

Agents in E-Supply Chains: Realizing the potential of intelligent infomediary-based e-marketplaces

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Article:

Supply chain management is a common strategy employed by businesses to improve organizational processes by optimizing the transfer of goods, information, and services between buyers and suppliers in the value chain [6]. Organizational value chains routinely extend business processes and information flows beyond corporate boundaries [7, 12]. A central tenet of this article lies in creating information transparency through effective integration of information flows by intelligent agents across the multiple electronic marketplaces (e-marketplaces) that comprise the e-chain. Here, we refer to information transparency across the e-chain as the availability of information through the multiple e-marketplaces of the supply chain in an unambiguously interpretable format. A fundamental ongoing endeavor of supply chain management is to foster information transparency that allows organizations to coordinate supply chain interactions efficiently in dynamic market conditions. However, the implementation of effective information transparency in Internet-enabled supply chains (e-chains) remains elusive. Even if this transparency were present, the information overload would be cognitively demanding for human decision makers.

The growing volume and complexity of information in modern business processes require an alliance of human analysis and judgment aided by intelligent systems. Intelligence in processing transparent information flows in e-marketplaces can help increase the efficacy for its participants and reduce users' cognitive load. Intelligent systems can support a range of e-marketplace processes and provide aggregate or product-specific cumulative demand or supply conditions in a single e-marketplace, and across multiple upstream or downstream e-marketplaces in the e-chain. Currently, e-chains suffer from paucity in information transparency extending to all participant e-marketplaces in the existing e-chain.

This article presents an agent-enabled architecture for infomediary-based e-marketplaces that exhibit information transparency and enable enhanced interaction among participants in the e-chain. Agents introduce intelligence to the discovery of business partners and facilitate transactions by incorporating experiential knowledge of past transactions and the effects of volatile demand and supply conditions across multiple e-marketplaces in the e-chain. Such agent-enabled e-marketplaces are integrated with each other through authenticated monitoring agents that gather and share market-related information to provide transparency through the entire e-chain. Intelligent agents monitor developments in multiple infomediary-based e-marketplaces and provide the necessary transparency to the information flows in the e-supply chain while reducing the cognitive load on human decision makers.

FACILITATING BUYER-SUPPLIER INTERACTION

Infomediaries play a critical role in e-marketplaces by managing the information flows to support business processes required of the e-marketplace [3]. Infomediaries bring together buyers and suppliers by identifying buyers with needs for suppliers' products and services and facilitating transactions between them. In addition, infomediaries provide value-added services in managing the information processes of the e-marketplace by deciphering complex product information and providing independent and observed assessment of the commitment of individual buyers and sellers. The critical role of infomediaries in managing required

information processes is applicable to both public and private e-marketplaces. Public e-marketplaces, such as Chem-Connect (www.chemconnect.com/), are hosted and offered by third parties along the supply chain; while private e-marketplace are hosted by a central hub company, such as Hewlett-Packard, to create efficiencies and cost effectiveness for participants. In this article, we make no distinction between the public and private e-marketplaces since both are infomediary-enabled e-marketplaces. Our focus is on creating information transparency by automating information flows within and across e-marketplaces in the e-chain.

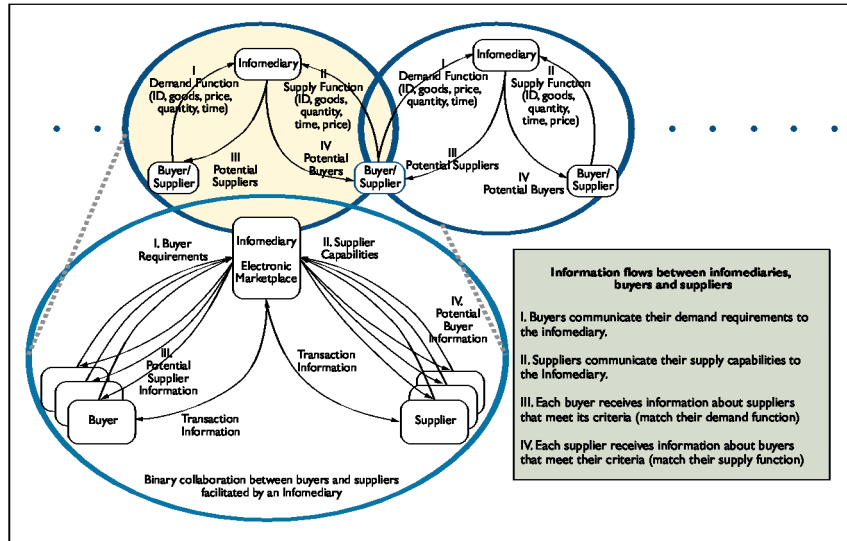


Figure 1. Infomediaries facilitate transactions between buyers and suppliers in e-marketplaces and become vital repositories of knowledge about transactions in the e-supply chain.

Three critical roles of the e-marketplace are: *Discovery* of buyers and suppliers that meet each others' requirements; *Facilitation* of transactions to enable information flows leading to the flow of goods and services between buyers and suppliers; and *Support* of decision processes leading to the development of collaborative relationships between e-marketplace participants [1]. Buyers and suppliers explicate their demand or supply functions and seek market participants to meet their requirements. Discovery involves the dynamic matching of buyers and suppliers, based on current requirements. This is influenced by the experiences of other buyers and suppliers in terms of reliability and trustworthiness. Infomediaries provide valuable insight to this process through experiential transactional histories that enable reputation-based information for subsequent transactions. Once a buyer and a supplier are selected, the infomediary facilitates transactions by enabling information flows between them, which ultimately lead to the flow of tangible goods or services. Figure 1 illustrates the role of the infomediary-enabled e-marketplace in enabling fundamental buyer-supplier interactions supported by most marketplaces. This role is extended to cover multiple infomediary-based e-marketplaces.

1. Accepted business ontologies for information and knowledge representation.
2. Transparent exchange of dynamic supply and demand information.
3. Dynamic acquisition of buyer-seller information.
4. Repository of information/knowledge for sharing and reuse.
5. Access and disseminate information/knowledge among trading partners.
6. Post transaction information on level of satisfaction with completed transactions.
7. Aggregation of information from a variety of heterogeneous data formats using XML from multiple infomediaries in the e-chain.
8. Security through authenticated access and information flows.

Table 1. Requirements of intelligent-infomediary-based e-marketplaces.

Collaborations between buyers and suppliers across e-marketplaces require the transparent flow of problem-specific information across organizations. Such information transparency goes beyond the technical integration of systems. It requires common language to express context-specific constructs and relevant business rules to assist autonomous system entities and decision makers in solving specific business problems [10]. Disparate

technical systems need the ability to share data, information, and knowledge. Ontologies allow for a common and shared understanding of the domain-specific concepts and the relations between them that is critical for creating integrative views of information and knowledge in e-marketplaces. Without integration of intelligence and knowledge across e-marketplaces, the benefits of intelligent e-chains remain elusive. In addition, the volatility and dynamic nature of the marketplace must be considered in systems designed to reduce cognitive load on humans. An analysis of the requirements for intelligent-infomediary-based e-marketplaces is summarized in Table 1.

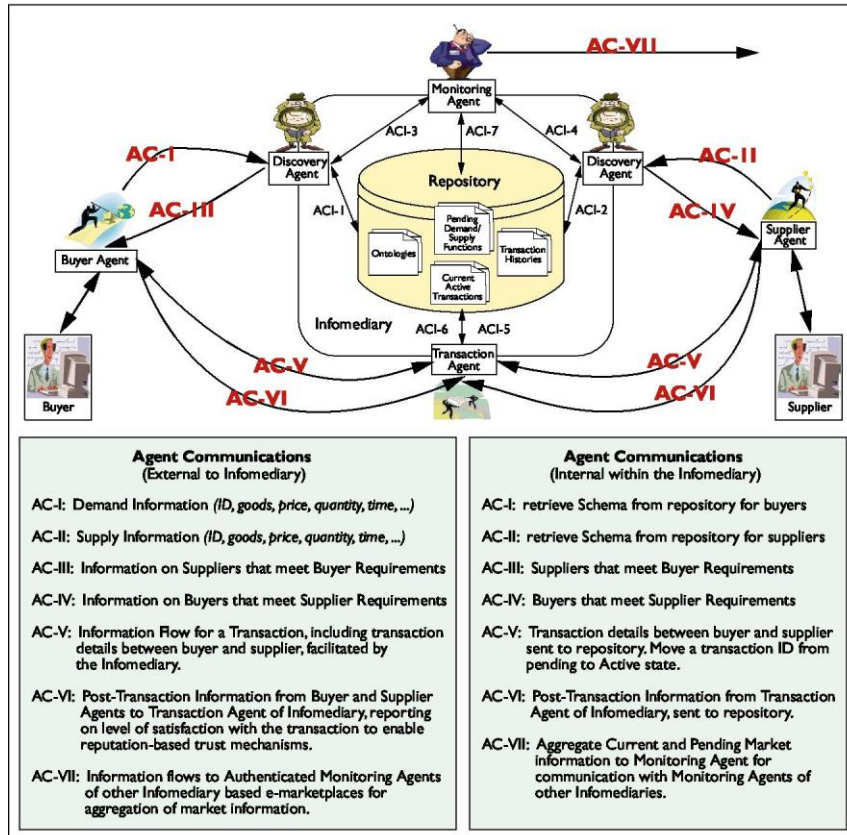


Figure 2. Agent communications in the agent-enabled e-marketplace model.

AGENT-ENABLED E-MARKETPLACES

Buyer agents and supplier agents represent buyers and suppliers in the agent-enabled e-marketplace. Infomediary functions to enable information flows are realized through three agent types: discovery agents, transaction agents, and authenticated monitoring agents. Figure 2 shows the information flows between agents required to facilitate the functions of the intelligent e-marketplace.

Buyer/Supplier Agent Registration. The agent-enabled e-marketplace comprises buyer and supplier agents that register with the infomediary to make them entities for subsequent transactions. The infomediary provides the buyer and supplier agents with the ontologies to allow buyers and suppliers to represent themselves in the e-marketplace through their respective buyer and seller agents. This is done by using the retrieving standard and accepted business ontologies from the infomediary repository that may be based upon the UN/CEFACT ebXML standard for Global Electronic Commerce. This ensures interoperability among global partners by enforcing a standard representation for all information interchange. Upon registration with the infomediary, each registered buyer and supplier agent is assigned a discovery agent. This flow of information is shown in Figure 2 as internal infomediary communication ACI-1 and ACI2, between assigned discovery agents and buyer and supplier agents.

Buyer/Supplier Discovery. Buyer activities are initiated when a buyer agent communicates buyer's demand to a discovery agent assigned to the buyer agent by the infomediary. The representation of buyer demand conforms to the ontology described earlier to ensure inter-operability of agent interactions. This is represented as Agent

Communication I (AC-I) in Figure 2. Receipt of buyer demand requirements triggers the discovery activity of the discovery agent. Discovery involves matching buyer demand with supplier capabilities. In addition, the discovery agent retrieves reputation-based ratings for every matched supplier. Information on matched suppliers is provided to the buyer agent. This communication between the discovery agent of the infomediary and the buyer agent is labeled AC-III in Figure 2.

Dynamic Supply and Demand Planning. The architecture presented here supports dynamic supply and demand planning by providing information transparency in e-marketplaces. This is achieved by aggregating information flows to create dynamic snapshots of authorized transactions and transactions currently under consideration by buyers and suppliers. The volume of authorized transactions in an e-marketplace, along with information that a supplier is under consideration by a buyer, indicate current product demand in the marketplace. Information about the match between supplier capabilities and buyer requirements provides vital planning information for participant organizations. Additionally, this indicates committed and uncommitted supply capacities in the e-marketplace and along the e-chain. These information flows, coordinated through the buyer, supplier, and discovery agents, allow synchronization of activities among participants while accommodating the volatile and dynamic supply and demand in the e-chain.

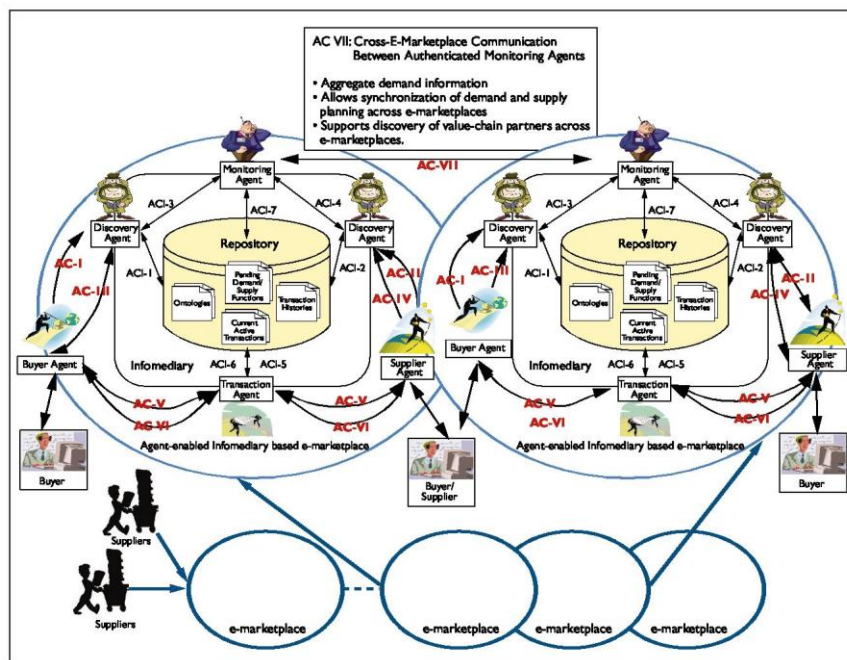


Figure 3. Integrated transparent information flows between multiple infomediary-based e-marketplaces.

Supplier agents are informed of every potential buyer currently considering them for potential transactions. This information flow, labeled AC-IV, is provided by the monitoring agent of the infomediary and is compiled by aggregating information flow ACI-3 for all buyers evaluating the supplier for potential transactions. This information is provided to the discovery agent assigned to specific suppliers through information flow ACI-4 and represents the set of potential customers for the supplier. In addition, suppliers receive dynamic updates on potential transactions in the marketplace by the monitoring agent. This is provided to the discovery agent when a supplier is matched as a potential transaction participant, and may be obtained upon request.

Information about active transactions and potential customers provides critical demand and supply planning information for the current, upstream, and down stream markets in the e-chain. In addition, this information allows suppliers to assess their competitiveness in the e-marketplace. For example, a supplier that is frequently evaluated yet infrequently chosen by buyers requires an analysis of the historical transaction in the e-marketplace to inform competitive positioning strategies pertinent to pricing or the reevaluation of product-service mix development. The intelligent e-marketplace enables transparent information flows and provides intelligent assistance to decision makers in participant organizations.

Agent Roles and Responsibilities	Information Flows and Agent Behavior
 <p>Buyer Agent: The buyer agent represents buyer interests and facilitates buyer processes in the infomediary-based e-marketplace</p>	<ul style="list-style-type: none"> • Receives ontology to represent buyer demand from e-marketplace • Communicate buyer requirements to discovery agent • Receives discovered suppliers from discovery agent • Provide intelligent support to buyer in supplier selection process • Initiate and authorize transactions by communications with transaction agent
 <p>Supplier Agent: The supplier agent represents suppliers' interests in the infomediary-based e-marketplace</p>	<ul style="list-style-type: none"> • Receives ontology to represent supplier capabilities from e-marketplace • Communicate supplier capabilities to discovery agent • Receives discovered buyers from discovery agent • Provide intelligent support supplier for assessment of competitiveness in the e-marketplace • Authorize and confirm transactions by communications with transaction agent
 <p>Discovery Agent: The discovery agent performs the discovery role of the infomediary in the e-marketplace</p>	<ul style="list-style-type: none"> • Identify suppliers that meet buyer requirements • Identify buyers that meet supplier requirements • Provide buyers and suppliers with reputation information based on past transaction histories • Provide buyer agent with information on potential suppliers that meet their requirements • Provide supplier agent with information on potential buyers for their goods and services
 <p>Transaction Agent: The transaction agent performs the transaction facilitation role of the infomediary in the e-marketplace</p>	<ul style="list-style-type: none"> • Facilitate flows of information leading to transfer of goods and services between buyers and suppliers • Facilitate information flows leading to confirmation of authorized transactions • Collect information on satisfaction levels of buyers and suppliers with their respective transactions
 <p>Monitoring Agent: The monitoring agent facilitates information transparency by communicating with authenticated monitoring agents of other e-marketplaces in the e-chain</p>	<ul style="list-style-type: none"> • Provide information to authenticated monitoring agent of related e-marketplaces on individual and aggregate demand and supply conditions

Table 2. Agents in e-marketplaces.

Buyer/Supplier Selection. Selecting a supplier from the potential suppliers identified by the infomediary is a human decision-making process supported by the buyer agent. Through Agent Communication AC-III, the discovery agent provides the buyer agent with knowledge of transaction histories for each matching supplier communicated to the buyer agent. This knowledge is available to the discovery agent through the infomediary repository. The discovery agent provides supplier-specific transaction histories available to buyer agents to inform the supplier selection decision. The buyer agent facilitates additional information gathering about individual sellers. Intelligent, rule-based induction learning capabilities are available to buyer agents for learning buyer preferences to continually adapt in making the selection process more efficient.

Transaction Facilitation. The buyer agent informs the transaction agent of the chosen supplier with a request to facilitate the transaction between the buyer and the identified supplier. This communication between the buyer agent and the transaction agent includes all operational details required for the transaction between buyer and supplier to occur. The transaction agent records these details in the repository, shown in information flow ACI-5, and provides the transaction request to the supplier. The supplier confirms the transaction with the buyer through the transaction agent of the infomediary, which allows the subsequent transfer of goods and services to ensue. These bidirectional information flows are labeled as agent communication AC-V in Figure 2. In addition, these communications are required to conform to standardized ontology for transaction requests provided to the buyer during the registration process for unambiguous content representation and interpretability of agent communications.

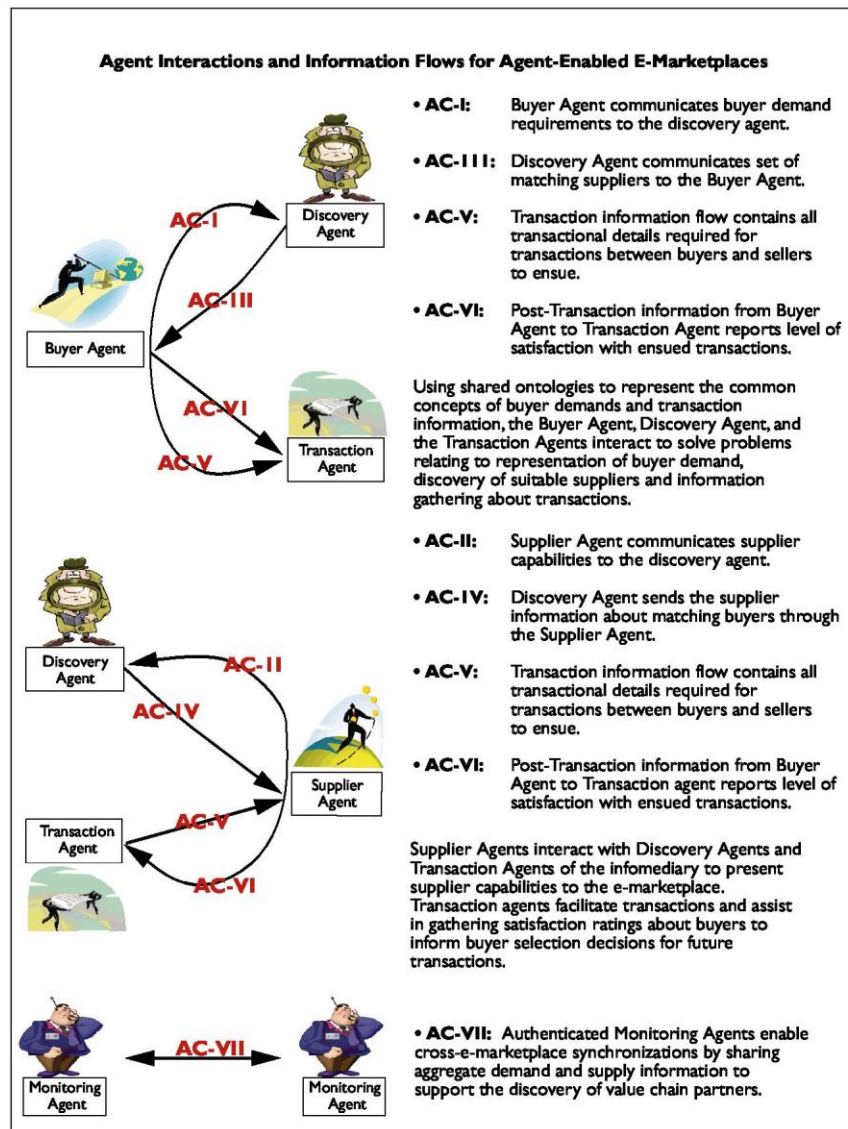


Table 3. Agent interactions in the agent-enabled e-marketplace.

Post-Transaction Information Gathering. Buyer and Supplier Agents must inform the transaction agent of their degree of satisfaction with the ensued transactions. This is agent communication AC-VI in Figure 2. The transaction agent records this transaction satisfaction history in the infomediaries repository through information flow ACI-VI. Aggregate transaction histories are used to develop reputation profiles of individual buyers and suppliers and facilitate the development of a reputation-based trust mechanism critical to the success of any e-marketplace [8, 11].

Cross-E-Marketplace Information Transparency. The information flows described previously extend to multiple e-marketplaces for cross-market information transparency by integrating multiple infomediaries as shown in Figure 3. Authenticated monitoring agents exchange volatile demand and supply information for trading partners in real time for informed planning throughout multiple infomediaries in the e-supply chain.

Monitoring agents of one e-marketplace communicate with authenticated monitoring agents of related e-marketplaces, shown as Agent Communication AC-VII in Figure 3, through information flow ACI-7. This information flow contains key market conditions, including market aggregate demand volume compiled by aggregating current transactions; potential volatile aggregate demand volume represented by aggregate of pending buyer demand functions; product information represented in ontologies that describe product characteristics; and market participant reputation information compiled from available transaction histories and reported levels of satisfaction. Thus, relevant information from single e-marketplaces is available to participants

in related e-marketplaces. In addition, suppliers in downstream e-marketplaces in the e-chain can assess their production plans by processing market-supplied upstream demand with their internal bills of materials and other ERP/MRP planning tools and generate demand functions for downstream e-marketplaces. The integrated e-chain shown in Figure 3 allows for dynamic and transparent planning of demand and supply requirements through real-time information integration across the e-chain. This provides distinct advantages for participants in intelligent e-chains over traditional supply chains.

Table 2 shows the roles and responsibilities of agents in the e-marketplace and Table 3 summarizes the interactions between agents to fulfill the functions of the e-marketplace. Emerging technologies offer unprecedented potential opportunities for e-chain participants to establish mutually beneficial and profitable relationships. In addition, this presents opportunities for creating an intelligent e-marketplace to enhance collaboration among participants in the e-chain. However, the dynamic nature of e-marketplaces in the e-chain, and resultant task complexities, require transparent information flows and the incorporation of intelligence in decision-support capabilities to realize the benefits of implementing such technologies to streamline business processes in an e-chain. This enhanced intelligent e-chain will provide significant advantages to all participants over less automated supply chains of competitors.

CONCLUSION

Technical elements and examples of rudimentary proofs of concept to create e-marketplaces using emerging technologies exist. With Hewlett-Packard's assistance, SpinCircuit (see ecat.edacafe.com/corpprofile.php?vendor_id=1000507) brings together geographically dispersed designers and manufacturers of electronic components in an e-marketplace for multiple collaborating companies. This e-marketplace provides a decided advantage to SpinCircuit over its competitors, and provides Hewlett-Packard with a learning curve advantage in creating e-marketplaces. Intelligent agents have also received significant attention as powerful modeling abstractions for B2B applications [4]. Together with emerging technologies like XML and Web services, these provide opportunities to develop integrative e-marketplaces throughout organizational value chains.

The vision of the agent-enabled infomediary-based e-marketplaces described here can benefit from the incorporation of elements of the Semantic Web initiative [2, 9]. The W3C developed the Resource Description Framework (RDF) as a standard for metadata to add formal semantics to the Web-based interactions. RDF is defined as extensions of XMLbased technologies that provide data models and syntactical convention to represent data semantics in standard and interoperable formats [5]. The RDF working group also developed RDF Schema (RDFS), an object-oriented system, as a minimal ontology modeling language. The W3C has made the Web Ontology Language (OWL) a recommendation. OWL facilitates greater machine interpretability of Web content than that supported by XML, RDF, and RDF-S by providing additional vocabulary along with a formal semantics (www.w3c.org/2004/OWL).

These initiatives form the basis to build more AI-inspired knowledge representation languages that are unambiguously computer-interpretable, making them amenable to agent interoperability and automatic reasoning techniques [5]. These developments bring the vision of agent-enabled infomediary-based e-marketplaces operating within the e-supply chain very close to reality. It is envisioned that numerous such infomediary-based e-marketplaces, built upon emerging technologies and accepted business ontologies, can provide discovery and transaction facilitation for participants, which is the first step toward creating intelligent e-marketplaces. Companies that incorporate these emerging technologies in their strategic vision can position themselves to realize the significant first-mover advantages that can be gained through information integration and transparency in these intelligent e-marketplaces [7]. Interestingly, what should be considered proactively in these emerging infomediary-based e-marketplaces is emphasis on intelligence to foster enhanced information transparency for the participants.

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