has already seen wide adoption, Huang and Keskar (Forthcoming 2007) used the SCOR metrics as part of their supplier performance metrics development effort following the method outlined by Lehmann and O'Shaughnessy (1982).

Huang and Kesker (Forthcoming 2007) defined five top level categories such as Reliability, Responsiveness, Flexibility, Cost and Financial, Asset and Infrastructure and Safety and Environmental (see Table 1 for definition of each category). These categories also form the foundational concepts related to supplier performance contract ontology used in our research.

### Table 1. Definition of Top Level Metrics For Supplier Performance Based On SCOR

<table>
<thead>
<tr>
<th>Metric Category</th>
<th>Adapted from Huang and Keskar (Forthcoming)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>Criteria related to the supplier performance in regards to delivering the ordered components to the right place, at the agreed upon time, within the required quality, packaging and quantity</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>Criteria related to the velocity at which the supplier provides products to the focal firm</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Criteria related to the agility of the supplier to respond to the demand changes of the focal firm</td>
</tr>
<tr>
<td>Cost and Financial</td>
<td>Criteria related to the cost and financial aspects of purchasing from the supplier</td>
</tr>
<tr>
<td>Asset and Infrastructure</td>
<td>Criteria related to the effectiveness with which the supplier manages assets to support the demands of the focal firm</td>
</tr>
<tr>
<td>Safety and Environment</td>
<td>Criteria regarding the supplier’s effort related to environmentally friendly production of components for the focal firm</td>
</tr>
</tbody>
</table>

In table 2, we present some sample adapted supplier performance criteria related to Supplier Reliability. Additionally, the different configuration such as Make-to-Order (MTO), Make-to-Stock (MTS) and Engineer-to-Order (ETO) are shown to illustrate the broad applicability of these criteria to different manufacturing and supply chain concerns.

### Table 2. Sample Supplier Reliability Metrics Based On SCOR

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Definition</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Percent orders received defect free</td>
<td>Number of orders received defect free by the focal firm divided by the number of orders processed in measurement time</td>
<td>MTS/MTO/ETO</td>
</tr>
<tr>
<td>2. Percent orders received complete</td>
<td>Number of orders received complete by the focal firm divided by the total number of orders processed in measurement time</td>
<td>MTS/MTO/ETO</td>
</tr>
<tr>
<td>3. Percent orders received on time to required date</td>
<td>Number of orders received on time to required date by the focal firm divided by the total number of orders processed in measurement time</td>
<td>MTS/MTO/ETO</td>
</tr>
<tr>
<td>4. Percent Orders received with correct shipping document</td>
<td>Number of orders received with correct shipping document divided by the total number of orders processed in measurement time</td>
<td>MTS/MTO/ETO</td>
</tr>
<tr>
<td>5. Fill rate</td>
<td>The percentage of ship-from-stock orders shipped within 24 hours of order receipt by the supplier</td>
<td>MTS/MTO</td>
</tr>
<tr>
<td>6. Inventory accuracy</td>
<td>The absolute value of sum of the variance between physical inventory and perpetual inventory</td>
<td>MTS/MTO</td>
</tr>
</tbody>
</table>
In this research we have adopted these SCOR criteria as developed, refined and presented by Huang and Kesker (Forthcoming, 2007) and made these performance criteria as properties of the concept ContractualPerformanceMetrics in our contract ontology.

Having the same set of widely agreed performance measures in both the ConractualPerformanceMetrics and ActualPerformanceMetrics allow one to then compare how the Supplier_Role is performing in comparison to what was agreed to and what had actually transpired using the same set of measures. This allows minimization of confusion and reduces the barrier to communication with the suppliers and to all contractual parties in terms of what is contractually expected and how performance will be measured.

Obligation concept is subsumed by the concept Modality. Additionally it has three properties: hasObligationViolationPernalty, hasSubject and hasBenefeciary. If the Supplier_Role is found to be in violation of any contractually agreed performance measure then this condition will lead to violation of contractual Obligation thus resulting in penalty. The violation can be easily determined by comparing value of the contractually agreed performance measure clause and its corresponding actual performance measure for the Supplier_Role enacted by a specific Individual of type ContractedSupplierCompany. In our contract ontology we have the Penalty concept. The Penalty concept has the property hasPenaltyValue which is a OWL DL DatatypeProperty.

In addition to Penalty concept, we have introduced the concept of Reward. The Reward concept has the property hasRewardValue of type integer similar to the hasPenaltyValue property. The idea of reward or positive incentives is not new and have been used in the supply chain literature under various circumstances.

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**Extending OWL DL with Semantic Web Rules Language (SWRL) and Representing Contract Rules in the Supplier Performance Contract Ontology**

Although OWL-DL is very expressive, it is a decidable fragment of first-order logic, and thus cannot express arbitrary axioms: the only axioms it can express are of a certain tree structure. To overcome this limitation, Horrocks and Patel-Schneider (2004) added a new kind of axiom to OWL DL, namely Horn clause rules, extending the OWL abstract syntax and the direct model-theoretic semantics for OWL DL to provide a formal semantics and syntax for OWL ontologies including such rules. This language is known as the Semantic Web Rules Language (SWRL).

Using this syntax, a rule asserting that the composition of parent and brother properties implies the uncle property might be written as:

\[
\text{parent}(?a, ?b) \land \text{brother}(?b, ?c) \rightarrow \text{uncle}(?a, ?c)
\]

Using the contract ontology, we can write the following example rule about an Agent and BusinessEnterprise and the employment of the Agent with the BusinessEnterprise.

\[
\text{BusinessEnterprise}(?x) \land \text{Agent}(?y) \land \text{isEmployedBy}(?y, ?x) \rightarrow \text{isEmployerOf}(?x, ?y)
\]

Interested reader is referred to Horrocks, Patel-Schneider, Bechhofer, and Tsarkov, (2005) for elaboration on the direct model theoretic semantics of extending OWL DL with rules. We have used the SWRTJess Bridge API in the implementation of our supplier performance contract monitoring and execution architecture.

**Business Rules Represented in SWRL and Jess**

![Business Rule Represented in Semantic Web Rules Language (SWRL)](image)
The employee or employed by rule example (discussed above) is shown in Protégé 3.2.1 in Figure 5 above. It is represented in SWRL syntax using the concepts and roles specified in the supplier performance contract ontology. The same rule is then translated using the SWRLJessRule Bridge in the Protégé 3.2.1.

![Figure 6. Representation Of The Same Rule As Above In JESS](image)

The corresponding representation of the related OWL DL supplier performance contract concepts in Jess Rule Engine representation is shown below in Figure 7. These concepts relate to above Employee Rule.

![Figure 7. Representation of Concepts Related To The Rule Above In JESS](image)

Here we present sample contract rules, based on our case study of an electronics manufacturer, and their corresponding representation in SWRL.

**Supplier Performance Contract Ontology based Business Rules in SWRL**

Example Rule:- If the Supplier Actual Performance in terms of Standard Lead Time in Hours exceeds the Supplier Contractual Performance in terms of Standard Lead Time then the Supplier will deemed to be in violation of its Obligation to the Focal Firm and will be subject to the Penalty agreed to by the parties in the Contract (see Figure 8).
In the next section, we present a real case study and prototype implementation of the supplier performance contract monitoring and execution decision support architecture.

**Case Study And Evaluation Of The Supplier Performance Contract Architecture And Implementation**

In order to maintain the confidentiality of the firm utilized in the case illustration, it is referred to as AdvancedElectronix throughout the discussion. AdvancedElectronix designs, develops, manufactures and markets proprietary radio frequency and electronics integrated circuits for wireless communications applications. The company has its headquarter and fabrication facilities in the U.S. Its supplier base is located both within and outside the U.S.

AdvancedElectronix has selected reliability, responsiveness, and cost as the three supplier performance categories based on the widely adopted SCOR model. Class A customers such as Nokia, Ericsson etc., have much tighter requirements and these customers represent the significant portion of AdvancedElectronix’s sales and revenue. So special attention has to be paid to the suppliers of components for Class A customers and to the performance measurement and monitoring processes related to these suppliers thus ensuring contract compliance.

The company wanted to standardize its contracting process to eliminate any confusion and miscommunication with the suppliers of components for its Class A customers. In this effort, the involved parties developed an agreed upon a set of performance criteria from the categories of responsiveness, reliability and cost (captured using the supplier performance contract ontology). Should a supplier fail to perform over time in this dimension, the supply chain managers at Advanced Electronix need to be aware of that fact immediately on a real time basis.

**Extended Enterprise Supplier Performance Contract Monitoring and Execution Architecture and Implementation**

The following illustration and description are based on Figure 9 –the Contract Monitoring and Execution Architecture.

A) Protégé OWL Ontology Editor 3.2.1 to be used by the Semantic KB Designer for creating the initial user interface and select the required set of contract clauses from the contract ontology depending upon the need of the focal firm and its supplier.
B) RacerPro Reasoner is then used for checking the classification and coherency of the contract ontology.

C) The Semantic KB Designer then develops rules based on the contractual clauses required in the contract with the help and input from the concerned supply chain managers. These are SWRL rules that are composed based on the concepts and roles from the OWL DL contract ontology.

D) After satisfactory evaluation, the supplier performance contract ontology is then stored in the accepted repository. This is the OWL document to be used for instantiating any subsequent contract ontology instances using the Protégé OWL API. The basic premise is that only one contract is used with all the suppliers (Nellore, 2004).

The user interface for supplier performance contract is generated by the OWLSupplierPerformanceContractAgent (see Figure 9) and presented to the Supply Chain Manager and the Supplier Representative as they negotiate the specific values of each the Contract Clauses. This electronic contract is essentially a OWLModel object (see Protégé 3.2.1 OWL API) generated from the

Figure 9. Semantic Contract Monitoring and Execution Architecture For Supplier Performance
supplier performance contract OWL document. The parameter values entered in the electronic contract essentially set the contractual performance criteria that the parties to the contract are obligated to fulfill. These contractual clause and corresponding values will be used later by the OWLSWRLJessContractExecution Software Agents (Figure 9) for executing the contracts using the SWRL rules that apply to the specific contract for a specific supplier Individual.

E) After the values are properly entered and agreed by the parties involved, pressing of the submit contract for execution button on the contract GUI begins the monitoring and execution of this instance of the contract (Figure 24).

F) At this stage, the OWLSuppliePerformanceContractAgent stores the OWLModel contract ontology object in the repository and notifies an available OWLContractMonitorningAgent to begin monitoring the contract instance (see Figure 23).

G) At this stage, the OWLContractMonitorningAgent instantiates the contract based on the contract ID supplied by the OWLSuppliePerformanceContractAgent and invokes the specific Services such as Reliability Service or Cost Service or Responsiveness Service to obtain the necessary actual performance values for the clauses that are part of the signed contract ontology instance. This part of the Architecture provides the connection through Web Services to both internal information systems from the focal firm or with external information systems of the supply partners.

H) Once the OWLContractMonitorningAgent has all of the required parameters related to the actual performance of the supplier, the OWLContractMonitorningAgent then invokes the OWLSWRLJessContractExecutionAgent and passes the OWLModel object of the completed contract.

I) The OWLSWRLJessContractExecutionAgent then executes the received OWLModel object using the executeContract Method as shown in the following Java code snippet.

J) After the completion of the execution of the contract OWLModel Object, the contract is then stored in the Executed Contract Repository (see Figure 9).

K) The stored Executed Contract objects can then be later accessed by the FocalFirmSupplierPerforancDSS Agent to provide decision support to the supply chain manager(s) (see Figure 9).

L) The Executed Contract instances can also be accessed by contracted supply partners for their own analysis through the EEContractSecurityAgent and the OWLContractRepositoryAgent (see Figure 9).

Discussion And Conclusion

Decision Support Features of Supplier Performance Contract Monitoring and Execution Architecture

Once the contracts are executed, the instances of those contracts are stored in the EE Executed Electronic Contract Repository in the Architecture ((see Figure 9) by the OWLSWRLJessContractExecutionAgent (from now ContractExecutionAgent). These stored executed contract instances can later be analyzed by the

Figure 10. Extended Enterprise Supplier Performance Report
Salam, Design and Implementation of Semantic DSS For Supplier Performance Contract Monitoring and Execution

Focal Firm Supplier Performance OWLDSSAgent (from now OWLDSSAgent) at the request of the Focal Firm Supply Chain Manager. In the Orders Received On Time to Date Clause the supplier company HighTech is not doing so well when compared with TransLight (see Figure 10). HighTech has received 7 Penalties in violation of its Contractual Performance Obligation by falling short in its Actual Performance in comparison with its Contractually Agreed Performance Obligation.

![Figure 11. Weekly Supplier Performance Report](image)

On the other hand, HighTech is fairly close in performance with TransLight on the Order Fulfillment Cost Clause (see Figure 29). Both companies received 2 and 4 Penalties and 21 and 22 Rewards in relation to their Obligation violation and Obligation Conformance respectively. It is clear that if this trend continues for HighTech then the Focal Firm Advanced Electronix will have to take some remedial measures as supplier improvement program with HighTech.

Our Contract Architecture has those important features that make it truly an Extended Enterprise Architecture for Decision Support. For example, individual suppliers such as HighTech and TransLight can view their own executed contract instances and can perform their own analysis (see Figure 11 and 12).

![Figure 12. Supplier Performance Report Available For Individual Supplier Partner](image)

Each supplier can request their own aggregate performance report in comparison with other suppliers that supply the same components to the Focal Firm. Figure above shows such a report for HighTech generated by the OWLDSSAgent.

These kind of integrated decision support is meaningful because all of the reports are performances are generated on the basis of agreed and signed contracts using a single agreed supplier performance contract ontology for the extended enterprise. This contract ontology provides the foundation for efficient and effective real-time communication between different partners in the extended enterprise. These are unique features and contributions of this research and of this contract architecture.

In this research, we have adopted a single contract ontology for all of the supply partners. That is there is one single contract for all of the suppliers. This is not an impractical assumption or application since there are companies that use a single contract for all of their suppliers (Nelore, 2004). But this limitation needs to be addressed to allow the architecture to incorporate companies that may use different contracts for different suppliers to implement their corporate strategy and policy. This limitation will be addressed in the future.
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