APPENDIX D: DEFECT INDICATORS, DETECTION METHODS AND FIX RECOMMENDATIONS

Tables 1, 2 and 3 show the desired quality *properties* of scenarios and their *verification heuristics*. These heuristics are implemented through different techniques. If the result after performing a heuristic is opposite to an expected result, a defect (indicator of violation) must be reported to the requirements engineer. These defects are categorized as: information, warning or mistake. *Information* reveals that the requirements engineer may have forgotten to specify information related to a scenario element. *Warning* reveals that the requirements engineer may have introduced confusing information or forgot to inform an important scenario element. *Mistake* reveals that the requirements engineer may have introduced incorrect information related to a scenario element. The presence of defects is a strong sign, although not conclusive, of incorrectness that must be fixed.

Integrity, coherency and uniqueness are evaluated by checking a main scenario against the other scenarios. Each one of these heuristics were implemented in a tool for editing, visualization and analysis of scenarios – C&L [21].

TABLE 1
UNAMBIGUITY PROPERTIES.

Property	Description	Verification Heuristic	Defect Category	Strategy	Technique
Vagueness	The sentence contains words or phrases having a non-uniquely quantifiable meaning [7].	Check that a sentence does not contain vague terms (e.g. adaptability, additionally);	Warning	Lexical	Dictionary
Subjectiveness	The sentence contains words or phrases expressing personal opinions or feeling [7].	Check that a sentence does not contain comparative/superlative adverbs/adjectives (e.g. similar, better);	Warning	Lexical	POS tagging
Optionality	The sentence contains words that give the developer latitude in satisfying the specification statements that contain them [47].	Check that a sentence does not contain optional words (e.g. as desired, at last);	Warning	Lexical	Dictionary
Weakness	The sentence contains clauses that are apt to cause uncertainty and leave room for multiple interpretations [47].	Check that a sentence does not contain weak terms (e.g. can, preferred);	Warning	Lexical	Dictionary
Multiplicity	The sentence has more than one main verb or subject (Adapted from [7]).	Check that a sentence does not contain conjunction or disjunction of verbs or subjects (e.g. and, or, and/or);	Warning	Syntactical	Dependency parsing
Implicitly	The sentence does not specify the subject or object by means of its specific name but uses pronoun or indirect reference [7] [47].	Check that a sentence does not contain implicit words (e.g. anyone, he, her);	Warning	Lexical, Syntactical	Dictionary, POS tagging, Dependency parsing
Quantifiability	Terms used for quantification can lead to ambiguity if not used properly [44].	Check that a sentence uses quantification words in a clear way (e.g. all, any, few);	Information	Lexical	Dictionary
Minimality	A sentence contains nothing more than basic attributes [55].	Check that a sentence does not contain additional information (Text after a dot, hyphen, semicolon or other punctuation mark)	Warning	Lexical	Dictionary

TABLE 2
COMPLETENESS PROPERTIES.

Property	Description	Verification Heuristic	Defect Category	Strategy	Technique
Atomicity	A scenario expresses exactly one situation (Adapted from [55]).	Check that Title defines exactly one situation [11];	Warning	Lexical	Dictionary
		Check that Goal satisfies exactly one purpose [11];	Warning	Lexical	Dictionary
		Check that Title contains a verb in infinitive form and an object [9] [11] ;	Warning / Information	Lexical Syntactical	POS tagging, Dependency parsing
Simplicity	A scenario should be as readable as possible.	Check that Episode-Sentence is described from user point of view (Subject + present simple tense and active form of verb + Object) or by another scenario (infinitive verb – base form + Object) [6] [9] [11] [17];	Warning	Lexical Syntactical	POS tagging, Dependency parsing
		Check that Alternative-Solution-Step-Sentence is described from user point of view (present simple tense and active form of verb + Object) or by another scenario (infinitive base form of verb + Object). Optionally, it contains a Subject [6] [9] [11] [17];	Warning	Lexical Syntactical	POS tagging, Dependency parsing
		Check that Title does not contain extra unnecessary information [8].	Warning	Lexical	Regular Expression
		Check that Episode coincidence only takes place in different situations [11];	Warning	Lexical	String Searching
		Check that episodes involving validation are described using the verbs verify/validate/ ensure/establish and followed by that; i.e., avoid verbs like check/see followed by If/Whether. Complicated validation steps can confuse the user and be difficult to understand [6] [9] [11];	Warning	Lexical	Regular Expression
		Check that nested IF statement is not used in a Conditional Episode, i.e., it can confuse the user and be difficult to read [6] [56];	Warning	Lexical	String Searching
		Check that alternative is handled by a simple action [11], i.e, if the interruption is treated by a sequence of steps (> 3), this sequence should be extracted to a separate scenario [6];	Warning	Lexical	String Searching
		Check that every alternative flow returns to a specific episode of the main flow or finishes the scenario [57].	Warning	Lexical	Regular Expression
Uniformity	Each scenario element should be described with significant information.	Ensure that Title is present [11];	Mistake	Lexical	String Searching
		Ensure that Goal is present [11];	Mistake	Lexical	String Searching
		Check the existence of more than one Actor per Scenario [11];	Mistake	Lexical	String Searching
		Ensure that Context contains its relevant sub-components [11];	Mistake	Lexical	String Searching
		Check the existence of more than one Episode per Scenario [11];	Mistake	Lexical	String Searching
		Ensure that Episode contains its relevant parts [11];	Mistake	Lexical	Regular Expression
		Ensure that non-sequential episodes construct have a begin and an end keywords (e.g. #);	Mistake	Lexical	String Searching
		Ensure that Alternative contains its relevant parts [11];	Mistake	Lexical	Regular Expression
	A scenario does not contain superfluous	Check that every Actor participates in at least one episode [11];	Warning	Lexical	String Searching
		Check that every Resource is used in at least one episode [11];	Warning	Lexical	String Searching

Usefulness	information, i.e., there should be consistency among scenario components. (Adapted from [58]).	Check that every Actor mentioned in episodes is included in the Actor section [11] or is the System [17] or, it is included in Resources;	Warning	Syntactical	Dependency pars-ing
		Check that every Resource mentioned in episodes is included in the Resource [11] section or, it is included in Actors;	Information	Syntactical	Dependency pars-ing
		Check that every Actor mentioned in alternatives is included in the Actor section [11] or is the System [17] or, it is included in Resources;	Warning	Syntactical	Dependency pars-ing
		Ensure that step numbering between the main flow and alternative flow are consistent [59];	Warning	Lexical	String Searching
		Check the existence of more than 2 and less to 10 episodes per scenario [6] [9] [60];	Warning	Lexical	String Searching
Conceptua-lly Soundness	Internal scenario elements are semantically coherent, i.e., elements satisfy the scenario goal [11].	Check that the Title describes the Goal;	Warning	Syntactical	Syntactic Similarity
		Ensure that Episodes contain only actions to be performed [11];	Warning	Syntactical	Dependency pars-ing
		Ensure that Alternatives contain only actions to be performed [11];	Warning	Syntactical	Dependency pars-ing
Integrity	Whenever a scenario refer-ences to another scenario, the related scenario should exist within the set of sce-narios.	Check that every included scenario (Pre-condition, Post-condition, Episode sentence, Alternative solution) exists within the set of scenarios [11];	Mistake	Lexical	String Searching
		Ensure that actions present in the Pre-conditions are already performed [11];	Information	Lexical	String Searching
		Check that Episode coincidence only takes place in different scenarios [11];	Warning	Syntactical	Dependency pars-ing
Coherency	Internal components of ex-plicitly related scenarios should be precise and use a common terminology, e.g. pre-conditions of related scenarios are coherent.	Check coherence between Pre-conditions in related scenarios [11];	Warning	Lexical	
		Check that Geographical and Temporal location of the related scenarios are equal or more restricted than those of the main scenario [11];	Warning	Lexical	String Searching, Levenshtein's distance
		Check that referenced scenarios do not reference the main scenario [20] (adapted from [59]);	Warning	Lexical	String Searching
Uniqueness	A scenario is unique when no other scenario is the same or too similar, i.e., duplicates are avoided because they are source of inconsistencies (Adapted from [55]).	Check that the Title of a scenario is not already included in another scenario;	Warning	Lexical	Levenshtein's dis-tance
		Check that the Goal of a scenario is not already included in another scenario;	Warning	Lexical	Levenshtein's dis-tance
		Check that the Pre-condition of a scenario is not already included in another scenario;	Information	Lexical	Levenshtein's dis-tance
		Check that the set of Episodes of a scenario is not already included in another scenario;	Warning	Lexical	Levenshtein's dis-tance
		Check that two scenarios does not have similar Titles;	Warning	Syntactical/ Semantical	Syntactic/ Semantic Similarity
Feasibility	It is possible to perform each operation described in a scenario.	Check that is possible to derive an initial system design from related scenarios [51];	Mistake	Petri-Net	Breadth-first search
		Check that initial system design does not contain isolated sub-systems [61];	Mistake	Petri-Net	Breadth-first search

TABLE 3
CONSISTENCY PROPERTIES.

Property	Description	Verification Heuristic	Defect Category	Strategy	Technique
Non-interferential	Every operation that negatively impact on others should be identified.	Check the absence of non-determinism, i.e., a set of operations are simultaneously enabled by common pre-conditions [31];	Warning	Petri-Net	Reachability
Boundedness	This property refers to the lim-ited capacity of a communica-tion channel or resource.	Check the absence of overflow, i.e., the number of elements in some communication channel or resource exceeds a finite capacity [31];	Information	Petri-Net	Reachability
Liveness	Every operation can be exe-cuted in the future	Check the absence of paths to *deadlocks* [31], e.g., it could occur when an alternative flow does not return to the main flow or finish the scenario;	Information	Petri-Net	Reachability
		Check the absence of never enabled operations, e.g., when the pre-conditions of an operation are never ful-filled;	Warning	Petri-Net	Reachability
Reversibility	This property guarantees that the described behavior reaches its initial state again	Check the automatic error recovery: If the executable model is not reversible, the automatic error is not possi-ble [50].	Warning	Petri-Net	Reachability

The following verification heuristics were implemented into the C&L tool. For each *quality property* and its *verification heuristics*, we define the *defect indicators*, detection methods and fix recommmendations.

The *input* of these heuristics are the *sentences* to be analyzed and the NLP *annotated information* (*tokens*, *subjects*, *direct-objects*, *indirect-objects*, *action-verbs*, *complement-action-verbs*, *modifier-action-verbs*, *modifier-subjects* and *complement-subjects*) extracted from them. *subjects*, *objects* and *action-verbs* are set of tokens. $token_i$ = {*index*, *word*, *POS*, *lemma*}

Vagueness

***Verification Heuristic**: Check that a sentence does not contain vague terms (e.g. adaptability, additionally).*

Indicator: The ***sentence*** (Title, Goal, Episode Sentence or Alternative Solution Step) contains ***vague*** words or phrases (e.g. adequate, also, unless, unnecessary, useful, varying, …). We use the list of *vague-terms* provided by the SREE tool [70].

- **Detection Method**: Check whether a *token* (or two consecutive tokens) in an *episode sentence* (or alternative solution step or title or goal) is included in *weak-dictionary* ($token_i$.word ∈ vague-dictionary ∣ $token_i$.word + $token_{i+1}$.word ∈ vague-dictionary ∣ $token_i$.word + $token_{i+1}$.word + $token_{i+2}$.word ∈ vague-dictionary ∣ $token_i$.word + $token_{i+1}$.word + $token_{i+2}$.word + $token_{i+3}$.word ∈ vague-dictionary). Extraction of tokens is done by the *Stanford Parser*.

- **Fix Recommendation**: Re-describe the sentence by removing vague terms.
- **Example**: "System contact with dLibra server to obtain all necessary data."

Subjectiveness

***Verification Heuristic**: Check that a sentence does not contain comparative/superlative adverbs/adjectives (e.g. similar, better).*

Indicator: The *sentence* (Title, Goal, Episode Sentence or Alternative Solution Step) contain words like *comparative/superlative adverbs/adjectives* (e.g. similar, better, similarly, best, as possible).

- **Detection Method**: Check whether a *token* in an *episode sentence* (or alternative solution step or title or goal) is a *comparative/superlative adverb or adjectives* (token.POS == JJR | JJS | RBR | RBS). Extraction of tokens and POS tags from the sentence is done with the help of the *Stanford Parser*.
- **Fix Recommendation**: Re-describe the sentence by removing subjective terms
- **Example**: "Allow customers to find the best supplier for a given order"

Optionality

***Verification Heuristic**: Check that a sentence does not contain optional words (e.g. as desired, at last).*

Indicator: The *sentence* (Title, Goal, Episode Sentence or Alternative Solution Step) contain words that express *optionality* (e.g. as desired, at last, probably, whether, …). We use the list of optional-terms provided by the SREE tool [70].

- **Detection Method**: Check whether a *token* (or two consecutive tokens) in an *episode sentence* (or alternative solution step or title or goal) is included in *optional-dictionary* ($token_i$.word ∈ optional-dictionary | $token_i$.word + $token_{i+1}$.word ∈ optional-dictionary). Extraction of tokens is done by the *Stanford Parser*.
- **Fix Recommendation**: Re-describe the sentence by removing optional terms.
- **Example**: "The MCSS shall be capable of operating on either one or both of its independent power supplies at any one time"

Weakness

***Verification Heuristic**: Check that a sentence does not contain weak terms (e.g. can, preferred).*

Indicator: The *sentence* (Title, Goal, Episode Sentence and Alternative Solution Step) contains clauses that are apt to cause *uncertainty* (e.g. can, could, may, might, …). We use the list of weak-terms provided by the SREE tool [70].

- **Detection Method**: Check whether a *token* (or two consecutive tokens) in an *episode sentence* (or alternative solution step or title or goal) is included in *weak-dictionary* ($token_i$.word ∈ weak-dictionary | $token_i$.word + $token_{i+1}$.word ∈ weak-dictionary). Extraction of tokens is done by the *Stanford Parser*.
- **Fix Recommendation**: Re-describe the sentence by removing weak terms.
- **Example**: "User select a client for whom new contract will be added"

Multiplicity

***Verification Heuristic**: Check that a sentence does not contain conjunction or disjunction of verbs or subjects (e.g. and, or, and/or).*

Indicator: The *title* contains *conjunction* or *disjunction* of verbs or subjects (e.g. and, or, and/or).

- **Detection Method**: Check whether a *token* in the *title* is included in *multiple-dictionary* (token.word ∈ multiple-dictionary). Extraction of tokens is done by the *Stanford Parser*.
- **Fix Recommendation**: Split the sentence into multiple sentences
- **Example**: "Scenario ends when users logs out or select a different option"

Indicator: The *Episode Sentence* or *Alternative Solution Step* has more than one *subject*.

- **Detection Method**: Check whether *episode sentence* (or alternative solution step) has more than one *subject*. Extraction of subjects from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the sentence into multiple sentences
- **Example**: "Guest and administrator upload files"

Indicator: The *Episode Sentence* or *Alternative Solution Step* has more than one *action-verb*.

- **Detection Method**: Check whether *episode sentence* (or alternative solution step) has more than one *action-verb*. Extraction of action-verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the sentence into multiple sentences
- **Example**: "The customer enters her login information and selects the password reminder option"

Implicitly

***Verification Heuristic**: Check that a sentence does not contain implicit words (e.g. anyone, he, her).*

Indicator: The *sentence* (Title, Goal, Episode Sentence or Alternative Solution Step) do not specify the subject or object by means of its specific name but uses *pronoun* or indirect reference (e.g. anyone, anybody, anything, everyone, he, her, hers, herself).

- **Detection Method**: Check whether a *subject* or *direct-object* or *indirect-object* of an *episode sentence* (or alternative solution step or title or goal) is included in *implicit-dictionary* (e.g. subject.word ∈ implicit-dictionary). Extraction of subjects and objects is done by the *Stanford parser*.
- **Fix Recommendation**: Re-describe the sentence by specifying subjects/objects by means of its specific name.
- **Example**: "Administrator types the message and posts it".

Quantifiability

***Verification Heuristic:** Check that a sentence uses quantification words in a clear way (e.g. all, any, few).*

Indicator: The *sentence* (Title, Goal) contain words that express *quantification* (e.g. all, any, few, little, many, much, several, some). We use the list of quantity-terms provided by the SREE tool [70].

- **Detection Method**: Check whether a *token* in the *title* (or goal) is included in *quantity-dictionary* (token.word ∈ quantity-dictionary). Extraction of tokens is done by the *Stanford parser*.

Fix Recommendation: Re-describe the sentence by removing quantifiable terms.

- **Example**: "User informs some product"

Indicator: The *sentence* (Episode Sentence or Alternative Solution Step) contain words that express *quantification* (e.g. all, any, few, little, many, much, several, some) followed by *vague* words. We use the list of quantity-terms and vague-terms provided by the SREE tool [70].

- **Detection Method**: Check whether a *token* in an *episode sentence* (or alternative solution step) is included in *quantity-dictionary* ($token_i$.word ∈ quantity-dictionary + $token_{i+1}$.word ∈ vague-dictionary). Extraction of tokens and POS tags is done by the *Stanford parser*.
- **Fix Recommendation**: Re-describe the sentence by removing quantifiable terms.
- **Example**: "User provides all required data"

Minimality

***Verification Heuristic:** Check that a sentence does not contain additional information (Text after a dot, hyphen, semicolon or otherpunctuation mark).*

Indicator: The *sentence* (Title, Goal, Episode Sentence or Alternative Solution Step) contain a *text after* a dot, hyphen, semicolon or other punctuation mark (e.g. : . ; : ! ?)**.**

- **Detection Method**: Check whether a *token* in an *episode sentence* (or alternative solution step or title or goal) is included in *non-minimal-dictionary* (token.word ∈ non-minimal-dictionary). Extraction of tokens is done by the *Stanford parser*.

Fix Recommendation: Split the sentence into multiple sentence

Example: "Administrator adds more channels. Proceed to step 7"

Atomicity

***Verification Heuristic**: Check that Title defines exactly one situation [11]*

Indicator: The *title* contains *conjunction* or *disjunction* of *verbs* or *subjects* (e.g. and, or, and/or).

- **Detection Method**: Check whether a *token* in the *title* is included in *multiple-dictionary* (token.word ∈ multiple-dictionary). Extraction of tokens is done by the *Stanford parser*.

- **Fix Recommendation**: Split the scenario into multiple scenari-os or remove one action-verbs or objects
- **Example**: "Submit and print order"

***Verification Heuristic**: Check that Goal satisfies exactly one purpose [11]*

Indicator: The *goal* contains more than one action-verb.

- **Detection Method**: Check whether *goal* has more than one *action-verb*. Extraction of action-verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix recommendation**: Split the scenario into multiple scenari-os or remove one action-verb
- **Example**: "The customer enters her login information and selects the password reminder option"

***Verification Heuristic**: Check that Title contains a verb in infinitive form and an object [9] [11]*

Indicator: Unnecessary *subjects* in the *Title*

- **Detection Method**: Check whether *title* has at least one *subject*. Extraction of subjects from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: It is not necessary subjects in Title
- **Example**: "User submit order"

Indicator: Missing *object* in the *Title*

- **Detection Method**: Check whether *title* is described without a *direct-object* (or indirect-object). Extraction of objects from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Inform an Object after the Action-Verb
- **Example**: "Search"

Indicator: Missing *action-verb* in the *Title*

- **Detection Method**: Check whether *title* is described without an *action-verb*. Extraction of verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Inform an Action-Verb in infinitive form
- **Example**: "Order"

Indicator: The *Title* contains more than one *action-verb*

- **Detection Method**: Check whether *title* has more than one *action-verb*. Extraction of action-verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the scenario into multiple scenarios or remove one action-verb
- **Example**: "Submit and register order"

Indicator: *Action-Verb* in the *Title* is not in INFINITIVE (base) FORM

- **Detection Method**: Check whether the *action-verb* of the *title* is not in infinitive form (token.POS != VB | VBP). Extraction of action-verbs and POS tags from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Inform an Action-Verb in infinitive form
- **Example**: "User submits order"

Simplicity

***Verification Heuristic**: Check that Episode-Sentence is described from user point of view (Subject + present simple tense and active form of verb + Object) or by another scenario (infinitive verb – base form + Object) [6] [9] [11] [17]*

Indicator: Missing *subject* in the *Episode Sentence*

- **Detection Method**: Check whether *episode sentence* is described without a *subject*. Extraction of subjects from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: IF sentence do not reference another scenario THEN Inform who (Subject) performs the Action-Verb
- **Example**: "register order"

Indicator: Missing *object* in the *Episode Sentence*

- **Detection Method**: Check whether *episode sentence* is described without a *direct-object* (or indirect-object). Extraction of objects from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Inform who (Object) is impacted by the Action-Verb
- **Example**: "The system prints"

Indicator: Missing action-verb in the *Episode Sentence*

- **Detection Method**: Check whether *episode sentence* is described without an *action-verb*. Extraction of verbs from the

sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Inform an Action-Verb an action-verb in the present simple tense and active form
- **Example**: "The system is online"

Indicator: The *Episode Sentence* contains more than one *subject*
- **Detection Method**: Check whether *episode sentence* has more than one *subject*. Extraction of subjects from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the sentence into multiple sentences
- **Example**: "Guest and administrator upload files"

Indicator: The *Episode Sentence* contains more than one *sentence*
- **Detection Method**: Check whether *episode sentence* is described by more than one *sentence*. Extraction of sentences from the episode sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the sentence into multiple sentences
- **Example**: "User sends the order. The system ends"

Indicator: The *Episode Sentence* contains more than one *action-verb*
- **Detection Method**: Check whether *episode sentence* has more than one *action-verb*. Extraction of action-verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the sentence into multiple sentences
- **Example**: "The customer enters her login information and selects the password reminder option"

Indicator: The *Episode Sentence* contains an *action-verb* not in the third form
- **Detection Method**: Check whether *action-verb* of a *episode sentence* is not in third form (token.POS != VBZ). Extraction of action-verbs and POS tags from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: IF sentence do not reference another scenario THEN Use an action-verb in the present simple tense and active form
- **Example**: "The system broadcast the order to the supplers"

Indicator: The *Episode Sentence* contains more than one *complement-action-verb*
- **Detection Method**: Check whether *episode sentence* is described by complement verbs and, the number of *complement-action-verbs* is more than one. Extraction of complement-action-verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the sentence into multiple sentences
- **Example**: "User wants to change and save his pin"

Indicator: The *Episode Sentence* contains more than one *modifier-action-verb*
- **Detection Method**: Check whether *episode sentence* is described by modifier verbs and, the number of *modifier-action-verbs* is more than one. Extraction of modifier-action-verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the sentence into multiple sentences
- **Example**: "User signals the system to proceed and save the transaction"

***Verification Heuristic**: Check that Alternative-Solution-Step-Sentence is described from user point of view (present simple tense and active form of verb + Object) or by another scenario (infinitive base form of verb + Object). Optionally, it contains a Subject [6] [9] [11] [17]*

Indicator: Missing object in the *Alternative Solution Step*
- **Detection Method**: Check whether *alternative solution step sentence* is described without a *direct-object* (or indirect-object). Exception ocurrs when the *subject* is the *"system"* or *"scenario"* or *"use case"* (e.g. use case ends). Extraction of subjects, objects from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Inform who (Object) is impacted by the Action-Verb
- **Example**: "User informs"

Indicator: Missing *action-verb* in the *Alternative Solution Step*
- **Detection Method**: Check whether *alternative solution step sentence* is described without an *action-verb*. Extraction of verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Inform an Action-Verb an action-verb in the present simple tense and active form
- **Example**: "System is offline"

Indicator: The *Alternative Solution Step* contains more than one *subject*
- **Detection Method**: Check whether *alternative solution step sentence* has more than one *subject*. Extraction of subjects from the sentence is done with the help of the *Stanford parser*.

- **Fix Recommendation**: Split the solution into multiple solution steps
- **Example**: "User or System restart the sensor"

Indicator: The *Alternative Solution Step* contains more than one *sentence*

- **Detection Method**: Check whether *alternative solution step* is described by more than one *sentence*. Extraction of sentences from the episode sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the solution into multiple solution steps
- **Example**: "User re-describe the order. System saves the order"

Indicator: The ***Alternative Solution Step*** contains more than one *action-verb*

- **Detection Method**: Check whether *alternative solution step sentence* has more than one *action-verb*. Extraction of action-verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the solution into multiple solution steps
- **Example**: "User describes and saves the order"

Indicator: The *Alternative Solution Step* contains an *action-verb* not in the third or infinitive form

- **Detection Method**: Check whether *action-verb* of an *alternative solution step sentence* is not in third or infinitive form (*token*.POS != VB | VBP | VBZ). Extraction of action-verbs and POS tags from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: IF sentence do not reference another scenario THEN Use an action-verb in the present simple tense and active form (or infinitive form)
- **Example**: "System is returning to step 1"

Indicator: The *Alternative Solution Step* contains more than one *complement-action-verb*

- **Detection Method**: Check whether *alternative solution step sentence* is described by complement verbs and, the number of *complement-action-verbs* is more than one. Extraction of complement-action-verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the solution into multiple solution steps
- **Example**: "User wants to change his pin and register a new order"

Indicator: The *Alternative Solution Step* contains more than one *modifier-action-verb*

- **Detection Method**: Check whether *alternative solution step sentence* is described by modifier verbs and, the number of *modifier-action-verbs* is more than one. Extraction of modifier-action-verbs from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Split the solution into multiple solution steps
- **Example**: "User signals the system to restart the sensor and rollback the transaction"

***Verification Heuristic**: Check that Title does not contain extra unnecessary information [8]*

Indicator: The *Title* contains unnecessary information

- **Detection Method**: Check whether *title* contains *text between parentheses* or *text representing an URI.* Extraction of parentheses and URIs is done by *Regular Expressions*.
- **Fix Recommendation**: Remove unnecessary information
- **Example**: "Create order (see http://.....)"

***Verification Heuristic**: Check that Episode coincidence only takes place in different situations [11]*

Indicator: Duplicated *Episode Sentence*

- **Detection Method**: Check whether several *episodes* have similar *sentences* (subject + predicate). Extraction of sentence is done by *Regular Expressions.* Comparison between any two sentences is done by measuring the *Levenshtein's distance*.
- **Fix Recommendation**: Remove or re-write one episode
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. Supplier submits a Bid
 3. Supplier submit a Bid
ALTERNATES/EXCEPTIONS:
```

Indicator: Duplicated *Episode Id/Step*

- **Detection Method**: Check whether several *episodes* have the same *step* (Id). Extraction of step/id is done by *Regular Expressions*.
- **Fix Recommendation**: Remove or re-write one episode
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. Supplier submits a Bid
 2. Supplier submit a Bid
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that episodes involving validation are described using the verbs verify/validate/ensure/establish and followed by that; i.e., avoid verbs like check/see followed by If/Whether. Complicated validation steps can confuse the user and be difficult to understand [6] [9] [11]*

Indicator: The *Episode Sentence* involves a validation action and it is hard to understand and follow (contain structures like checks if / see whether)

- **Detection Method**: Search for specific keywords in an *episode sentence*, such as *"check"* | *"see"* followed by *"if"* | *"whether"*. Extraction of keywords is done by *Regular Expressions*.
- **Fix Recommendation**: Instead, re-write using the optimistic scenario, use one of the other validation verbs (verify / validate / ensure / establish followed by that) or relocate conditions and their actions to alternate/exception flow section
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. System checks whether the movement is valid
 3. Supplier submit a Bid
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that nested IF statement is not used in a Conditional Episode, i.e., it can confuse the user and be difficult to read [6] [56]*

Indicator: More than one ***Episode-Sentence*** inside a nested IF structure

- **Detection Method**: Check whether two consecutive episodes have similar steps/Ids, i.e., second episode step = first episode step + "." + $(digit)^+$. Extraction of step/Id is done by *Regular Expressions*.
- **Fix Recommendation**: Create a new scenario and extract the sequence to it, or It should be in a separate Alternate/Exception flow section
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. If user is valid:
  2.1. System process the Bid
  2.2. System broadcasts the Bid
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that alternative is handled by a simple action [11], i.e, if the interruption is treated by a sequence of steps (>3), this sequence should be extracted to a separate scenario [6]*

Indicator: The *Alternative Solution* has too many steps (> 3)

- **Detection Method**: Check whether the number of *steps* in an *alternative solution* is more than 3 (alternative.solution.lenght > 3). Extraction of steps is done by *String Searching* and *Regular Expressions*.
- **Fix Recommendation**: Extract the sequence to a separated scenario
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
ALTERNATES/EXCEPTIONS:
 1.a. Order is not valid:
  1.a.1. System process the Bid
  1.a.2. System cancels the Bid
  1.a.3. …
  1.a.4. System exits
```

-

***Verification Heuristic**: Check that every alternative flow returns to a specific episode of the main flow or finishes the scenario [57]*

<u>Indicator</u>: The *Alternative* does not return to the main flow in the *last solution step*

- **Detection Method**: Search for specific keywords in an *alternative solution step*, such as "(GO | BACK | RETURN | RESUME) + TO + (STEP | EPISODE)? + <Step>", where <Step> is an episode step/Id and the *alternative solution step* is not the last element in the alternative solution collection. Extraction of keywords is done by *Regular Expressions*.
- **Fix Recommendation**: Move the solution step with GO TO to the last position
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. …
 3. …
ALTERNATES/EXCEPTIONS:
 2.a. Order is not valid:
  2.a.1. System process the Bid
  2.a.2. System goto step 1
  2.a.3. System cancels the Bid
```

<u>Indicator</u>: The *Alternative* returns to the main flow using an invalid episode *Id/Step*

- **Detection Method**: Search for specific keywords in an *alternative solution step*, such as "(GO | BACK | RETURN | RESUME) + TO + (STEP | EPISODE)? + <Step>", where <Step> is an invalid (not exist) episode step/Id. Extraction of keywords is done by *Regular Expressions*.
- **Fix Recommendation**: Inform a valid episode Id/Step
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. …
 3. …
ALTERNATES/EXCEPTIONS:
 2.a. Order is not valid:
  2.a.1. System process the Bid
  2.a.2. System goto step 4
```

<u>Indicator</u>: The *Alternative* does not finish the scenario in the *last solution step*

- **Detection Method**: Search for specific keywords in an *alternative solution step*, such as ((SYSTEM | USE CASE | SCENARIO) + (ENDS | TER-MINATES | FINISHES))", and the *alternative solution step* is not the last element in the alternative solution collection. Extraction of keywords is done by *Regular Expressions*.
- **Fix Recommendation**: Move the solution step which "ends or finishes" the scenario to the last position
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. …
 3. …
ALTERNATES/EXCEPTIONS:
 2.a. Order is not valid:
  2.a.1. System process the Bid
  2.a.2. Use case ends
  2.a.3. System cancels the Bid
```

Uniformity

***Verification Heuristic**: Ensure that Title is present [11]*

Indicator: Missing *Title*

- **Detection Method**: Check whether the sentence describing a *title* is empty. Extraction of sentence is done by *String Searching*.
- **Fix Recommendation**: Inform the Title
- **Example**:

***Verification Heuristic**: Ensure that Goal is present [11]*

Indicator: Missing *Goal*

- **Detection Method**: Check whether the sentence describing a *goal* is empty. Extraction of sentence is done by *String Searching*.
- **Fix Recommendation**: Inform the Goal
- **Example**:

***Verification Heuristic**: Check the existence of more than one Actor per Scenario [11]*

Indicator: Missing *Actors*

- **Detection Method**: Check whether *actors* is empty (actors.lenght == 0). Extraction of actors is done by *String Searching* and *Regular Expressions*.
- **Fix Recommendation**: Inform at least one Actor
- **Example**:

***Verification Heuristic**: Ensure that Context contains its relevant sub-components [11]*

Indicator: *Context* does not contain its relevant subcomponents

- **Detection Method**: Check whether scenario pre-condition is empty (and *post-condition* is empty and *temporal-location* is empty and *geographical-location* is empty). Extraction of context subcomponents is done by *String Searching* and *Regular Expressions*.
- **Fix Recommendation**: Inform at least one Pre-condition, Postcondition, Temporal Location or Geographical Location
- **Example**:

```
TITLE: Submit order
CONTEXT:
   Pre-condition:
   Post-condition:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. System …
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check the existence of more than one Episode per Scenario [11];*

Indicator: Missing *Episodes*

- **Detection Method**: Check whether *episodes* is empty (episodes.lenght == 0). Extraction of episodes is done by *String Searching* and *Regular Expressions*.

- **Fix Recommendation**: Inform at least one Episode
- **Example**:

***Verification Heuristic**: Ensure that Episode contains its relevant parts [11]*

__Indicator__: The *Episode* does not contain an Id/Step

- **Detection Method**: Check whether the *step/Id* of an ***episode*** is empty. Extraction of step/id is done by *Regular Expressions*.
- **Fix Recommendation**: Inform at least: Id/Step and Sentence
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 Supplier receives the Order and examines it
 System …
ALTERNATES/EXCEPTIONS:
```

__Indicator__: The *Episode* does not contain a Sentence

- **Detection Method**: Check whether the *sentence* of an ***episode*** is empty. Extraction of sentence is done by *Regular Expressions*.
- **Fix Recommendation**: Inform at least: Id/Step and Sentence
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. IF user is valid
ALTERNATES/EXCEPTIONS:
```

__Indicator__: The *Conditional* or *Loop Episode* does not contain its Conditions

- **Detection Method**: Check whether an *episode* is "conditional" or "loop", and its *condition* is empty. Extraction of episode type and condition is done by *String Searching* and *Regular Expressions*.
- **Fix Recommendation**: IF episode is Conditional or Loop THEN inform at least: Id, Condition and Sentence
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. System searches the database, when
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Ensure that non-sequential episodes construct have a begin and an end keywords (e.g. #)*

__Indicator__: Missing *end* instruction in *Non-sequential Construct* (episodes delimited by # **...** #)

- **Detection Method**: Given an *episode* e_i that begins (starts with the keyword "#") a non-sequential group, check there exist an *episode* e_j that ends (ends with the keyword "#") the group ($i < j$). If there not exist $\boldsymbol{e_j}$, the non-sequential group of episodes is incomplete. Identification of keywords ("#") is done by *String Searching*.
- **Fix Recommendation**: Complete the non-sequential construct: begin and end keywords # ... #
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and #it
 2. …
 3. #Local supplier …
 4. International supplier …
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Ensure that Alternative contains its relevant parts [11][24]*

Indicator: The *Alternate/Exception* does not contain an Id/StepRef

- **Detection Method**: Check whether the *stepRef/Id* of an *alternative* is empty. Extraction of stepRef/id is done by *Regular Expressions*.
- **Fix Recommendation**: Inform at least: Id/StepRef, cause and Sentence
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. …
 3. …
ALTERNATES/EXCEPTIONS:
 Order is not valid:
  System process the Bid
```

Indicator: The *Alternate/Exception* does not contain a Solution

- **Detection Method**: Check whether the *solution* of an *alternative* is empty. Extraction of solutions steps is done by *Regular Expressions*.
- **Fix Recommendation**: Inform at least: Id/StepRef, cause and Sentence
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. …
 3. …
ALTERNATES/EXCEPTIONS:
 2.a. Order is not valid
```

Indicator: The *Alternate/Exception* does not contain its *Causes*

- **Detection Method**: Check whether the *cause* of an *alternative* is empty. Extraction of cause is done by *String Searching* and *Regular Expressions*.
- **Fix Recommendation**: Inform at least: Id/StepRef, cause and Sentence
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. …
 3. …
ALTERNATES/EXCEPTIONS:
 2.a. System cancels the order
```

Usefulness

***Verification Heuristic**: Check that every Actor participates in at least one episode [11]*

Indicator: *Actor* does not participate in the *situation* – episodes

- **Detection Method**: Check that every *actor* in actors is mentioned in at least one *episode sentence* (subject or direct-object or indirect-object of the sentence). Extraction of subject, direct-object and indirect-object from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Mention the actor in at least one episode
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: User
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. System submit a Bid
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that every Resource is used in at least one episode [11]*

Indicator: *Resource* does not participate in the *situation* - episodes

- **Detection Method**: Check that every *resource* in resources is mentioned in at least one *episode sentence* (subject or direct-object or indirect-object of the sentence). Extraction of subject, direct-object and indirect-object from the sentence is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Mention the resource in at least one episode
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE: GPS
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. System submit a Bid
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that every Actor mentioned in episodes is included in the Actor section [11] or is the System [17] or, it is included in Resources*

Indicator: The *Episode Sentence* contains an undeclared *Actor*

- **Detection Method**: Check whether the *subject* of an *episode sentence* is defined as an *actor* (or resource or is the "system"). Extraction of subject is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Include the Subject in Actors or use the "System" word
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: User
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. Supplier submits a Bid
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that every Resource mentioned in episodes is included in the Resource [11] section or, it is included in Actors;*

Indicator: The *Episode Sentence* contains undeclared *Resource*

- **Detection Method**: Resources are preferentially *Objects*. Check whether an *indirect-object (nsubj(A, B), **nmod**(A, C))* of an *episode sentence* is defined as a *resource* (or actor or is the "system"). Extraction of object is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Include the Indirect-Object in Resources or Actors
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: User
RESOURCE:
EPISODES:
 1. System receives the Order
 2. The Broker System sends the Bid to the Customer
 3. System prints on the screen
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that every Actor mentioned in alternatives is included in the Actor section [11] or is the System [17] or, it is included in Resources*

Indicator: The *Alternative Solution Step* contains undeclared Actor

- **Detection Method**: Check whether the *subject* of an *alternative solution step sentence* is defined as an ***actor*** (or resource or is the "system"). Extraction of subject is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Include the Subject in Actors or use the "System" word
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. System submit a Bid
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
```

***Verification Heuristic**: Ensure that step numbering between the main flow and alternative flow are consistent [59]*

Indicator: *Branching Episode* of an *Alternative* is missing

- **Detection Method**: Check that the *step* (<step> from <step> + <Ref>) part of an *alternative* is equal to an *episode step* in episodes Extraction of step is done by *Regular Expressions*.
- **Fix Recommendation**: Update the alternative Id/StepRef to appoint the correct episode
- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. System submit a Bid
ALTERNATES/EXCEPTIONS:
 5.1 Supplier is offline
```

***Verification Heuristic**: Check the existence of more than 2 and less to 10 episodes per scenario [6] [9] [60]*

Indicator: Number of *episodes* in current scenario is less than 3 or more than 9

- **Detection Method**: Check whether the number of *episodes* is between 3 and 9. Extraction of episodes is done by *String Searching* and *Regular Expressions.*
- **Fix Recommendation**: Re-write the scenario to keep between 3 and 9 episodes
- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
ALTERNATES/EXCEPTIONS:
```

Conceptually Soundness

***Verification Heuristic**: Check that the Title describes the Goal*

Indicator: The *Title* and the *Goal* does not *share action-verbs and direct-objects*

- **Detection Method**: Check whether *title* and *goal* have *common action-verbs* and *direct-objects*. When direct-objects is empty, use indirect-objects; when action-verbs is empty, use complement-action-verbs or modifier-action-verbs. Extraction of verbs and objects from the sentences is done with the help of the *Stanford parser*. Comparison of sentences is done by *Syntactic Similarity.*
- **Fix Recommendation**: Re-write the Title to satisfy the Goal
- **Example**:

```
TITLE: Submit order
GOAL: Print order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Ensure that Episodes contain only actions to be performed [11]*

Indicator: Missing Action-Verb in the *Episode Sentence*

- **Detection Method**: Check whether *episode sentence* has at least one *action-verb*. Extraction of verbs from the sentences is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Inform an action-verb in the present simple tense and active form
- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System is online
ALTERNATES/EXCEPTIONS:
```

-

***Verification Heuristic**: Ensure that solutions in Alternatives contain only actions to be performed [11]*

Indicator: Missing Action-Verb in the *Alternative Solution Step*

- **Detection Method**: Check whether *alternative solution step* has at least one *action-verb*. Extraction of verbs from the sentences is done with the help of the *Stanford parser*.
- **Fix Recommendation**: Inform an Action-Verb an action-verb in the present simple tense and active form
- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. System submit a Bid
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System is online
```

Integrity

***Verification Heuristic**: Check that every included scenario (Pre-condition, Post-condition, Episode sentence, Alternative solution) exists within the set of scenarios [11]*

Indicator: *Pre-condition* references to a scenario that does not exist within the set of scenarios

- **Detection Method**: Check whether a *sentence* describing a *pre-condition* is *uppercase* (capital letters) and, that this *sentence* does not exist in the set of *scenarios* (compare to titles). Extraction of sentences in uppercase from a pre-condition is done by *Regular Expressions*.

- **Fix Recommendation**: Include the related scenario to the set of scenarios
- **Example**:

```
TITLE: Register Customer
GOAL:
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
ALTERNATES/EXCEPTIONS:
```

```
TITLE: Process Bid
GOAL:
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
ALTERNATES/EXCEPTIONS:
```

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
    PRE-CONDITION: FILL ORDER
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. System submit a Bid
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
    2.1.1 System exits
```

Indicator: *Post-condition* references to a scenario that does not exist within the set of scenarios

- **Detection Method**: Check whether a *sentence* describing a *post-condition* is *uppercase* (capital letters) and, that this *sentence* does not exist in the set of *scenarios* (compare to titles). Extraction of sentences in uppercase from a post-condition is done by *Regular Expressions*.
- **Fix Recommendation**: Include the related scenario to the set of scenarios
- **Example**:

```
TITLE: Register Customer
GOAL:
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
ALTERNATES/EXCEPTIONS:
```

```
TITLE: Process Bid
GOAL:
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
ALTERNATES/EXCEPTIONS:
```

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
    POST-CONDITION: PAY ORDER
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. System submit a Bid
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
    2.1.1 System exits
```

Indicator: *Episode sentence* references to a scenario that does not exist within the set of scenarios

- **Detection Method**: Check whether a *sentence* describing an *episode* is *uppercase* (capital letters) and, that this *sentence* does not exist in the set of *scenarios* (compare to titles). Extraction of sentences in uppercase from an episode is done by *Regular Expressions*.
- **Fix Recommendation**: Include the related scenario to the set of scenarios
- **Example**:

```
TITLE: Register Customer
GOAL:
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
ALTERNATES/EXCEPTIONS:
```

```
TITLE: Process Bid
GOAL:
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
ALTERNATES/EXCEPTIONS:
```

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
   PRE-CONDITION:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. SUBMIT BID
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System exits
```

Indicator: *Alternative solution step* references to a scenario that does not exist within the set of scenarios

- **Detection Method**: Check whether a *sentence* describing an *alternative solution step* is *uppercase* (capital letters) and, that this *sentence* does not exist in the set of *scenarios* (compare to titles). Extraction of sentences in uppercase from an alternative solution is done by *Regular Expressions*.
- **Fix Recommendation**: Include the related scenario to the set of scenarios
- **Example**:

```
TITLE: Register Customer
GOAL:
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
ALTERNATES/EXCEPTIONS:
```

```
TITLE: Process Bid
GOAL:
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
ALTERNATES/EXCEPTIONS:
```

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
   PRE-CONDITION:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. System submit a Bid
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 FILL ORDER
```

***Verification Heuristic**: Ensure that actions present in the Pre-conditions are already performed [11]*

Indicator: Missing scenario *Post-condition* (of another scenario) that satisfies the current *Pre-condition*

- **Detection Method**: Check whether a scenario *pre-condition* is not described as *post-condition* in another scenario. Comparison of sentences is done by *String Matching*.
- **Fix Recommendation**: IF the pre-condition is not an uncontrollable fact THEN describe it as post-condition of another scenario
- **Example**:

***Verification Heuristic**: Check that Episode coincidence only takes place in different scenarios [11]*

Indicator: Duplicated *Episode Sentence*

- **Detection Method**: Check whether several *episodes* have similar *sentences* (subject + predicate). Extraction of sentence is done by *Regular Expressions*. Comparison between any two sentences is done by measuring the *Levenshtein's distance*..
- **Fix Recommendation**: Remove or re-write one episode
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. Supplier submits a Bid
 3. Supplier submit a Bid
ALTERNATES/EXCEPTIONS:
```

Indicator: Duplicated *Episode Id/Step*

- **Detection Method**: Check whether several *episodes* have the same *step* (Id). Extraction of step/id is done by *Regular Expressions*.
- **Fix Recommendation**: Remove or re-write one episode
- **Example**:

```
TITLE: Submit order
CONTEXT:
ACTOR: System
RESOURCE:
EPISODES:
 1. Supplier receives the Order and examines it
 2. Supplier submits a Bid
 2. Supplier submit a Bid
ALTERNATES/EXCEPTIONS:
```

Coherency

Verification Heuristic: Check coherence between Pre-conditions in related scenarios [11]

Indicator: *Pre-conditions* of a related scenario are not coherent with the Pre-conditions of the main scenario

- **Detection Method**: *Difficult to be automated*.
- **Fix Recommendation**: Re-write the pre-conditions of related or main scenario
- **Example**:

Verification Heuristic: Check that Geographical and Temporal location of the related scenarios are equal or more restricted than those of the main scenario [24]

Indicator: *Geographical location* of a related scenario is not in the set of Geographical locations of the main scenario

- **Detection Method**: Check whether the *geographical location* of a sequentially related scenario is not described as *geographical location* in the main scenario. Comparison of sentences is done by *Levenshtein's distance*.
- **Fix Recommendation**: Re-write the Geographical locations of related scenario to be more restrict to the main scenario
- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
  GEOGRAPHICAL LOCATION: Location 1
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. PROCESS BID
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System exits
```

```
TITLE: Process Bid
GOAL:
CONTEXT:
  GEOGRAPHICAL LOCATION: Location 2
ACTOR:
RESOURCE:
EPISODES:
 1. Customer examines the bid
 2. Customer signals the system to proceed with bid
 3. HANDLE PAYMENT
ALTERNATES/EXCEPTIONS:
```

Indicator: *Temporal location* of a related scenario is not in the set of Temporal locations of the main scenario

- **Detection Method**: Check whether the *temporal location* of a sequentially related scenario is not described as *temporal location* in the main scenario. Comparison of sentences is done by *Levenshtein's distance*.
- **Fix Recommendation**: Re-write the Temporal locations of related scenario to be more restrict to the main scenario
- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
 TEMPORAL LOCATION: Location 1
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. PROCESS BID
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System exits
```

```
TITLE: Process Bid
GOAL:
CONTEXT:
 TEMPORAL LOCATION: Location 2
ACTOR:
RESOURCE:
EPISODES:
 1. Customer examines the bid
 2. Customer signals the system to proceed with bid
 3. HANDLE PAYMENT
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that referenced scenarios do not reference the main scenario [20] (adapted from [59])*

Indicator: *Circular inclusion* (The related scenario reference in its description to the main scenario)

- **Detection Method**: Check whether a *related scenario* references in its description (episodes, alternatives, context pre-condition or context post-condition) the *title* of the main scenario. Comparison of sentences is done by *String Matching*.
- **Fix Recommendation**: Remove the reference to the main scenario (in referenced scenario)
- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
   PRE-CONDITION:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. PROCESS BID
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System exits
```

```
TITLE: Process Bid
GOAL:
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
 2. SUBMIT ORDER
ALTERNATES/EXCEPTIONS:
```

Uniqueness

***Verification Heuristic**: Check that the Title of a scenario is not already included in another scenario*

Indicator: Two scenarios have similar *Titles*

- **Detection Method**: Check whether the *title* of a scenario is equal to the *title* of another scenario. Comparison of sentences is done by *Levenshtein's distance*.
- **Fix Recommendation**: IF the sets of episodes are the same THEN remove one scenario; IF the sets of episodes are not the same THEN rename the Title of one scenario.
- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
   PRE-CONDITION:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. …
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System exits
```

```
TITLE: Submit Orders
GOAL:
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
 2. …
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that the Goal of a scenario is not already included in another scenario*

Indicator: Two scenarios have similar *Goals*

- **Detection Method**: Check whether the *goal* of a scenario is equal to the *goal* of another scenario. Comparison of sentences is done by *Levenshtein's distance*.
- **Fix Recommendation**: IF the sets of episodes are the same THEN remove one scenario; IF the sets of episodes are

not the same THEN rename the Goal of one scenario.

- **Example**:

```
TITLE: Submit order
GOAL: The broker Submit order to suppliers
CONTEXT:
   PRE-CONDITION:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. …
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System exits
```

```
TITLE: Submit Orders
GOAL: The broker Submits order to suppliers
CONTEXT:
ACTOR:
RESOURCE:
EPISODES:
 1. …
 2. …
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that the Pre-condition of a scenario is not already included in another scenario*

Indicator: Two scenarios have similar *Pre-conditions*

- **Detection Method**: Check whether the *pre-conditions* of a scenario are equal to a subset of the *pre-conditions* of another scenario. Comparison of sentences is done by *Levenshtein's distance*.
- **Fix Recommendation**: IF the sets of episodes are the same THEN remove one scenario
- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
  PRE-CONDITION: Local Supplier has submitted a bid
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. PROCESS BID
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System exits
```

```
TITLE: Process Bid
GOAL:
CONTEXT:
  PRE-CONDITION: Local Supplier has submitted a bid
ACTOR:
RESOURCE:
EPISODES:
 1. Customer examines the bid
 2. Customer signals the system to proceed with bid
 3. HANDLE PAYMENT
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that the set of Episodes of a scenario is not already included in another scenario*

Indicator: Two scenarios have similar ***Episodes***

- **Detection Method**: Check whether the *episodes* of a scenario are equal to a subset of the *episodes* of another scenario. Comparison of sentences is done by *Levenshtein's distance*.
- **Fix Recommendation**: IF the set of episodes of scenario_2 is a subset of scenario_1 THEN remove the duplicated episodes in scenario_1 and reference to scenario_2; IF the sets of episodes are the same THEN remove one scenario
- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
  PRE-CONDITION: System is online
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. Customer examines the bid
 4. Customer signals the system to proceed with bid
 5. HANDLE PAYMENT
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System exits
```

```
TITLE: Process Bid
GOAL:
CONTEXT:
  PRE-CONDITION: Local Supplier has submitted a bid
ACTOR:
RESOURCE:
EPISODES:
 1. Customer examines the bid
 2. Customer signals the system to proceed with bid
 3. HANDLE PAYMENT
ALTERNATES/EXCEPTIONS:
```

***Verification Heuristic**: Check that two scenarios do not have similar Titles*

Indicator: Two scenarios share action-verbs and direct-objects in their *Titles*

- **Detection Method**: Check whether two *titles* have *common action-verbs* and *direct-objects*. When direct-objects is empty, use indirect-objects. Extraction of verbs and objects from the sentences is done with the help of the *Stanford parser*. Comparison of titles is done by *Syntactic Similarity*.
- **Fix Recommendation**: IF the sets of episodes are the same THEN remove one scenario; IF the sets of episodes are

not the same THEN rename the Title of one scenario

- **Example**:

```
TITLE: Submit order
GOAL: Submit order
CONTEXT:
  PRE-CONDITION:
ACTOR: System
RESOURCE:
EPISODES:
 1. System receives the Order
 2. System prints the order
 3. PROCESS BID
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System exits
```

```
TITLE: Customer Submits Order
GOAL:
CONTEXT:
  PRE-CONDITION:
ACTOR:
RESOURCE:
EPISODES:
 1. Customer examines the bid
 2. Customer signals the system to proceed with bid
 3. HANDLE PAYMENT
ALTERNATES/EXCEPTIONS:
```

<u>**Indicator**</u>: Two scenarios share action-verbs and the direct-objects (in synonymous forms) in their *Titles*

- **Detection Method**: Check whether two *titles* have *common action-verbs* and a *direct-objects*. When direct-objects is empty, use indirect-objects. When *action-verbs* or *objects* are not equal, use their *synonymous* forms. Extraction of verbs and objects from the sentences is done with the help of the *Stanford parser*. We can get the synonymous forms of the objects with the help of WordNet database. Comparison of sentences is done by ***Semantic Similarity*.**
- **Fix Recommendation**: IF the sets of episodes are the same THEN remove one scenario; IF the sets of episodes are not the same THEN rename the Title of one scenario
- **Example**:

```
TITLE: Withdraw Cash
GOAL: Submit order
CONTEXT:
  PRE-CONDITION:
ACTOR: System
RESOURCE:
EPISODES:
 1. …
 2. …
 3. …
ALTERNATES/EXCEPTIONS:
 2.1 Supplier is offline
   2.1.1 System exits
```

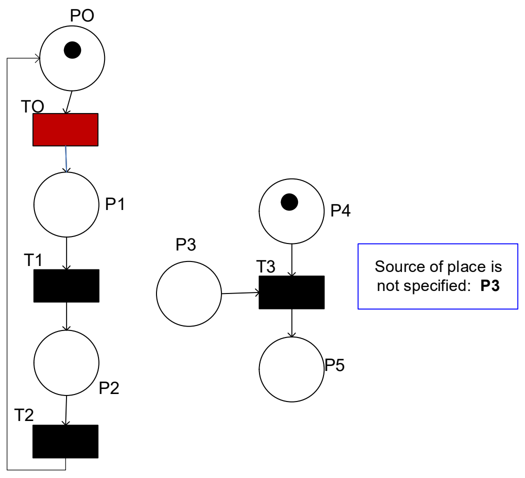
```
TITLE: Withdraw money
GOAL:
CONTEXT:
  PRE-CONDITION:
ACTOR:
RESOURCE:
EPISODES:
 1. …
 2. …
 3. …
ALTERNATES/EXCEPTIONS:
```

<u>Feasibility</u>

***Verification Heuristic**: Check that is possible to derive an initial system design from related scenarios [51]*

<u>**Indicator**</u>: Source or destination of events is not specified

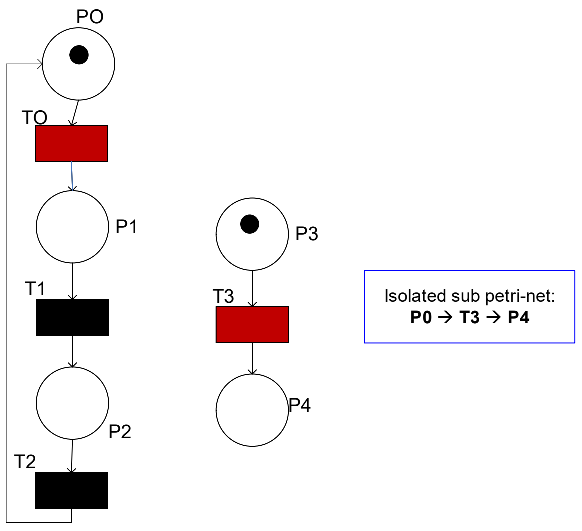
- **Detection Method**: Every *place* (transformed from epiodes and alternatives) in the *Petri-Net* must have at least one input arc (that is not a pre-condition) and an output arc (that is not a post-condition). If they are missing, the tokens in the Petri-Net cannot *pass correctly*.
- **Fix Recommendation**: Inform the relevant parts of Episodes and Alternatives
- **Example**:



***Verification Heuristic**: Check that initial system design does not contain isolated sub-systems [61]*

Indicator: *Isolated* events – unreachable operations

- **Detection Method**: The *transitions* (transformed from epiodes and alternatives) in the *Petri-Net* should interact with each other to exchange information (tokens). If there are transitions that do not interact with others, it will cause *isolated sub Petri-Nets.*
- **Fix Recommendation**: Inform the relevant parts of Episodes and Alternatives
- **Example**:

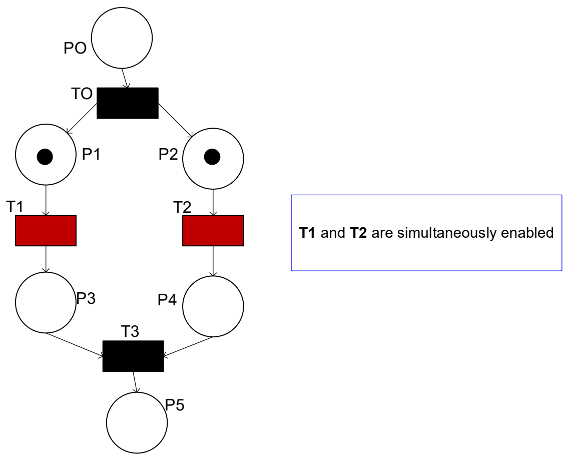


Non-interferential

***Verification Heuristic**: Check the absence of non-determinism, i.e., a set of operations are simultaneously enabled by common pre-conditions [31]*

Indicator: *Simultaneously* enabled operations

- **Detection Method**: Check whether the Petri-net contains *non-deterministic execution paths*, i.e., a set of *transitions* that are simultaneously enabled due to presence of tokens in their input places. *Reachability analysis* can reveal simultaneously enabled *transitions*.
- **Fix Recommendation**: Check that all pre-conditions or constraints associated to the episode/alternative corresponding to the transition are fulfilled; Notify to the next software development activities
- **Example**:

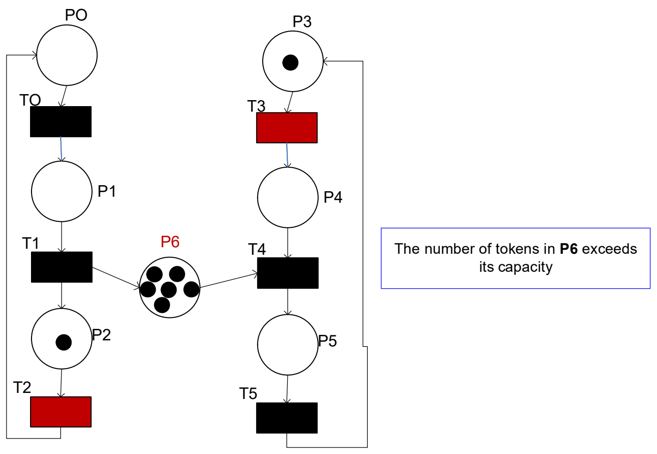


Boundedness

***Verification Heuristic**: Check the absence of overflow, i.e., the number of elements in some communication channel or resource exceeds a finite capacity [31]*

Indicator: *Overflowed* resources

- **Detection Method**: An *overflow* exists in a Petri-Net when the number of *tokens* in some place exceeds a finite number ***k*** for any marking reachable from initial marking ***M₀***. If the Petri-Net is not *bounded*, overflow exists in some place [37] [50]. *Reachability analysis* can reveal unbounded *places*.
- **Fix Recommendation**: Check that the overflowed resource is a critical shared resource modified by several operations or scenarios; Check that the overflowed resource capacity; Notify to the next software development activities
- **Example**:

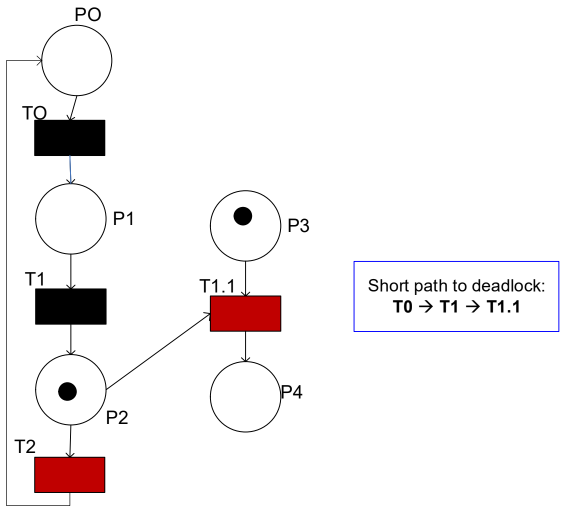


Liveness

***Verification Heuristic**: Check the absence of paths to deadlocks [31], e.g., it could occur when an alternative flow does not return to the main flow or finish the scenario*

Indicator: Path to *deadlock*

- **Detection Method**: Check whether the Petri-net contains a *short path* (consecutive transitions) that blocks the execution of the Petri-Net, i.e., the Petri-Net is not *deadlock free*. *Reachability analysis* can reveal short *paths* to *deadlock*.
- **Fix Recommendation**: Check whether there are shared resources modified by the scenarios and their relationships; Check that every alternative flow returns to a specific episode of the main flow or finishes the scenario; Notify to the next software development activities
- **Example**:

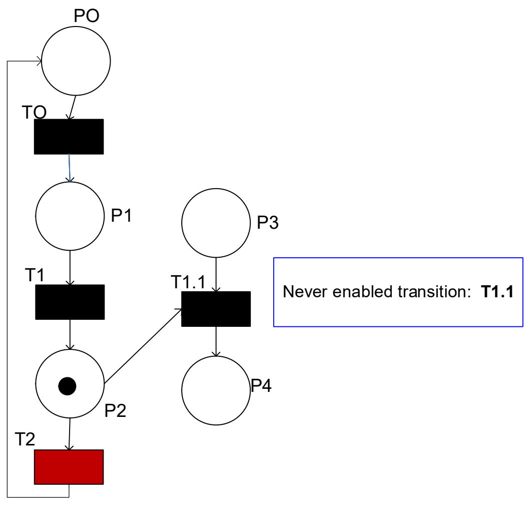


***Verification Heuristic**: Check the absence of never enabled operations, e.g., when the pre-conditions of an operation are never fulfilled*

Indicator: *Never enabled* operations

- **Detection Method**: Check whether the Petri-net contains a set of *transitions* that are never enabled (unreachable code in programs). *Reachability analysis* can reveal short *never enabled transitions*.
- **Fix Recommendation**: Check that all pre-conditions, constraints, conditions or causes of the episode/alternative corresponding to the transition are fulfilled; Notify to the next software development activities

- **Example**:



Reversibility

***Verification Heuristic**: Check that automatic error recovery is possible [50]*

Indicator: Automatic *error recovery* is not possible.

- **Detection Method**: If the reachability analysis reveals that the *Petri-Net* is not *bounded*, not *safe* (1-bounded) and not *live*, then, the Petri-Net is not reversible [37] [50].
- **Fix Recommendation**: Check that the performed scenarios are releasing resources, pre-conditions and constraints after completion; Check that every alternative flow returns to a specific episode of the main flow or finishes the scenario; Check the absence of deadlocks or never enabled operations
- **Example:**