Enhancing Business Processes with Trustworthiness using Blockchain: A Goal-Oriented Approach

Haan Johng
University of Texas at Dallas
Texas, USA
haanmo.johng@utdallas.edu

Doohwan Kim
Chungbuk National University
Cheongju, South Korea
dhkim@selab.cbnu.ac.kr

Grace Park
State Farm
Texas, USA
g.e.park@ieee.org

Jang-Eui Hong
Chungbuk National University
Cheongju, South Korea
jehong@chungbuk.ac.kr

Tom Hill
Fellows Consulting Group, LLC
Texas, USA
tom@fellowsconsultinggroup.com

Lawrence Chung
University of Texas at Dallas
Texas, USA
chung@utdallas.edu

ABSTRACT

Blockchain technologies are intended to help enhance the trustworthiness of information, by improving transparency, traceability, and immutability of business logic and information, hence with the potential to be applicable to business process reengineering (*BPR*). However, an ad hoc approach to adopting blockchain technologies during BPR may lead to not better, but worse, than the current business processes, and with disappointments. In this paper, we present *Fides* - a framework for systematically utilizing blockchain towards enhancing business processes with trustworthiness. Fides takes a goal-oriented approach, in which trust-related concerns are explicitly represented as (soft)goals to be achieved, problems for achieving the goals are diagnosed, and then alternatives are explored in terms of business processes for eliminating or alleviating the problems, while at the same time achieving the goals. Finally, a selection is made among the alternatives that best utilize blockchain. To illustrate, and also see both strengths and weaknesses of Fides, a retail chain for a food supply chain is used throughout the paper, and is implemented using Ethereum and Hyperledger Fabric. Feedback from companies and students indicates that Fides leverages the level of confidence in the quality of the reengineered business processes, in utilizing blockchain.

CCS CONCEPTS

• **Applied computing → Cross-organizational business processes**; • **Software and its engineering →** *Extra-functional properties*; Software notations and tools;

KEYWORDS

Business Process Reengineering, Goal-Orientation, Blockchain, Non-Functional Requirements

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1 INTRODUCTION

A key challenge in business process reengineering (*BPR*) is enhancing trust among inter-organizational stakeholders to deliver value to customers (e.g., assuring food safety), by renovating and innovating business processes. In this regards, *blockchain*, which decentralizes information and its ownership by sharing a copy of data and business logic among the stakeholders, is expected to revolutionize numerous area with enhanced trust, and BPR seems no exception to this, as blockchain is intended to provide transparency, traceability, and immutability of information [1–5]. *But, how do we systematically and rationally utilize blockchain to enhance the trustworthiness of business processes*?

Inappropriate adoption of blockchain may well lead to a new business process, which can hurt the intended business goals, including increased cost, timing delays, or even less trust. An organization's business process should be carefully examined in determining where to use blockchain technologies in eliminating the most threatened parts of the process. For example, should all business tasks in business processes be converted to blockchain-based tasks? What are the trade-offs of various types of blockchains in achieving organizations goals? The questions to understand the rationale of BPR using blockchain would be important in adopting blockchain to business, but little work helps to answer the questions [6].

In this paper, we present *Fides*[1] - a framework for systematically and rationally utilizing blockchain, towards enhancing the trustworthiness of business processes. Specifically, Fides provides 1) an ontology for BPR with blockchain, 2) a comprehensive process with (semi-) formal representations, and 3) an assistant tool for modelling business processes utilizing blockchain together with template (block-) chain code. Fides takes a goal-oriented approach, in which trust-related concerns are explicitly represented as (soft) goals to be achieved, problems on current business processes in

[1] Fides is the Roman version of PISTIS in Greek mythology, the goddess of public trust

achieving the goals are diagnosed with more explicit and (semi-) formal representations, and then business process alternatives with different blockchain schemes are explored for eliminating or alleviating the problems, while at the same time achieving the goals. Goals can be expressed as Key Performance Indicators (KPIs) in analyzing trade-offs among the alternatives. Finally, a selection is made among the alternatives that best utilize blockchain in eliminating/alleviating the problems and achieving the goals. This way, Fides helps with reasoning, including constraint checking, consistency checking, as well as semi-automatic generation of blockchain-associated smart contracts.

The key technical (3) distinctives of our work lie in the use of blockchain, in the context of business process reengineering, and in a goal-oriented manner. Many blockchain articles have been well-studied on blockchain data and security analysis, such as [7, 8]. However, there seems a lack of studies describing how to redesign business activities that involve trust-related issues to blockchain-supported business activities. Some proposals on goal-oriented approaches have been made towards reengineering business processes more rationally [9, 10], however, trust-related concerns and solutions have not been discussed yet in the goal-orientations. In this paper, we go beyond by viewing trustworthiness as a (soft) goal and refining with a blockchain specific goal qualification and quantification scheme. Some recent studies also exist on automatically generating blockchain application code (e.g., smart contract or chain-code) from a business process; but, here, (reengineered) business process models are assumed given as the starting point [11, 12]. Our work is complementary to these recent approaches, by helping them find such reengineered business processes, therby helping prevent waste in time, cost and efforts for retrofitting business processes, only after the fact use of blockchain is found not to achieve, or even adversely affect, the anticipated goals.

To validate our approach, we developed prototype systems using Ethereum and Hyperledger Fabric, in two consequent senior design project courses, supported by a consulting company. Feedback from domain experts of two companies showed that use of Fides leverages the level of confidence in the quality of the reengineered business processes with enhanced trust, in utilizing blockchain.

Section 2 describes business processes of a retail chain as running examples and also for an initial empirical study. Section 3 presents the Fides framework, and Section 4 describes an experiment, together with a discussion of the applicability of the Fides. At the end, a summary of the paper and future work are described.

2 RUNNING EXAMPLE

Throughout this paper, to illustrate the key Fides concepts and assist with the initial understanding of the applicability of Fides, a reference apple-selling process model and a supplier-auditing process model of Walmart (somewhat sanitized) are used as running examples, where trustworthiness among stakeholders has been recognized as a critical factor, and yet challenging concerns. The business processes are illustrated in Fig. 1 using Business Process Model and Notation (*BPMN*). In Fig. 1(a), a supplier distributes apples with a food certification to a trader, who in turn distributes the apples to a retailer, who sells the apples to consumers. In Fig. 1(b), a retailer requests an audit agreement to suppliers and has the suppliers audited via an audit firm [13, 14].

Consumers rarely have a choice but to trust food certification labels. However, food scandals have lessened consumer trust in food certifications, and the auditing process is time-consuming and costly to respond to food scandals properly, leading to damages on the retailer's reputation and profit [1, 15]. The examples will be used to describe how Fides helps to derive better business processes using blockchain, in a systematic, explicit, and formal manner.

3 FIDES: A GOAL-ORIENTED FRAMEWORK FOR UTILIZING BLOCKCHAIN IN BPR

As described in Fig. 2, Fides helps turn current AS-IS business processes into TO-BE business processes utilizing blockchain together with template (block-) chain code rationally - rational in the sense of exploring alternatives, evaluating trade-offs among them, and selecting significant one by using goals as criteria. Fides consists of three parts: a reference ontology, a reference process, evolving prototype. The Fides ontology and process are intended to work as *a* reference model, rather than *the* reference model.

3.1 The Fides Ontology and Representations

The Fides ontology, described in Fig. 3(a), offers essential concepts, relationships among the concepts, and constraints for BPR using blockchain for a food supply chain, together with (semi-) formal representations. The essential concepts are extracted from the literature [2–6, 9, 10, 15–22].

In detail, business processes (*BP*) along with operationalizations (*OP*) are captured. Goals (*G*) and problems (*P*) in the business processes turned into explicit with clear traceability among them, in order to understand why and where to apply blockchain. Agents (*A*), such as suppliers, traders, or retailers, are captured because a key factor for maintaining a sustainable food supply chain is collaboration among agents. In addition, the incentive (*IC*) is captured as motivating the agents to have collaborative attitudes relies on incentive alignment. Cryptocurrency (*CC*) is captured as a way to provide an immediate the incentive [19].

Instances of the ontologies are semi-automatically represented in a formal manner by adopting the main representation idea used for goal modelling using scenarios [17]. For example, Walmart is an instance of Agent (*A*), enhancing the trust in apples is an instance of Goal (*G*), and using a food certification is an instance of operationalization (*OP*) to achieve the goal. The instances are represented as below:

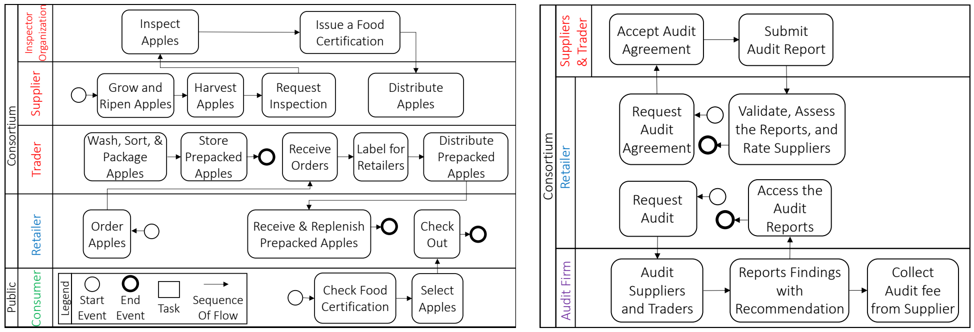
$$\begin{aligned}&\textit{Walmart}_A\ \textit{(wants to enhance the trustworthiness}\\&\textit{of apples by (using a food certification)}_{OP_1})_{G_3}\end{aligned} \tag{1}$$

The semi-formalization 1 is turned into a formal representation by adopting the NFR Framework as below [16]:

$$\textit{Satisficing } OP_1 \textit{ helps satisficing } G_3 \tag{2}$$

Then the NFR framework turns it into a formal representation in propositional logic as below:

$$\begin{aligned}&\textit{satisficed}(OP_1) \wedge \textit{satisficed}(\textit{help}(OP_1, G_3))\\&\rightarrow \textit{weakly satisficable}(G_3)\end{aligned} \tag{3}$$



(a) An Apple-Selling Business Process Model. (b) A Supplier-Auditing Business Process Model.

Figure 1: AS-IS business process models of a food supply chain using BPMN, as running examples.

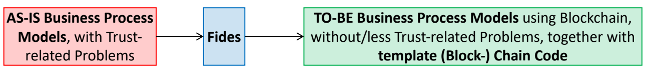


Figure 2: A high level view of the Fides framework.

The formalization 3 can be shortly expressed as below:

$$OP_1 \xrightarrow{+} G_3. \quad (4)$$

The NFR Framework represents non-functional requirements, having no clear-cut criteria to determine a level of satisfaction, as softgoals. Operationalizations to *satisfice* the softgoals (instead of satisfying) are represented as operationalizing softgoals. The NFR Framework visualizes the softgoals by using Softgoal Interdependency Graph (SIG) as illustrated in Fig. 4. A softgoal is depicted as a thin cloud symbol, and an operationalizing softgoal is illustrated as think cloud. The NFR framework offers make($\xrightarrow{++}$), help($\xrightarrow{+}$), hurt($\xrightarrow{-}$), and break($\xrightarrow{--}$) operators, resulting in satisficable, weakly satisficable, weakly deniable, and deniable respectively. The short formal representation and visualization using SIG will be used throughout this paper to describe the Fides process [16].

3.2 The Fides Process

The Fides reference process, depicted in Fig. 3(b), describes steps for reengineering business processes using blockchain in a rational and systematic way. The process consists of three stages; problem diagnosis, solution exploration, and process reengineering. Our process borrowed the key process idea for BPR using goals, and we extended the idea with (trust-) problems, a domain-specific goal model and ontology, and blockchain-specific solutions [10].

During the process, implicit (trust-related) issues and objectives on AS-IS business processes are diagnosed then turned into explicit by using a goal model. The AS-IS business process models, enhanced with the explicit problems and goals, provide insights into where and why to apply blockchain. Then, TO-BE business processes alternatives are explored, and their trade-offs are analyzed, using goals as evaluation criteria, such as Key Performance Indicators (KPIs). At last, the alternative that best achieves the goals is selected.

3.3 Fides In Action

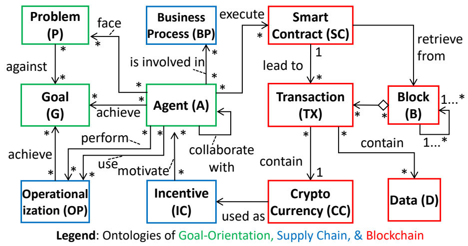
By applying Fides ontology and process to the running examples, we illustrate how Fides can be applied to BPR using blockchain.

3.3.1 ***Step 1 - Problem Diagnosis.*** For (selling apples)$_{BP_1}$, a retailer has used (a food certification)$_{OP_1}$ to (enhance the trustworthiness of apples)$_{G_3}$. The trust in apples helps consumers$_A$ to (assure food safety)$_{G_1}$. However, (scandals on certified food)$_{P_1}$ (have lessened the trust in food certifications)$_{P_2}$. Due to (the use of the isolated databases)$_{OP_2}$ among (suppliers, traders, and retailers)$_A$, consumers$_A$ have (a lack of transparency and traceability on provenance information)$_{P_3}$, e.g., how apples are produced and distributed, leading to a negative impact on (the trustworthiness of the food)$_{G_3}$.

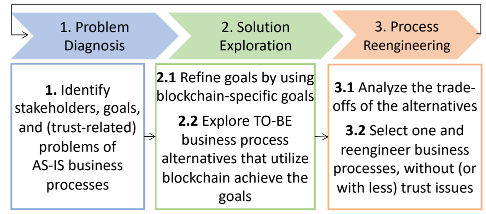
The semi-formal description above is a simple thread of applying Fides to the running examples. According to the formalization 4, we can briefly express the simple thread as follows. $OP_1 \xrightarrow{+} G_3$ and $G_3 \xrightarrow{+} G_1$. $P_1 \xrightarrow{++} P_2$ and $P_2 \xrightarrow{--} OP_1$. Therefore OP_1 is denied, G_3 is denied, G_1 is denied. Moreover, $OP_2 \xrightarrow{++} P_3$ and $P_3 \xrightarrow{--} G_3$.

Fides helps to model the semi-formal description and propositional logic above, as illustrated in Fig. 4. Business Process Modeling Notation (BPMN) is extended with Softgoal Interdependency Graph (SIG) of the NFR Framework to illustrate traceability among business tasks, problems, and goals explicitly. The simple thread is highlighted with thick arrows. The business tasks involved in the transparency and traceability issue on provenance information are colored red as the tasks to be reengineered using blockchain. The (supplier-auditing process)$_{BP_2}$ is modeled with thin arrows in Fig. 4 and can be formalized in the same way with the simple thread.

3.3.2 ***Step 2 - Solution Exploration.*** After modelling the problems and goals on AS-IS business processes, Fides helps refine the unsatisfied softgoals and explore TO-BE business process alternatives utilizing blockchain to achieve the softgoals. The softgoal of (enhancing the trustworthiness of food)$_{G_3}$ is not satisfied due to (a lack of consumer trust in food certifications)$_{P_2}$ and (issues on transparency and traceability provenance information)$_{P_3}$. Instead of using a food certification$_{OP_1}$, a retailer$_A$ sets new softgoals of (enhancing food provenance information)$_{G_{10}}$ by improving information (traceability and transparency)$_{G_{11,12}}$ [1].



(a) A Fides Reference Ontology for a Supply Chain using Blockchain.



(b) A Fides Generic Reference Process.

Figure 3: The Fides ontology and process for reengineering AS-IS business processes, utilizing blockchain.

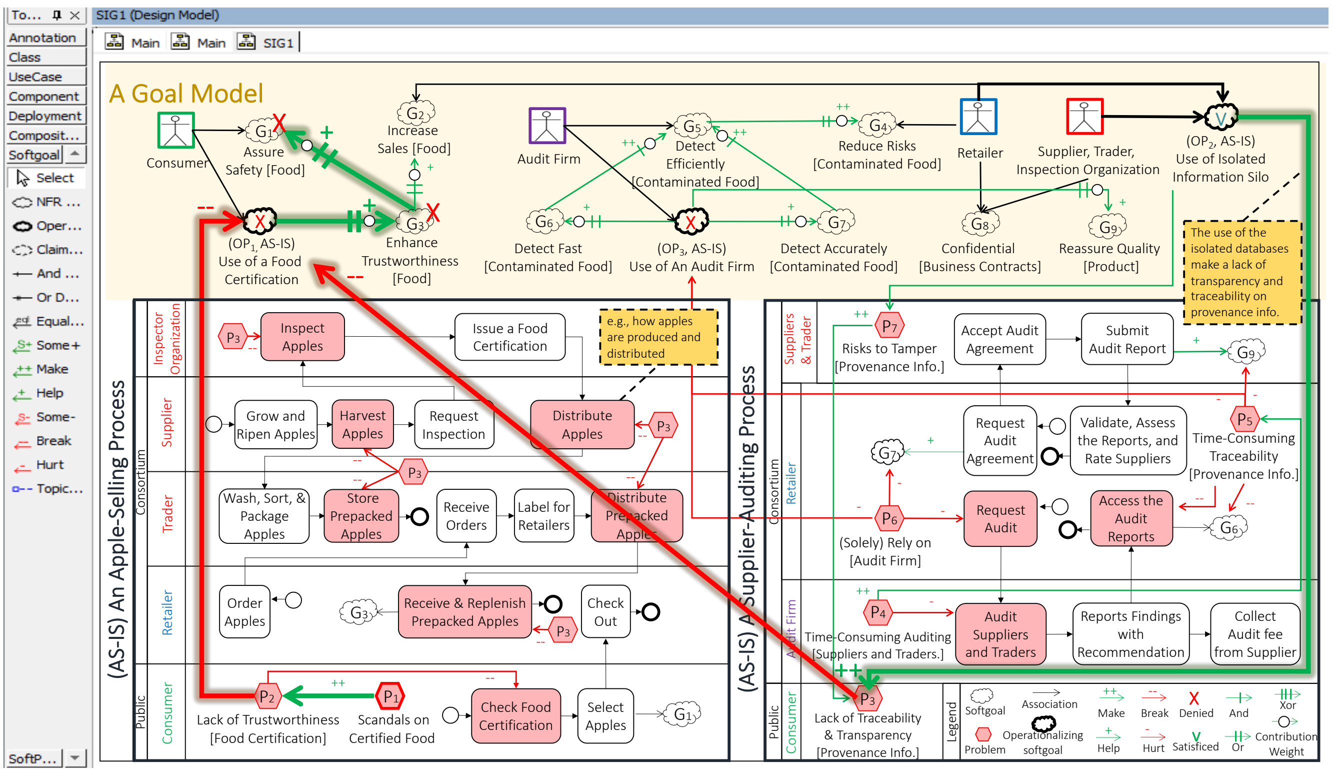
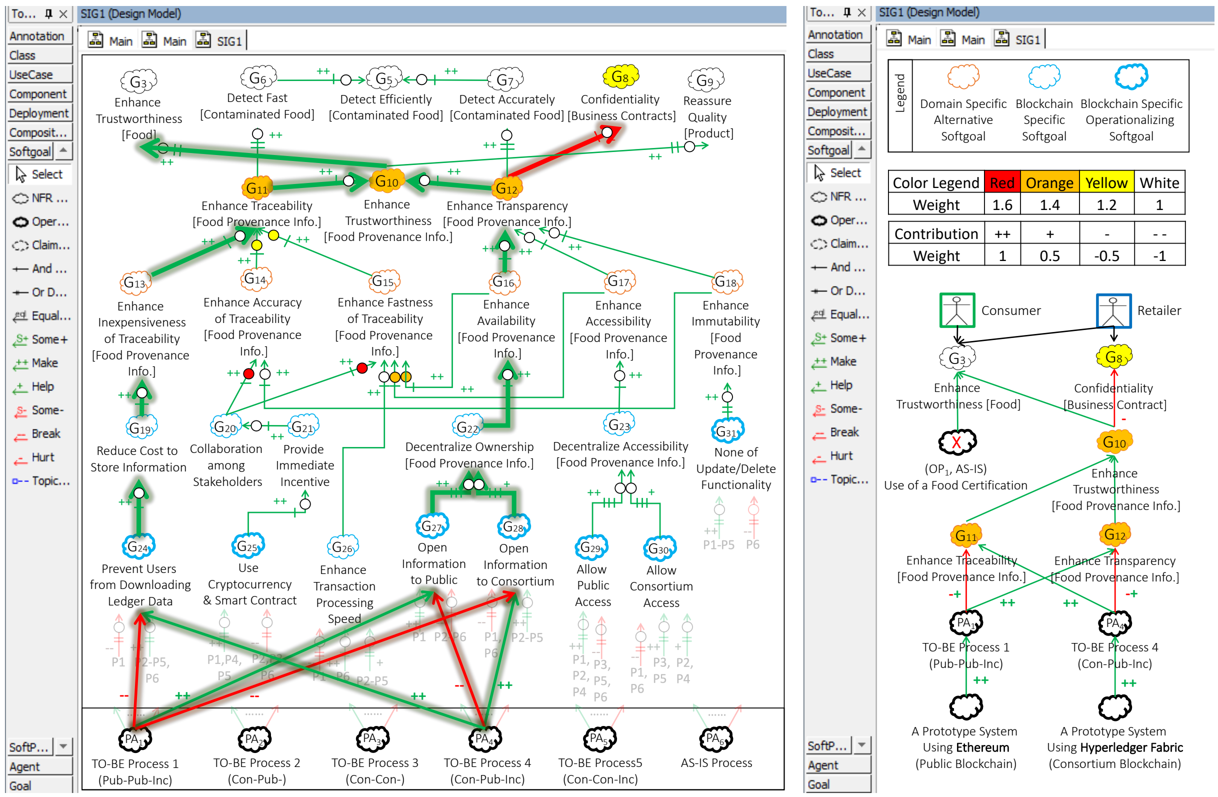


Figure 4: The Fides process step 1 - Diagnosing problems and associated (unsatisfied) goals on AS-IS business processes.

Fides helps decompose the new softgoals into fine-grained subgoals to define a way to achieve the goals explicitly. Fig. 5(a) illustrates a reference goal model to show an example of how to decompose the new softgoal of enhancing the trustworthiness of food provenance information and how to derive TO-BE business process alternatives achieving the softgoals. A simple thread of Fig. 5(a) is highlighted with thick arrows and simplified in Fig. 5(b).

Definitions of traceability$_{G_{11}}$ and transparency$_{G_{12}}$ are adopted from supply chain literature. Traceability$_{G_{11}}$ is defined as an ability to access any or all information related to food provenance information accurately$_{G_{14}}$ and trace upward and track downward at anytime quickly$_{G_{15}}$ (without the expensive cost)$_{G_{13}}$. Our running definition of transparency$_{G_{12}}$ is the degree of availability$_{G_{16}}$ and accessibility$_{G_{17}}$ of food provenance information (without loss, noise, or distortion)$_{G_{18}}$. However, increased transparency$_{G_{12}}$ has a potential conflict of (leaking business contact information$_{G_8}$) to other competitors. Fast traceability$_{G_{15}}$ can be satisficed by enhancing availability$_{G_{16}}$, accessibility$_{G_{17}}$, collaboration$_{G_{20}}$ among stakeholders, and (transaction processing speed)$_{G_{26}}$. Accurate traceability$_{G_{14}}$ is satisficable by the enhancing immutability$_{G_{19}}$ and the collaboration$_{G_{20}}$. Providing incentive$_{G_{21}}$ has practiced in the field to encourage stakeholders to have the collaborative attitude [19–22].

The softgoals are further decomposed into blockchain specific softgoals. As the use of blockchain decentralizes ownership$_{G_{22}}$ and accessibility$_{G_{23}}$ of information, the availability$_{G_{16}}$ and accessibility$_{G_{17}}$ of food provenance information can be enhanced. Moreover, as



(a) A Reference Goal Model - A Full Thread. (b) A Simple Thread.

Figure 5: The Fides process step 2 - Defining domain-specific alternative softgoals to resolve the unsatisfied softgoals, discovering goal conflicts, exploring blockchain-specific softgoals to achieve the domain-specific softgoals, and exploring TO-BE business processes together with trade-offs to the softgoals, using Softgoal Interdependency Graph (SIG).

blockchain (does not offer the update and delete functionalities)$_{G_{31}}$, the provenance information stored on blockchain can be immutable$_{G_{18}}$. Public blockchains involve issues of storing the massive size of a ledger. Hence, inexpensive$_{G_{13}}$ traceability of provenance information defined as (reducing the cost to store data)$_{G_{19}}$ by (preventing participants from downloading the large size ledger)$_{G_{24}}$. The decentralization level of the accessibility can be either public$_{G_{29}}$ or consortium$_{G_{30}}$. Likewise, the degree of decentralizing ownership also can be either public$_{G_{27}}$ or consortium$_{G_{28}}$. The use of a cryptocurrency$_{G_{25}}$ is captured to implement immediate incentive alignment, encouraging employees to deliver fast and accurate provenance information. The semi-formal description is visualized in Fig. 5(a) and can be formally expressed by following Formalization 4. For example, $(G_{11}$ and $G_{12}) \xrightarrow{++} G_{10}$ and $(G_{27}$ xor $G_{28}) \xrightarrow{++} G_{22}$.

From the fine-grained blockchain-specific goals, we can derive TO-BE business process alternatives utilizing blockchain. In our case, we derived five process alternatives (PA_{1-5}) having different blockchain configuration options. PA_1 (Pub-Pub-Inc) decentralizes the ownership and accessibility to the public by using a public blockchain with cryptocurrency as an incentive system. PA_2 (Con-Pub-) uses a consortium blockchain without the use of an incentive system, decentralizing the ownership only to a consortium but enabling the public to access the information through authentication. PA_3 (Con-Con-) decentralizes the ownership and accessibility only to a consortium, without the use of an incentive system. PA_4 (Con-Pub-Inc) and PA_5 (Con-Con-Inc) are same as PA_2 and PA_3 respectively but the use cryptocurrency as an incentive system.

3.3.3 *Step 3 - Process Reengineering*.

Fides utilizes the NFR Framework to identify the most suitable one and threatening ones in satisfying the goals. Qualified and Quantified goals act as criteria and Key Performance Indicators (KPIs) to evaluate the trade-offs of the alternatives and select the reasonable one [16].

For qualifying the alternatives, Fides helps to model trade-offs of the alternatives in achieving the goals. For example, PA_1 using a public blockchain decentralizes the data ownership$_{G_{27}}$ to the public towards higher transparency$_{G_{12}}$. However, PA_1 has issues of synchronizing a massive size ledger$_{G_{24}}$ and low performance$_{G_{26}}$ in consensus algorithms, leading to reduced traceability$_{G_{11}}$ for consumers$_A$. Moreover, enhanced transparency$_{G_{12}}$ may or may not hurt the goal of confidentiality$_{G_8}$ of business contract. On the other hand, PA_3 utilizing a private blockchain maintains a lower volume of the ledger$_{G_{24}}$ and uses faster performance$_{G_{26}}$ in consensus algorithms, leading to enhanced traceability$_{G_{11}}$. However,

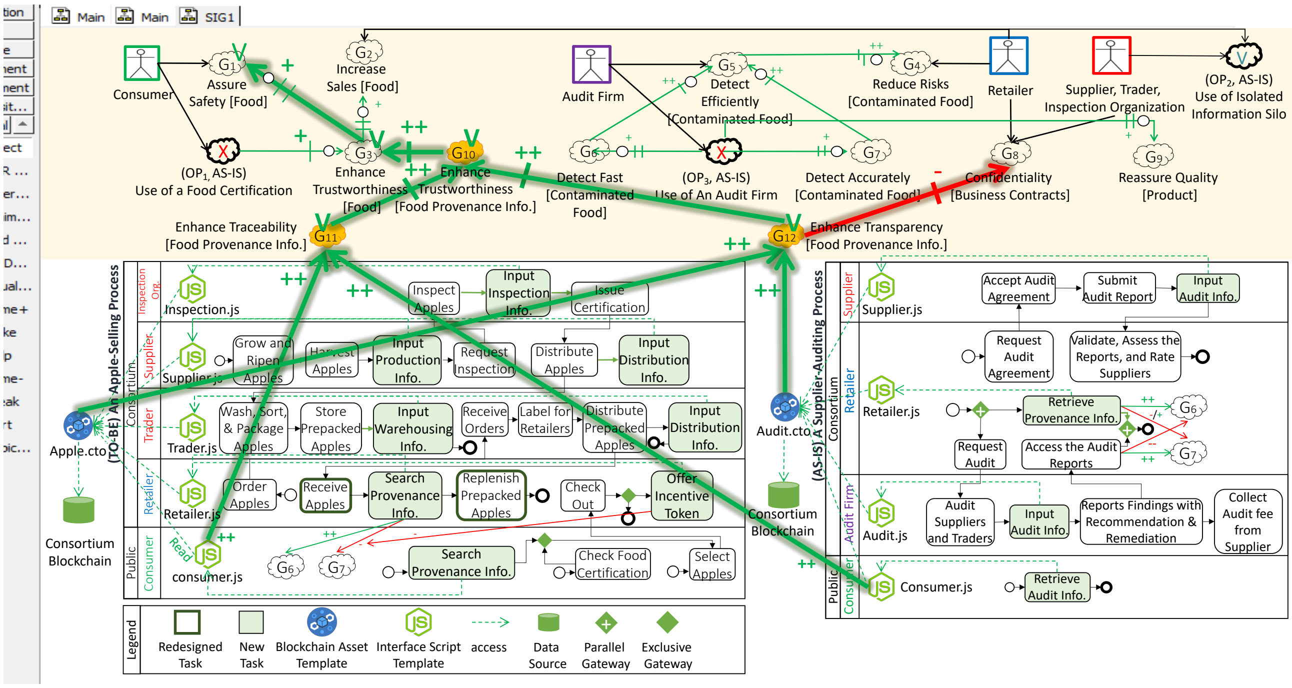


Figure 6: The Fides process step 3 - Reengineering AS-IS business processes according to the selected TO-BE business process and generating template (block-) chain code.

as PA_3 opens ownership$_{G_{28}}$ and accessibility$_{G_{30}}$ only to a consortium, PA_3 results in less transparency$_{G_{12}}$. Therefore, PA_1 and PA_3 have trade-offs among the traceability$_{G_{11}}$, transparency$_{G_{12}}$, and confidentiality$_{G_8}$. PA_2 alleviates the trade-offs by allowing the public to access the information [3, 21]. The examples above can be expressed in propositional logic as follows and are illustrated at the bottom of Fig. 5(a). For example, $PA_1 \xrightarrow{++} G_{27}$, but $PA_1 \xrightarrow{--} G_{24}$.

Fig. 5(b) describes a simple thread of the qualification. PA_1 that uses Ethereum enhances transparency but breaks traceability. On the other hands, PA_4 that utilizes Hyperledger Fabric provides better traceability but offers weaker transparency thatn PR_1.

For quantifying the qualified goal model, we extended the NFR Framework with a scheme using a fuzzy control logic and analytic hierarchy process. A goal contribution link has a weight to express the relative importance of a sub-goal to other goals. For example, G_{20} is one of two sub-goals of G_{14} and is one of four sub-goal of G_{15}. Accordingly, G_{20} is relatively less important to G_{15} than G_{14}. Additionally, each goal also has a relative importance weight. We used a color scheme from white to red to express the relative importance. A user definable rule for mapping from the color scheme (e.g., goal contributions and relative importance) to a quantification scheme is illustrated in Fig. 5(b). Fides automatically quantifies the goal achievements as below:

$$S_G = w_G * \sum_{i=1}^{n} (S_{G_{sub_i}} * C_{G_{sub_i}} * w_{C_{G_{sub_i}}}) \quad (5)$$

S_G (a satisfaction score of a goal G) is the product between w_G (the weight of G) and the sum of the propagated satisfaction score from G_{sub_i} (the subgoals of G). $S_{G_{sub_i}}$ is the satisfaction score of G_{sub_i}, $C_{G_{sub_i}}$ is the score of the contribution from G_{sub_i} to G, and $w_{C_{G_{sub_i}}}$ is the weight of this contribution. For example, in case of $PA_2 \xrightarrow{+} G_{26}$, G_{sub_i} is PA_2. $w_{G_{26}}$ is 1 (white color), S_{PA_2} is 1 (white), C_{PA_2} is 0.5 (help, +), $w_{C_{PA_2}}$ is 1 (white); therefore $S_{G_{26}}$ is 0.5.

Table 1: Quantified goal satisfaction (*QGS*)

	$S^{C_1}_{G_{10}}$	$S^{C_1}_{G_8}$	$S^{C_2}_{G_{10}}$	$S^{C_2}_{G_8}$	$S^{C_3}_{G_{10}}$	$S^{C_3}_{G_8}$
PA_1	0.921	-0.560	0.527	-0.300	0.133	-0.039
PA_4	0.605	-0.213	1	-0.473	0.803	-0.343

Table 1 shows an example of quantified goal satisfaction (*QGS*) scores of high-level softgoals (G_{10} and G_8) for PA_1 and PA_4. The scores are Min-Max normalized from -1 (break) to 1 (make). The score color follows the scheme described in Fig. 5(b). C_i is a configuration setting for goals in a xor relationship. For example, C_1 is (G_{28} and G_{30}), C_2 is (G_{29} and G_{30}), and C_3 is (G_{29} and G_{31}).

Through the QGS, Fides detects conflicts among high-level goals then selects an alternative that alleviates the conflicts. Fides identifies conflicts as below:

$$QGS[PA_i, S^{C_j}_{G_k}] * QGS[PA_i, S^{C_j}_{G_{k'}}] < 0 \\ \rightarrow Conflict(G_k, G_{k'}) \quad (6)$$

Given QGS that outputs a satisfaction score of G_k using PA_i with C_j, $Conflict$ outputs whether G_k and $G_{k'}$ are in conflict. For example, as $QGS[PA_1, S^{C_1}_{G_{10}}]$ is positive and $QGS[PA_1, S^{C_1}_{G_8}]$ is negative. Their product is negative, hence implying that G_{10} and G_8 are in conflict. Then, a selection is made according to (user-definable) rules as described in algorithm 1.

Algorithm 1 (User-Definable) Alternative Selection

procedure ALTERNATIVE_SELECTION(QGS)
  if $Conflict(G_k, G_{k'})$ **then**
    return PA_i, where
    $\max_{i,j,k \in \mathbb{Z}} (QGS[PA_i, S_{G_k}^{C_j}] + QGS[PA_i, S_{G_{k'}}^{C_j}])$
  else
    return PA_i, where
    $\max_{i,j,k \in \mathbb{Z}} (QGS[PA_i, S_{G_k}^{C_j}])$, where G_k has $\max(w_G)$

In our case, PA_4 with C_2 is identified as the most suitable one. Fig. 6 shows the redesigned TO-BE business processes through Fides, according to the PA_4. The business tasks diagnosed as problems are reengineered with blockchain-specific tasks. For example, in the (apple-selling process)$_{BP_1}$, if consumers$_A$ doubt a food certification$_{OP_1}$, consumers$_A$ can track the provenance information of food to alleviate their trust-related concerns, such as P_2 and P_3. If the consumer search leads to an actual purchase$_{G_2}$, a retailer$_A$ can offer an incentive token$_{IC}$ to suppliers$_A$ and traders$_A$ for a sustainable supply chain. In the (supplier-auditing process)$_{BP_2}$, the retailer$_A$ can retrieve the provenance information from blockchain to respond to the food scandals quickly$_{G_6}$, instead of waiting for the (time-consuming auditing reports)$_{P_{6,7}}$.

3.4 The Fides Evolving Prototype

The Fides Assistant utilizes and extends the RE-Tool that provides modelling and reasoning features for BPMN and SIG [23], with blockchain-specific modelling and reasoning support for utilizing blockchain during BPR. The Fides Assistant helps with reasoning, including constraint checking, consistency checking, and semi-automatic blockchain code generation (e.g., smart contract and chain code) via deductive or abductive derivation - possibly via capturing and reusing previous knowledge, experience, and patterns.

After modeling TO-BE business processes as described in Fig 6, Fides generates template (block-) chain code (semi-) automatically according to the TO-BE models. Each stakeholder in a swimlane considers as a participant of the blockchain, and the access links from the stakeholder to blockchain asset symbols consider as access rules to the assets. For example, a simple template code for Hyperledger Fabric for the customer and the apple asset can be generated as described in Listing 1. The read access link from customer to the apple asset represents a read-only constraint. The Search Provenance Information task for the customer generates transaction template code and event template code.

Listing 1: Chain code snippets (smart contract) of Customer, Apple, and Search Provenance Information task

```
asset Apple identified by key{
  o String    key
  --> Apple    ref[]    optional
}
participant Customer extends Stakeholder {
   o String key
}
rule AppleCustomerPermission {
   participant: "Stakeholder.Customer"
   operation: READ
   resource: "Apple.*"
   action: ALLOW
}
transaction SearchProvenanceInfo{
  o String    key
}
event eventSearchProvenanceInfo{
  o String    key
  o DateTime   timestamp
}
```

This helps, especially when relationships and constraints among the assets, participants, and transactions are complicated. This simple template code can be enhanced if more knowledge and patterns of applications are developed and adapted.

4 EXPERIMENTATION AND DISCUSSION

Our experimentation through interviews aims to validate the applicability of Fides in leveraging the level of confidence during BPR and the quality of the reengineered business processes employing blockchain. The confidence level is defined as the degree of rational BPR and the quality is evaluated based on Key Performance Indicators (KPIs) that act as evaluation criteria. Prioritized softgoals, such as traceability, transparency, and trustworthiness, or confidentiality, are utilized as the KPIs. The degree of softgoal satisfaction quantifies the KPIs, and the quantification scheme is Make (+1), Help (+0.5), Hurt (-0.5), Break (-1), and Not Sure (0) [16].

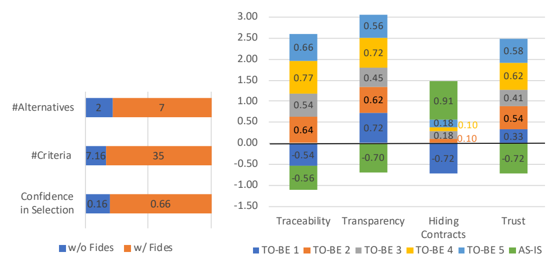
4.1 Experimentation Setting

Interviewees consisted of four domain experts from a consulting company, six engineers from a small-to-medium retail company, eight researchers from a university, and twelve students in two consequent senior design courses. During the interview, the interviewees used our prototype systems that implement the TO-BE business processes described in our approach using Ethereum and Hyperledger Fabric. Private Ethereum is employed to implement an incentive system as a proof of concept.

Feedbacks from the interview are described in Fig. 7. Before initiating Fides projects, six students were asked to redesign AS-IS business processes for adopting blockchain. To evaluate how rationally and systematically the interviewees redesign the AS-IS processes, we captured the number of business process alternatives the interviewees captured and the number of criteria to analyze the trade-offs among the alternatives. The interviewees rated their confidence level in selecting one of the alternatives according to the quantification scheme. After developing Fides, we repeated the same interview with the other six students and the other eighteen interviewees (domain experts, engineers, and researchers) with the help of Fides, then compared with the first group. They also evaluated KPIs of the reengineered business processes using our prototype systems (e.g., traceability, transparency, trust, and confidentiality) to see the applicability of blockchain.

4.2 Observation

Fig. 7(a) shows that Fides leverages the confidence level during BPR using blockchain. As interviewees generate more business process alternatives and evaluation criteria, they showed higher confidence levels. Specifically, interviewees from industry extended our reference goal model to customize KPIs for their industry, such as enforceability or liability of blockchain-based contracts and derived seven business process alternatives, leading to increasing the confidence level in selecting an alternative.



(a) Confidence Level during BPR.

(b) KPIs of Reengineered Business Processes.

Figure 7: Feedbacks on the applicability of Fides.

Fig. 7(b) shows feedbacks that the use of blockchain helps to enhance the trustworthiness of business processes but potentially breaks the confidentiality of contracts by exposing data in transactions to competitors. TO-BE business processes scored higher KPIs than AS-IS business processes, however, the TO-BE business process 1 using Ethereum obtained negative scores on traceability and confidentiality of data, because storing the public ledger of Ethereum is expensive and time-consuming. In addition, a Chief Technical Officer of a giant system integration company showed a strong interest in using our proposal for their systems.

4.3 Threats to Validity

Our evaluation is based on the human confidence level as BPR requires human effort and decision. As our evaluation can be subjective and incomplete, our evaluation scale seems necessary to be broadened with more number of industry experts. In order to apply our approach to a variety of different business domains directly, we have a lack of reference models guiding ontology, goals, conflicts, and associated solutions as a catalog - a catalog for selecting similar one to a specific domain and customizing the model. Furthermore, more in-depth reference models are required for other goals except for trustworthiness, such as confidentiality. For example, what types of data need to confidential (or open to the blockchain) and how blockchain achieves the confidentiality.

5 CONCLUSION

In this paper, we have presented Fides - a goal-oriented framework for enhancing business process reengineering (BPR) with trustworthiness, by utilizing blockchain systematically and rationally. Feedback from domain experts and students indicates that Fides helps increase the level of confidence in the quality of reengineered business processes utilizing blockchain, at least for a food supply chain. More specifically, Fides offers 1) a reference ontology for capturing essential concepts in a food supply chain and relationships between them, 2) a reference process for using the ontology in helping BPR with blockchain, where key business concerns are represented as (soft-) goals, problems are diagnosed, alternative business processes are explored as solutions and the most suitable selection is made - all these with more explicit and (semi-) formal representations, and 3) an assistant tool for modelling blockchain-based business processes according to the Fides process and (semi-) automating blockchain code generation.

There are several lines of future work. For broader applicability of Fides, we are planning to apply Fides to various types of applications, such as aviation supply chain, insurance, and the like, while involving larger groups of students and industrial practitioners. Fuller implementation of the evolving Fides tool is underway, using rule-based automation and blockchain code generation.

REFERENCES

[1] D. Galvin, "IBM and Walmart: Blockchain for Food Safety," 2017.
[2] M. Hammer and J. Champy, *Reengineering the Corporation: Manifesto for Business Revolution, A,* Zondervan. 2009.
[3] M. Swan, *Blockchain: Blueprint for a New Economy,* O'Reilly Media, Inc. 2015.
[4] G. Wood, "Ethereum: A Secure Decentralised Generalised Transaction Ledger," *Ethereum Project Yellow Paper.* 2014.
[5] C. Cachin, "Architecture of the Hyperledger Blockchain Fabric," *Workshop on Distributed Cryptocurrencies and Consensus Ledgers.* 2016.
[6] J. Mendling, et al., "Blockchains for Business Process Management-Challenges and Opportunities," *ACM Transactions on Mgmt. Info. Sys., 9(1).* 2018.
[7] M. E. Maouchi, O. Ersoy, and Z. Erkin, "DECOUPLES: a decentralized, unlinkable and privacy-preserving traceability system for the supply chain," *Proc.,* 34^{th} *ACM/SIGAPP Symposium on Applied Computing.* 2019. pp. 364-373.
[8] V. Reniers et al., "Analysis of architectural variants for auditable blockchain-based private data sharing," *Proc.,* 34^{th} *ACM/SIGAPP Symposium on Applied Computing.* 2019. pp. 346-354.
[9] E. S. K. Yu and J. Mylopoulus, "Using Goals, Rules, and Methods to Support Reasoning in Business Process Re-engineering," *Intell. Sys. in Accounting, Finance and Mgmt., 5(1).* 1996. pp. 1-13.
[10] G. Park, L. Chung, L. Khan and P. Sooyong, "A Modeling Framework for Business Process Reengineering using Big Data Analytics and a Goal-orientation," 11^{th} *Int. Conf. on Research Challenges in Info. Science.* 2017. pp. 21-32.
[11] I. Weber, et al., "Untrusted Business Process Monitoring and Execution using Blockchain," *Int. Conf. on Business Process Mgmt.* 2016. pp. 329-347.
[12] T. Astigarraga, et al., "Empowering Business-Level Blockchain Users with a Rules Framework for Smart Contracts," *Int. Conf. on Svc.-Or. Comp.* 2018. pp. 111-128.
[13] C. N. Verdouw, et al., "Process Modelling in Demand-Driven Supply Chains: A Reference Model for the Fruit Industry," *Computers and Elec. in Agri., 73(2).* 2010. pp. 174-187
[14] Walmart, "Audit and Assessment Policy and Guidance," 2017.
[15] R. Johnson, "Food Fraud and Economically Motivated Adulteration of Food and Food Ingredients," *Congressional Research Service.* 2014.
[16] L. Chung, B. A. Nixon, E. Yu, and J. Mylopoulos, *Non-functional Requirements in Software Engineering,* Kluwer Academic Publisher. 2000.
[17] C. Rolland, et al., "Guiding Goal Modeling using Scenarios," *IEEE Trans. on Soft. Eng. 24(12).* 1998. pp. 1055-1071.
[18] K. Belhajjame and M. Brambilla, "Ontology-based description and discovery of business processes," *Enterprise, Business-Process and Information Systems Modeling.* 2009. pp. 85-98.
[19] N. Pakdeechoho and V. Sukhotu, "Sustainable Supply Chain Collaboration: Incentives in Emerging Economies," *Journal of Manufacturing Tech. Mgmt., 29(2).* 2018. pp. 273-294.
[20] P. M. Wognum, et al., "Systems for Sustainability and Transparency of Food Supply Chains–Current Status and Challenges," *Adv. Eng. Informatics, 25(1).* 2011. pp. 65-76.
[21] G. J. Hofstede, et al., "Hide or Confide: the Dilemma of Transparency," *Reed Business Media.* 2004.
[22] M. M. Aung and Y. S. Chang, "Traceability in a Food Supply Chain: Safety and Quality Perspectives," *Food Control, Vol. 39.* 2014. pp. 172-184.
[23] S. Supakkul and L. Chung, "The RE-Tools: A multi-notational requirements modeling toolkit," *IEEE Int. Requirements Engineering Conf.* 2012. pp. 333-334.