Change Impact Analysis of Indirect Goal Relations: Comparison of NFR and TROPOS Approaches Based on Industrial Case Study

Abelneh Teka, Nelly Condori-Fernández, Ivan Kurtev
Department of Computer Science
University of Twente
Enschede, Netherlands
a.y.teka@student.utwente.nl
{N.CondoriFernandez, I.K.Ivanov}@utwente.nl

Dick Quartel, Wilco Engelsman
Department of Research and Development
BiZZdesign B.V.
Enschede, Netherlands
{d.quartel, w.engelsman}@bizzdesign.nl

***Abstract*—Along with recent trends in using goal-oriented approaches for requirements engineering and system development activities, various techniques for managing adaptable stakeholder goals and requirements are proposed and used by the software engineering industry. Enterprise Architecture (EA) models which tie business goals, business processes and supporting IT systems are also expected to support reasoning on impact of changes on goals and requirements. Unfortunately common Enterprise Architecture (EA) frameworks like The Open Group Architecture Framework (TOGAF) and EA modeling languages like Archimate lacks support for analyzing goal and requirement change impacts in EA goal models. This paper reports an effort to fill this gap by extending a metamodel of already existing requirements and goal modeling language. The extension adds semantically reach definitions for goal influence relations that support reasoning on these relations. To leverage existing change impact analysis techniques, a literature review was conducted on existing goal change management techniques. Two candidate approaches (TROPOS and NFR framework) were chosen from the review results based on comparative analysis study. However, there is no evidence suggesting which of these two approaches suits more for EA goal model analysis. To find empirical evidence on the applicability of these approaches, we develop an adapted algorithm as well as a tool support for both techniques and apply both approaches on an industrial case study. Two main lessons were learned from the result of the case study. First both approaches have some limitations when applied to EA goal analysis and second, the NFR/Fuzzy logic based approaches provide more concrete results than the TROPOS based approaches.**

Keywords-goal change management; goal reasoning; indirect influence relations; enterprise architecture

I. Introduction

Business environments nowadays are becoming increasingly more dynamic, demanding continuous adaptation in business process designs and realizations. Enterprise Architectures (EA) models, which tie business processes and supporting/enabling IT systems, are also expected to cope with the dynamics of business processes to make sure the EA achieves the intended purposes.

The changes in business processes and/or IT systems are primarily caused by various changes in the business environments. But from the system development perspective, changes occur when the stakeholder's goals and requirements are altered to cope with the changes in business environments. Correspondingly, EA frameworks are expected to have techniques for managing goal and requirement changes and their impacts. Unfortunately common EA frameworks like TOGAF [1] lack the ability to analyze the impact of goals and requirements changes in EA models.

Goals and requirements modeling in EA helps in understanding, structuring and analyzing the way business requirements are related to IT requirements and vice versa thereby facilitating business-IT alignment [2]. From the system development perspective, stakeholder goals are very important because they can play a vital role in requirements acquisitions, management of requirement conflicts, maintaining of traceability between requirements and organizational contexts, etc. [3]. These prominent advantages of goals in system development process have given rise to relatively new approaches of Requirement Engineering(RE) like Goal Oriented Requirement Engineering (GORE) [4] and approaches of system development methodologies like TROPOS[5].

Involving initial stakeholder goals in system development processes is not enough for sustaining continuous satisfaction of stakeholder goals. In fact, managing the dynamicity of stakeholder goals is at least as important as the elicitation and specification of goals themselves because it can facilitate and maintain the required adaptability of business processes and supporting/enabling IT systems. The rising of a number of goal based approaches for goal and requirement change management is a an indicator for the effort in utilizing the benefits of goal change managements in system development processes (e.g. [3], [5], [6]).

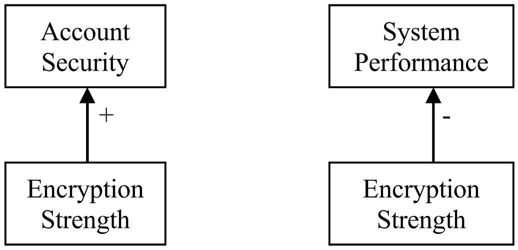

Figure 1. A) Positive causal effect. B) Negative causal effect.

Though goal oriented approaches have their roots in system development activities, they are not widely used in Enterprise Architecture (EA) methodologies and frameworks [7]. For instance, in the Architecture Development Methodology (ADM) of the Open Group Architecture Framework (TOGAF) [1], [8], requirements play a central role to drive other phases of EA development process.

However, there is no explicit way of modeling the goal and requirements of the EA as well as the various types of relation between goals and requirements. The lack of explicit representation of relations between goals results in inability to model the goal contribution relations and correspondingly the goal change impacts in enterprise architectures.

Generally two types of influence relations are used in goal change impact analysis techniques: positive influence and negative influence. In a positive influence, the change in the influencer entity is directly proportional to the change in the affected entity. For instance, an increase in the strength of encryption algorithm for customers account will increase the security of the account management system (Figure 1, a). Obviously, third party factors should be handled separately or should be ignored when dealing with this kind of analysis.

In order to represent this kind of goal influence relations in EA models, Engelsman et al. [8] have proposed a requirements modelling language named ARMOR that supports requirements and goal management in EA frameworks. This approach uses classic goal influence notation styles like ++ and - - to model the contribution relation between two goals.

Goal models usually have a chain of contribution relations where a change in one of the goals affects directly related goals. The newly affect goal will in turn influence its directly related goals and so on. The ability to analyze these direct and indirect relations between goals of a system is a crucial factor that can affect the decision making process and the allocation of resources to the right goals. Moreover a goal change impact analysis is not limited to goal-to-goal relations. The analysis of the impact of changing a certain goal can be extended to higher level EA components and organizational structures or to lower level software architecture and implementation components.

Hence EA modelling frameworks like TOGAF should be extended to support management of evolving goals and requirements. In the context of the ARMOR language, the semantics of the contribution relation between goals is the key enabler for performing change impact analysis. There are approaches for dealing with evolving requirements in the context of the NFR framework and the TROPOS methodology [9], [10]. These two techniques rely on two different semantics of the contribution relation. In this paper, we report on results obtained from applying both approaches in an industrial case study. A comparative analysis is carried out with the purpose of determining which approach is more feasible for analysing EA models.

The rest of the paper is organized as follows: section 2 introduces the industrial problem context and the metamodel used as the base for defining requirement and goal change relations. Section 3 discusses the candidate approaches for goal change impact analysis while section 4 presents the result of the test case on both approaches. Finally section 5 summarizes the paper and proposes possible future works.

II. Industrial Research Context: TOGAF and ARMOR language

The problem to be addressed in this paper is raised at BiZZdesign B.V.[1], a company in the Netherlands that offers integrated solutions to design and improve business processes of organizations. BiZZdesign uses ArchiMate[2] language in a tool named BiZZdesign Architect [11].

In a number of EA and other system development projects, BiZZdesign has observed that, though goal based approaches are rooted in system development activities, they are not widely used in most Enterprise Architecture (EA) methodologies and frameworks [7]. It is already noted in the introduction part, that TOGAF and ArchiMate 2.0 language lack the ability of managing goals and requirements changes.

To fill this gap in modelling the motivation aspect of EA design, researchers at BiZZdesign have developed ARMOR language that enables incorporation of requirement and goal management in EA frameworks and modelling languages[8]. ARMOR language is defined by a meta-model shown in Figure 2. It allows EA designers to represent the rationale why EA components are available by incorporating concepts like *stakeholder*, *goals* and *requirements*.

ARMOR allows representation of qualitative goal change effects among directly related goals by means of classic contribution notations (like ++ and - -). However, currently it is not possible to model and predict the effect of stakeholder goal changes on higher level and indirectly related goals of the system. This task requires employing a suitable semantics for the goal contribution relation and developing analyzing tools.

1 http://www.bizzdesign.com/

2 Archimate is an open standard EA modeling language from The Open Group. (http://www3.opengroup.org/subjectareas/enterprise/archimate)

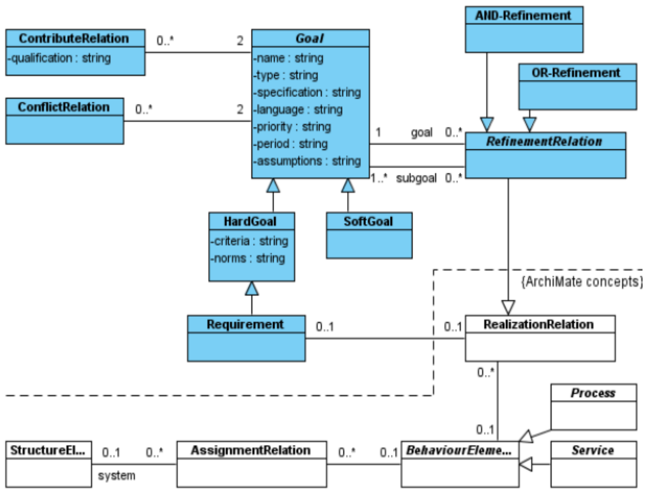

Figure 2. The ARMOR language metamodel.

III. Selected Goal Reasoning Approaches

There are number of change impact analysis techniques for foal-oriented approaches to system development activities. Most of existing approaches are expected to be applicable due the similarity between (higher level) system goals and business goals. Hence we decided to conduct a literature review on existing approaches that can be applied in goal change impact analysis in EA models. The selected/adapted change impact analysis technique will be then used as an extension to the ARMOR language.

The literature study provides us two candidate approaches applicable for EA designs. We adapted them to EA design contexts and applied them on an industrial case study. The two candidate approaches are based on TROPOS methodology and on a combination of Fuzzy logic/NFR based approaches. TROPOS is an agent-oriented software development methodology, based on i*, applicable for early and late RE activities as well as software architecture designs [5]. NFR framework is a well-known qualitative reasoning based methodology for dealing with non-functional requirements [12]. The qualitative reasoning of NFR can be extended to quantitative reasoning by employing fuzzy logic reasoning on satisfaction and contribution levels of goals and relations respectively [13].

A point we would like to stress out here is that NFR/Fuzzy logic and TROPOS are not the only goal change impact analysis techniques we found in the literature. For instance, the well known KAOS GORE method proposes probabilistic density approach for Goal change impact analysis in [14]. However, this approach involves relatively complex mathematical expressions that can be an obstacle for most modellers especially stakeholders with low technical background. These conditions make TROPOS and NFR framework good candidates to goal analysis because they are easy to understand and use and are well documented.

The industrial case used in this paper to compare and validate the two approaches is provided by one of the client organizations of BiZZdesign B.V. The organization is primarily involved in production and delivery of drinking water in Netherlands. The relevant data needed for this paper are collected by one of the authors for examining the applicability of ARMOR language in industrial cases. Since our work is based on ARMOR language, the data is also found to be applicable in this paper.

A. NFR/Fuzzy Logic and Influence

The first of the two goal reasoning approaches selected for comparison is the NFR/Fuzzy logic based approach. Considering the year of its publication (1992), the NFR(Non Functional Requirements Framework [9], [12]) can be taken as a pioneer in (non functional) requirement change impact analysis techniques. NFR uses a number of well defined yet qualitative definitions for non functional requirement achievement levels and contribution relations.

Measuring precisely the achievement levels of non functional requirements and the majority of business (soft) goals is difficult if not impossible due to the fuzzy nature of goals and non functional requirements. The same is true in quantifying the contribution relations between non functional requirements and (soft) goals. Due to this similarity in the fuzzy nature of achievement levels and contribution types between requirements and (soft) goals, the NFR framework can also be extended to goal change impact analysis.

Employing NFR framework based on goal analysis has a number of advantages [9]. First, there are guidelines that can help in eliciting and decomposing goals. Second, it provides a wide range well defined yet subjective goal achievement levels and contribution types for indirect influence analysis. Third, based on the results from the previous step, it helps in choosing better alternatives among available change options.

Both direct and indirect influence relations analysis is possible via the NFR framework. The reasoning techniques employed in the NFR are based on AND/OR decompositions. This will not be a problem by itself but it makes it difficult to analyze and simulate feedback loop effects (a case when the influence relations form a cycle). Furthermore, the NFR based qualitative reasoning approaches tend to be too vague for deep and accurate understanding of goal models. Besides, decision procedures for multiple goals contributions also tend to result in undetermined satisfaction levels for higher level goals [13], [14].

B. Fuzzy Logic Extension to NFR

Earlier we have noted that due to the very nature of soft (goals), satisfaction level measurement is not possible. Take the goal “Maintain availability of a system” as an example, for a mission critical system anything less than 100% availability is considered as failure while to an online based game, 95% availability can be considered as acceptable level of availability.

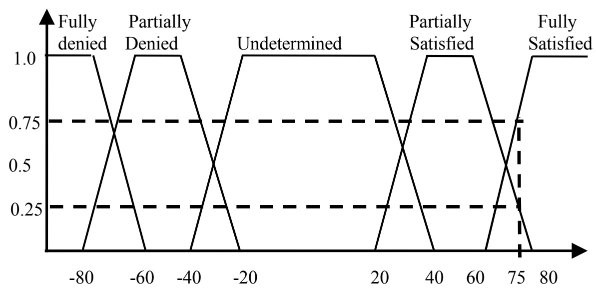

Figure 3. A goal, whose satisfaction level is termed as 75, can belong to both partially satisfied and fully satisfied with different membership value

In this kind of vague concepts, fuzzy logic can be applied. Fuzzy logic, based on fuzzy sets proposed by Zadeh [15], [16], uses a concept of membership function to determine the membership value of a certain input to a set. Quite contrary to conventional crisp sets, a given value can belong to two fuzzy sets in fuzzy logic. For instance a temperature of 10°C can be considered as 60% cold and 40% warm. Of course these percentage values will depend on the membership functions[15] 3.

Due to the possibility of labeling a goal satisfaction level in two different sets (e.g. A goal can be perceived as satisfied or partially satisfied from different perspectives as shown in Figure 3), fuzzy logic has got its applications in requirements engineering especially in reasoning with non-functional requirements. In fact, [13] shows a fuzzy logic extension of NFR framework for a dynamic management of non-functional requirements management.

But the approach in [13], doesn't consider the fuzzy nature of goal contribution types. This limitation is prevalent in areas where relation between two goals is fuzzy just like the satisfaction level of goals themselves. Nevertheless, our intention here is to use this kind of fuzzy set based extension to the satisfaction levels and contribution relations of the NFR framework.

Inspired by [13], the shapes of the fuzzy sets used in the our approach are trapezoidal as shown in Figure 3. But we make the boundary values of the sets more relaxed to accommodate various levels of vague goal satisfaction values. These boundary values are not meant to be static; rather they can be adjusted based on users interest and the nature of the goals in the goal model to be analyzed.

C. NFR/Fuzzy Logic Algorithm

NFR employs 6 levels of satisfaction for goal achievement levels: Denied, weak negative, Conflicting, Undetermined, Weak Positive and Weak Negative [9]. To avoid misunderstanding with contribution types, we call Weak positive and Weak Negative satisfaction levels as partially denied and partially satisfied respectively.

[3] More on fuzzy sets can be found in [16]

TABLE I. GOAL SATISFACTION LEVELS FUZZY SET BOUNDARIES

Goal Satisfaction Level	Value on scale from -100 to 100
Fully Denied (FD)	-100 to -60
Partially Denied (PD)	-80 to -20
Undetermined	-40 to 40
Partially Satisfied (PS)	20 to 80
Fully Satisfied (FS)	60 to 100
Conflicting	When one input link has positive contribution and another link has negative contribution.

TABLE II. GOAL SATISFACTION LEVELS FUZZY SET BOUNDARIES

Goal Contribution Type	Value on scale from -100 to 100
Break - -	-100 to -60
Hurt -	-80 to -20
No Effect	-40 to 40
Help +	20 to 80
Make ++	60 to 100

NFR has also seven types of contribution relation types. Namely: Break --, Some -, Hurt-, unknown, Help, Some+ and Make [9]. Some+ and Some- are used when the contribution types are known to be positive and negative respectively but whether the contribution type effect is full or partial is vague.

In our case, we are using Fuzzy logic based NFR system which allows us to use satisfaction values that can be assigned to two different sets. Hence we left out these contribution types in our analysis.

To use a fuzzy logic based extension to NFR framework, the goal satisfaction levels and contribution types should be mapped to fuzzy sets as shown in Figure 3 and tables 1 and 2. These values are not meant to be constant; rather they can be adjusted based on the goal types in the goal model and the interest of the stakeholders of the system.

In addition to the contribution types discussed in table 2, Goal can be decomposed based on AND/OR decomposition guidelines. AND decomposition propagates the minimum value of the contributing goals satisfaction level while OR propagates the maximum value of the contributing goals satisfaction level.

Based on the goal satisfaction levels and contribution types discussed in table 1 and 2, the reasoning rules of NFR framework from [9] are adapted to our context as shown below in table 3.

To use the fuzzy reasoning rules shown in table 1, initial goal satisfaction levels and contribution strengths should be assigned a membership value. These membership values are based on the fuzzy sets like the one shown in Figure 3. For instance a goal, whose satisfaction level is 75, will have two membership values, 0.25 and 0.75 as shown in Figure 3.

TABLE III. ADAPTED IMPACT ANALYSIS RULES OF NFR FRAMEWORK.

	Upon Parent label, given off-spring parent contribution types				
	Break(--)	***HURT (-)***	***Unkn***	***HELP (+)***	***Make (++)***
Fully Denied (FD)	FS	PS	U	PD	FD
Partially Denied (PD)	PS	PS	U	PD	PD
Unknown (U)	U	U	U	U	U
Partially Satisfied (PS)	PD	PD	U	PS	PS
Fully Satisfied (FS)	FD	PD	U	PS	FS
Conflicting (C)	C	C	C	C	C

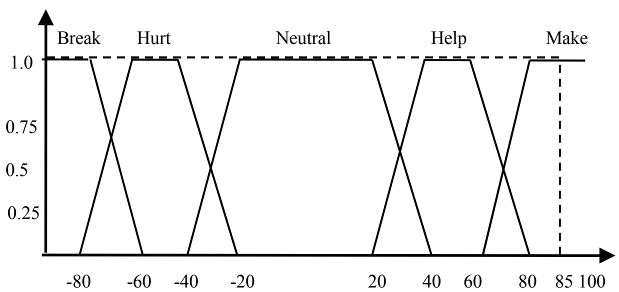

Figure 4. An influence relation, whose strength is termed as 85, belongs to strongly positive (Make) fuzzy set with membership value of 1.0.

Listing 1 depicts an abstracted algorithm showing how to use these membership values to reason on goal satisfaction levels.

```
For each goal determine the satisfaction level membership value
For each relation determine the contribution membership value
For all goal g in Goal graph G {
   If (g != leaf Goal){
        Find influencing goals of G
        Apply the fuzzy inference rules shown in table 3 on influencing
goals.
        Aggregate the results of multiple contributions to a single goal
        Defuzzify the final value, i.e. Generate crisp results
   }
}
```

Listing 1. Abstracted fuzzy logic algorithm

Note that, the input of the algorithm is a goal graph whose goal satisfaction values and contribution types are specified on a scale from -100 to 100 (See Figure 4).

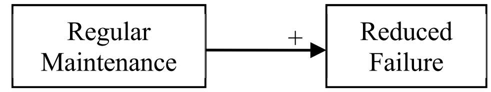

Figure 5. A simple positive influence relations between two goals

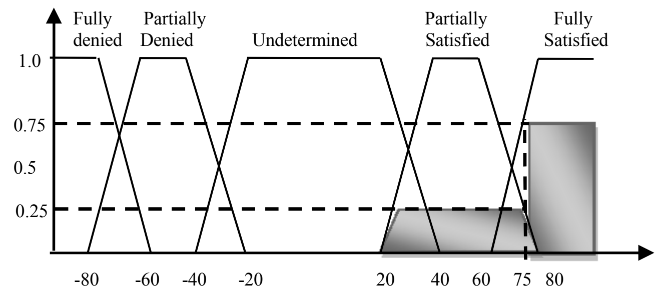

Figure 6. Results of applying fuzzy rules on case i and ii.

To illustrate the applicability of the fuzzy reasoning engine in goal satisfaction analysis let's take a simple goal model shown in Figure 5. Let's assume the initial satisfaction level of the goal "Regular Maintenance" is set to be +75 and the influence relation strength is +85.

The membership values of the influencing goal satisfaction level is 0.25 fully satisfied and 0.75 partially satisfied as shown in Figure 3. Similarly, the membership values of the influence relation strength can be computed to be 1.0 fully positive as shown in Figure 4.

Two rule combinations can be obtained from this case:

i. Goal value = 0.25 partially satisfied and influence value of 1.0.
ii. Goal value = 0.75 fully satisfied and influence value of 1.0.

In both cases, the minimum of the membership values will be taken due to the AND combination effect [15]. i.e. Min(0.25 and 1) = 0.25 and Min (0.75 and 1) = 0.75.

Using the rules shown in table 3, this minimum values will be assigned to partially satisfied and fully satisfied fuzzy sets as shown in the shaded region of Figure 6.

The next step will be aggregating theses two results and changing this aggregated result to goal satisfaction value. The goal satisfaction value will be based on a scale with a range of -100 to 100. A common technique to do this is finding the centroid of the shaded region shown in Figure 6.

Using simple geometrical calculations, it is easy to show that the centroid of the region lies at a position x = 78.125.

This value (78.125) will represent the satisfaction level of the goal "Reduced Failure Rate" in Figure 5. And this value is the sole result of a positive influence from the goal "Regular Maintenance".

D. TROPOS and Influence Relations

TROPOS is an agent oriented software development methodology based on i* [5]. Using i* as a base enables

TROPOS to use i*'s indirect analysis features (which are of course similar to NFR). Hence, indirect influence relation is possible in TROPOS. But TROPOS employs both qualitative and reasonably understandable quantitative techniques for indirect influence relation analysis making it a more convenient approach than pure NFR framework based approach.

Even a more interesting feature of the goal models of TROPOS is the presence of goal cycles (feedback loops). In addition to the common AND - OR goal decomposition types, TROPOS allows modeling of contribution link chains that makes loops in goal diagrams [5].

E. TROPOS Algorithm

Just like NFR, TROPOS also uses a number of predefined satisfaction levels and contribution types for goals and relations respectively. The qualitative reasoning approach of TROPOS separates satisfaction and deniability values of a goal. Goals in TROPOS analysis will have two attributes for goal satisfaction level, one for the satisfiability level and the other one for deniability level[17]. This kind of separation is helpful in situations where a goal can be considered satisfied and denied at the same time when perceived from different views.

The satisfiability attributes of goals can be assigned a value of Satisfied, Partially Satisfied or Neutral for Satisfiability and Denied, Partially Denied and Neutral for deniability attributes. The contribution relations possible values are AND, OR, --, - , + and ++.

In addition to separation of satisfiability and deniability TROPOS employs asymmetrical contribution relations where a relation can propagate either satisfiability or deniability. Though these kinds of relation types can be helpful in dealing with complex goal models, we believe that they will not affect our comparison results. Discarding these asymmetrical relations will also help in avoiding complexity of the comparison process. Hence we simply adapt the symmetrical propagation rules of TROPOS in this paper as shown in table 4. "Sat" and "Den" represent *Satisfiability* and *Deniability* respectively of a goal in a goal model and the notation "P" represent *Partial satisfiability*.

TABLE IV. SYMMETRICAL GOAL INFLUENCE RULES IN TROPOS

	(G2^G3) →G1	**(G2vG3) →G1**	**G2 →--G1**	**G2→-G1**	**G2 →+G1**	**G2 →++G1**
Sat(G1)	Min $\begin{cases} Sat(G2), \\ Sat\ (G3) \end{cases}$	Max $\begin{cases} Sat(G2), \\ Sat(G3) \end{cases}$	Den(G2)	Min $\begin{cases} Den(G2), \\ P \end{cases}$	Min $\begin{cases} Sat(G2), \\ P \end{cases}$	Sat(G2)
Den(G1)	Max $\begin{cases} Den(G2), \\ Den(G3) \end{cases}$	Min $\begin{cases} Den(G2), \\ Den(G3) \end{cases}$	Sat(G2)	Min $\begin{cases} Sat(G2), \\ P \end{cases}$	Min $\begin{cases} Den(G2), \\ P \end{cases}$	Den(G2)

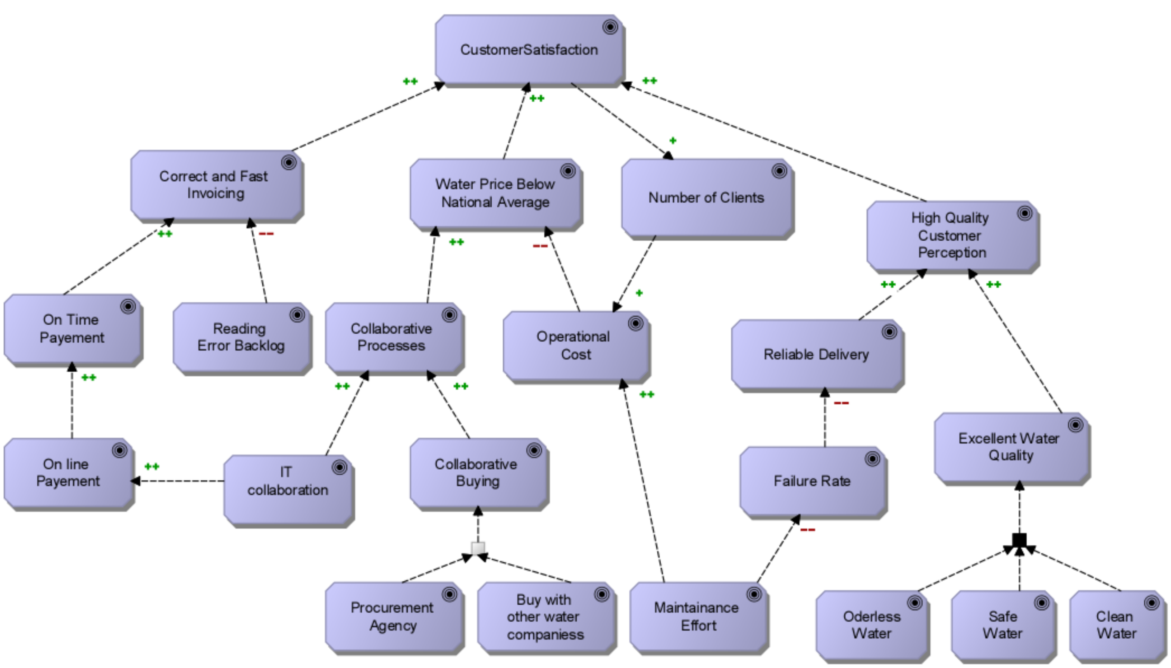

Figure 7. A portion of a goal model taken during study, the shaded box represents "AND" decomposition while the light box represents an "OR" decomposition.

```
For each goal assign the initial satisfiability value
For each goal assign the initial deniability value
For each relation assign the contribution relation type
For all Goal g in Goal graph G {
  If g! = Leaf Goal {
    List SatList;
    List DenList;
    for all relation r contributing to g {
        Satisfiability = ApplySatisfiabilityRules();
        Deniability = ApplyDeniabilityrules();
        SatList.add(Satisfiability);
        DenLists.add(Deniability);
      }
    SatisfiabilityValue = MaxElement(SatList);
    DeniabilityValue = MaxElement(DenList);
  }
}
```

Listing 2. Abstracted TROPOS Algorithm

IV. Case Study

The case used in this paper is a study conducted at a drinking water production organization located in the Netherlands. The organization was under some structural changes due to shrinking budget resulting in changes of various stakeholder goals making it a good case study for testing our approach.

The primary data about goals of the organization was collected by one of the authors of this paper and is presented in detail in [18]. There are about ninety goals identified from relevant documents and interviews. Due to privacy issues, space limitations and complexity of the entire goal graph, we will use only a small portion of the organization goal graph. Figure 7 shows decomposition of "customer satisfaction" goal, which is of course one of the many goals of the company's Board of Directors.

The primary contributors of "Customer satisfaction" goal are "Correct and fast invoicing", "Water price below national average" and "High quality customer perception". Each of these goals is further decomposed in to a number of more concrete goals. There are also AND/OR decompositions like the "OR" decomposition of "collaborative buying" in to "Procurement Agency" and "Buy with other water companies" and the "AND" decomposition of "Excellent water Quality" in to "Odorless water", "Safe Water" and "clean water" goals.

Based on algorithms discussed in the previous subsections a tool support for reasoning was developed. The tool support was an extension of already existing EA modeling tool that is approved by The Open Group [19].

Two kinds of goal analysis can be done on goal graphs: forward tracking and backward tracking. The forward tracking, which is the main focus of this paper, focuses on assigning values to leaf goals and tries to estimate the effect on top level goals. The backward algorithm setting a certain desired value for a certain (root) goal and try to find what assignment to leaf goals will result in the desired values [20].

A. Application of the NFR/Fuzzy Approach

The first step in testing the NFR framework is to reset the values of goals to zero (neutral) satisfaction level. The leaf goals were then assigned input values as shown in a table 5 and we run our NFR framework based fuzzy logic reasoning tool. These inputs are selected in consultation with stake holders of BiZZdesign, to make sure the majority of goal contribution types and satisfaction levels are incorporated in the case study.

TABLE V. Input Values For Leaf Goals Satisfaction Levels

Leaf Goal	Satisfaction Level
Buy with other water companies	50.0
Clean Water	99.0
IT collaboration	45.0
Maintenance Effort	-84.0
Odorless Water	86.0
Procurement Agency	88.0
Reading Error Backlog	-45.0
Safe Water	95.0

We consult the output of our tool shown in table 6, with the intended stakeholders of BiZZdesign. Though they were unable to specify expected goal satisfaction levels in terms of concrete numbers, the natural language expression of their expectation match the output of the tool. For instance, for the goal "Reliable Delivery", they expect a high level denial which matches the -85 satisfaction value predicted by our tool.

A point we observe in the obtained results is that NFR based fuzzy logic reasoning will aggregate a Fully Denied and a Fully Satisfied levels to a neutral satisfaction level which may not be logical in some cases. For instance, goal "High Quality Customer Perception" receives fully satisfied (+85) contribution from "Excellent water quality" and a fully denied (-85) from "Reliable delivery" goal. The fuzzy logic aggregation results will show a value of zero for satisfaction level of "High Quality Customer Perception" which is of course not the real case. We will see shortly how TROPOS based approaches handle such issues.

B. Application of the TROPOS Approach

The possible input values for TROPOS qualitative reasoning approach are only Full (F), Partial (P) and None (N). These values will be used as inputs for satisfiability and deniability values of goals. The selected input values, again based on consultation with stakeholders of BiZZdesign, that match the values used in table 5, are shown in table 7.

TABLE VI. THE RESULT OF THE FUZZY LOGIC ANALYSIS ON GOAL SATISFACTION LEVELS.

Goal	Satisfaction Level
Buy with other water companies	50
Clean Water	99
Client Growth	28
Collaborative Buying	85
Collaborative Processes	67
Correct and Fast Invoicing	50
Customer Satisfaction	30
Excellent Water Quality	85
Failure Rate	85
High Quality Customer Perception	0
IT collaboration	45
Maintenance Effort	-84
Odorless Water	86
On line Payment	50
On Time Payment	50
Operational Cost	-26.525
Procurement Agency	88
Reading Error Backlog	-45.0
Reading Error Backlog	-45
Reliable Delivery	-85
Safe Water	95
Water Price Below National Average	34.075

TABLE VII. INPUT VALUES FOR LEAF GOALS SATISFIABILITY AND DENIABILITY VALUES.

Leaf Goal	Satisfaction Level	Deniability Level
Buy with other water companies	P	P
Clean Water	F	N
IT collaboration	P	P
Maintenance Effort	N	F
Odourless Water	F	N
Procurement Agency	F	P
Reading Error Backlog	P	P
Safe Water	F	N

The output of the TROPOS based reasoning tool is shown in table 8. Goals in which weak conflict (Partial Satisfaction and partial Deniability) influence is received are marked with * and Goals which receive strong conflicts (Fully Satisfied and Fully Denied) are marked with **. In both cases, we use the minimum of the contributing values to continue propagating change impacts.

An apparent limitation of this approach is the lack of extended range values to the goal satisfaction levels. This limitation is manifested especially in two conditions. First, when two goals are partially satisfied but with different degree of satisfaction there is often a need in differentiating the satisfaction level. Second, when there are two or more partial satisfaction contributions to a single goal and we need to aggregate the results into more "semi fully satisfied" value.

As an example, consider the goal "Collaborative Process" in table 8, this goal receives two partial goal satisfaction inputs from "IT collaboration" and "Collaborative Buying". Logically it is expected that if two partial satisfaction levels are affecting a goal, then at least the aggregated effect should be somehow bigger than the effect of a single partial satisfaction contribution. But since TROPOS has only one type of partial satisfaction contribution type, these kind of contribution aggregation is not possible.

TROPOS authors use a quantitative reasoning that tries to resolve these limitations [17], However, the quantitative reasoning is limited since the vague nature of the influencing relations is not incorporated in it. In general, the issue of having conflicting goal satisfaction levels, which we discussed as a limitation of the NFR based approach, is less severe in TROPOS since satisfiability and deniability are separated.

C. Comparison

The extensive literature study we took does not reveal any comparative study on the applicability of these approaches in EA goal models. We opt to do a comparative study to assess the applicability of the two approaches by finding their advantages and disadvantages.

But due to their difference in describing goal satisfaction levels (TROPOS uses textual descriptions and Fuzzy logic uses numbered values), it is difficult to have a common comparison criteria. Yet, it is still logical to assume very low negative values of fuzzy approach (like –86) will represent availability of Full (F) evidence for deniability of a goal. Similarly, a partially (P) satisfied goal in TROPOS approach is a good analogy for a goal whose satisfaction level is approximately 50 in fuzzy logic based approach.

Using these approximations, the results of the two approaches were compared. As can be seen in table 9, the results obtained from the two methodologies are fairly consistent. For instance the goal "Reliable Delivery" is termed as fully denied in TROPOS and assigned a value of -85 which is consistent with our analogy.

A notable difference is the presence explicit of goal conflict detection in TROPOS based approach. Fuzzy logic based reasoning engine rule aggregation feature is useful in combining two or more influence effects but it also results zero satisfiability value when there are conflicting goal influences (e.g. the goal "High Customer Perception" shown in table 9). But a satisfaction level of zero can also be an effect of a goal which is neither satisfied nor denied. This can make fuzzy logic based goal influence reasoning approach vague and less useful in decision making process.

TABLE VIII. THE RESULT OF THE TROPOS BASED GOAL ANALYSIS ON SATISFACTION LEVELS.

Goal	Satisfaction Level	Deniability Level
Buy with other water companies	P	P
Clean Water	F	N
Client Growth	P	P
Collaborative Buying	F	P
Collaborative Processes	P	P
Correct and Fast Invoicing*	P	P
Customer Satisfaction*	P	P
Excellent Water Quality	F	N
Failure Rate	F	N
High Quality Customer Perception**	P	P
IT collaboration	P	P
Maintenance Effort	N	F
Odorless Water	F	N
On line Payment	P	P
On Time Payment	P	P
Operational Cost	N	F
Procurement Agency	F	P
Reading Error Backlog	P	P
Reliable Delivery	N	F
Safe Water	F	N
Water Price Below National Average*	P	P

The TROPOS approach can identify both partial and full conflicts since the satisfiability and deniability are separated. As an example, the goal "Collaborative Processes" receives partially conflicting contributions while the goal "High Customer Perception" faces strongly conflicting inputs. But this ability to detect conflicts comes with a cost of limiting expressiveness of the result.

For instance, both "Client growth" and "IT collaboration" goals set to partial level of satisfiability and deniability. But the degree to which they are satisfied is different as can be seen from the fuzzy logic approach (28 and 50). This will make TROPOS qualitative reasoning less useful in detailed goal analysis scenarios and other goal model analysis applications like resource allocation estimation.

TABLE IX. OUTCOME OF BOTH TROPOS AND NFR BASED FUZZY REASONING APPROACHES

	Fuzzy Logic Approach	**TROPOS Approach**	
Goal	***Satisfaction Level***	***Satisfaction Level***	***Deniability Level***
Buy with other water companies	50	P	P
Clean Water	99	F	N
Client Growth	28	P	P
Collaborative Buying	85	F	P
Collaborative Processes	67	P	P
Correct and Fast Invoicing	50	P	P
Customer Satisfaction	30	P	P
Excellent Water Quality	85	F	N
Failure Rate	85	F	N
High Quality Customer Perception	0	P	P
IT collaboration	45	P	P
Maintenance Effort	-84	N	F
Odorless Water	86	F	N
On line Payment	50	P	P
On Time Payment	50	P	P
Operational Cost	-26.525	N	F
Procurement Agency	88	F	P
Reading Error Backlog	-45.0	P	P
Reliable Delivery	-85	N	F
Safe Water	95	F	N
Water Price Below National Average*	34.075	P	P

The presence of limitations on both sides will make it difficult to choose one of them as a winner approach. Both are applicable for goal influence analysis though their usefulness depends on the type of the user and intended results.

For high level goal analysis on goal models to be done by non technical people, we recommend using TROPOS based approach due to its conflict resolution feature and easy to use natural language expression. But if a deep investigation of goals and requirements is necessary, then employing NFR based fuzzy logic reasoning approach is a good choice as it provides concrete values assuming its users are capable of assigning concrete values to input goals of the goal model.

V. Conclusion and Future Work

This paper reports on a case study in which we assigned two different semantics to the relation between goals in the context of the ARMOR language. NFR framework and TROPOS methodology are adapted to obtain a change impact analysis algorithm for managing evolving stakeholder goals in EA designs.

The industrial case study shows that both approaches are applicable for analyzing goal influence relations though each of them has their own limitations. The Fuzzy logic based reasoning provides concrete values for more detailed goal analysis and can handle aggregation of multiple contribution types while the TROPOS approach is suitable in providing high level goal analysis and handling of goal conflicts.

Our future work will focus on combining the advantages of these two approaches to provide more accurate analysis on goal satisfaction levels. We also plan to incorporate asymmetrical goal relations of TROPOS in our approach and to test the applicability of fuzzy logic as an extension to TROPOS based approach. Modeling, analyzing and simulating effects of goal cycles (feedback loops) is a work in progress. It is a natural extension of the results presented in this paper.

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