APPENDIX D: DEFECT INDICATORS, DETECTION METHODS AND FIX RECOMMENDATIONS

Table 1 shows 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 [43].

TABLE 1
UNAMBIGUITY, COMPLETENESS AND CONSISTENCY PROPERTIES.

Property	Description	Verification Heuristic
Vagueness	The sentence contains words or phrases having a non-uniquely quantifiable meaning [6].	Check that a sentence does not contain vague terms (e.g., adaptability, additionally).
Subjectiveness	The sentence contains words or phrases expressing personal opinions or feelings [6].	Check that a sentence does not contain comparative/superlative adverbs/adjectives (e.g., similar, better).
Optionality	The sentence contains words that give the developer latitude in satisfying the specification statements that contain them [52].	Check that a sentence does not contain optional words (e.g., as desired, at last).
Weakness	The sentence contains clauses that are apt to cause uncertainty and leave room for multiple interpretations [52].	Check that a sentence does not contain weak terms (e.g., can, preferred).
Multiplicity	The sentence has more than one main verb or subject (Adapted from [6]).	Check that a sentence does not contain conjunction or disjunction of verbs or subjects (e.g., and, or, and/or).
Implicitly	The sentence does not specify the subject or object by means of its specific name but uses pronoun or indirect reference [6] [52].	Check that a sentence does not contain implicit words (e.g., anyone, he, her);
Quantifiability	Terms used for quantification can lead to ambiguity if not used properly [49].	Check that a sentence uses quantification words in a clear way (e.g., all, any, few).
Minimality	A sentence contains nothing more than basic attributes [58].	Check that a sentence does not contain additional information (Text after a dot, hyphen, semicolon, or other punctuation mark)
Atomicity	A scenario expresses exactly one situation (Adapted from [58]).	Check that the Title defines exactly one situation [12].
		Check that the Goal satisfies exactly one purpose [12].
		Check that the Title contains a verb in infinitive form and an object [10] [12].
Simplicity	A scenario should be as readable as possible.	Check that an Episode-Sentence is described from user's point of view (Subject + present simple tense and active form of verb + Object) or in another scenario (infinitive verb – base form + Object) [5] [10] [12] [15]
		Check that an Alternative-Solution-Step-Sentence is described from user's point of view (present simple tense and active form of verb + Object) or in another scenario (infinitive base form of verb + Object). Optionally, it contains a Subject [5] [10] [12] [15].
		Check that the Title does not contain extra unnecessary information [7].
		Check that an Episode coincidence only takes place in different situations [12].
		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 [5] [10] [12].
		Check that a nested IF statement is not used in a Conditional Episode, i.e., it can confuse the user and be difficult to read [5] [59].
		Check that an alternative is handled by a simple action [12], i.e, if the interruption is treated by a sequence of steps (> 3), this sequence should be extracted to a separate scenario [5].
		Check that every alternative flow returns to a specific episode of the main flow or finishes the scenario [60].
Uniformity	Each scenario element should be describedwith significant information.	Ensure that the Title is present [12].
		Ensure that the Goal is present [12].
		Check the existence of more than one Actor per Scenario [12].
		Ensure that the Context contains its relevant sub-components [12].
		Check the existence of more than one Episode per Scenario [12].
		Ensure that an Episode contains its relevant parts [12].
		Ensure that a non-sequential episodes construct has a begin and end keywords (e.g., #).
		Ensure that an Alternative contains its relevant parts [12].
Usefulness	A scenario does not contain superfluous information, i.e., there should be consistency among scenario components. (Adapted from [61]).	Check that every Actor participates in at least one episode [12].
		Check that every Resource is used in at least one episode [12].
		Check that every Actor mentioned in episodes is included in the Actor section [12] or is the System [15] or, it is included in Resources.
		Check that every Resource mentioned in episodes is included in the Resource [12] section or, it is included in Actors.
		Check that every Actor mentioned in alternatives is included in the Actor section [12] or is the System [15] or, it is included in Resources.
		Ensure that step numbering between the main flow and alternative flows is consistent [62].
		Check the existence of more than 2 and less than 10 episodes per scenario [5] [10] [63].
Conceptually Sound-ness	Internal scenario elements are semantically coherent, i.e., elements satisfy the scenario goal [12].	Check that the Title describes the Goal.
		Ensure that the Episodes contain only actions to be performed [12].
		Ensure that the Alternatives contain only actions to be performed [12].
Integrity	Whenever a scenario references to another scenario, the related scenario should exist within the set of scenarios.	Check that every included scenario (Pre-condition, Post-condition, Episode sentence, Alternative solution) exists within the set of scenarios [12].
		Ensure that actions present in the Pre-conditions are already performed [12].
		Check that Episode coincidence only takes place in different scenarios [12].
Coherency	Internal components of explicitly 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 [12].
		Check that the Geographical and Temporal locations of the related scenarios are equal or more restricted than those of the main scenario [12].
		Check that referenced scenarios do not reference the main scenario [55] (adapted from [62]).

Uniqueness	A scenario is unique when no other scenario is the same or too similar, i.e., duplicatesare avoided because they are a source of inconsistencies (Adapted from [58]).	Check that the Title of a scenario is not already included in another scenario.
		Check that the Goal of a scenario is not already included in another scenario.
		Check that the Pre-condition of a scenario is not already included in another scenario.
		Check that the set of Episodes of a scenario is not already included in another scenario.
		Check that two scenarios do not have similar Titles.
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 [13].
		Check that the initial system design does not contain isolated sub-systems [64].
Persistence	For any two enabled operations, the execution of one operation will not disable the other.	Check the absence of non-deterministic execution paths, i.e., a set of episodes are simultaneously enabled by common pre-conditions, and only one of them may happen [35].
Boundedness	This property refers to the limited capacity of a communication channel or resource.	Check the absence of overflow, i.e., the number of elements in some communication channel or resource exceeds a finite capacity [35].
Liveness	Every operation can be ex-ecuted in the future	Check the absence of paths to *deadlocks* [35], e.g., it may occur when an alternative flow does not return to the main flow, does not finish the scenario or is not treated/handled.
		Check the absence of never enabled operations, e.g., when the pre-conditions of an operation are never fulfilled.
Reversibility	This property guarantees that the described behavior reaches its initial state again	Check that is possible to return to the initial state from any path.

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 [73].

- **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 [73].

- **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 [73].

- **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 [73].

- **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 [73].

- **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 [12]*

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 [12]*

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 [10] [12]*

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 in other scenario (infinitive verb – base form + Object) [5] [10] [12] [15]*

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 suppliers"

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 in other scenario (infinitive base form of verb + Object). Optionally, it contains a Subject [5] [10] [12] [15]*

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 [7]*

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 [12]*

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 [5] [10] [12]*

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 [5] [59]*

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 [12], i.e, if the interruption is treated by a sequence of steps (>3), this sequence should be extracted to a separate scenario [5]*

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 [60]*

Indicator: 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
```

Indicator: 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
```

Indicator: 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 [12]

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 [12]*

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 [12]*

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 [12]*

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 [12];*

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 [12]*

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 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 [12][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 [12]*

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 [12]*

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 [12] or is the System [15] 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 [12] 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 [12] or is the System [15] 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 [62]*

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 [5] [10] [63]*

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 [12]*

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 [12]*

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 [12]*

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 [12]*

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 [12]*

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 [12]*

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 [55] (adapted from [62])*

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:
```

Indicator: 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
```

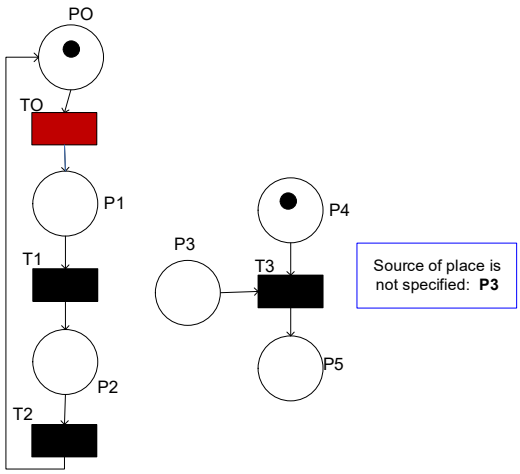
```
TITLE: Withdraw money
GOAL:
CONTEXT:
  PRE-CONDITION:
ACTOR:
RESOURCE:
EPISODES:
 1. …
 2. …
 3. …
ALTERNATES/EXCEPTIONS:
```

Feasibility

***Verification Heuristic**: Check that is possible to derive an initial system design from related scenarios [13]*

Indicator: Source or destination of events is not specified

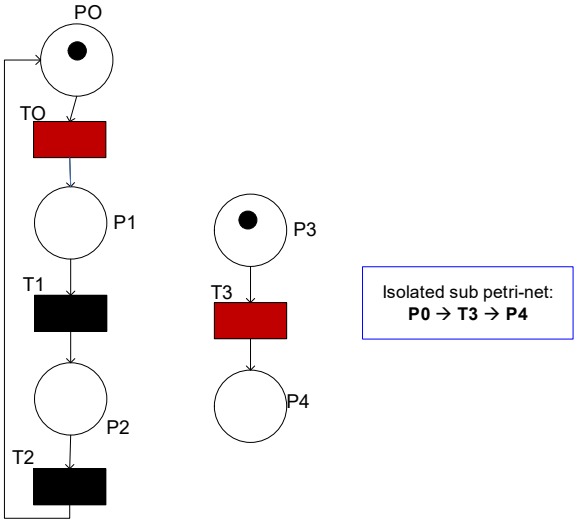
- **Detection Method**: Every *place* (transformed from epiodes and alternatives) in the *Petri-Net* must have at least one input arc (that is not a pre-condition) and an output arc (that is not a post-condition). If they are missing, the tokens in the Petri-Net cannot *pass correctly*.
- **Fix Recommendation**: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



***Verification Heuristic**: Check that initial system design does not contain isolated sub-systems [64]*

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**:



Persistence

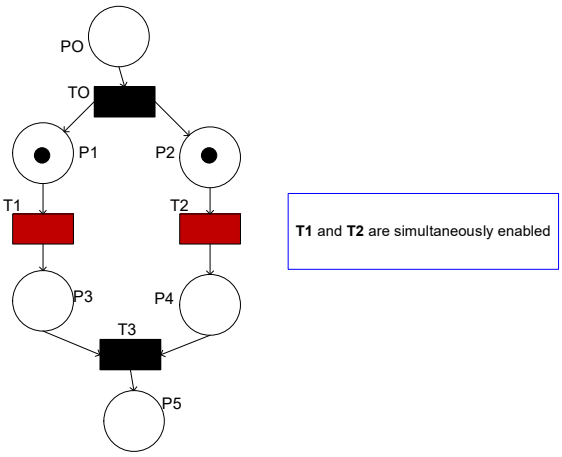
***Verification Heuristic**: Check the absence of non-deterministic execution paths, i.e., a set of episodes are simultaneously enabled by common pre-conditions, and only one of them may happen [35]*

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**:

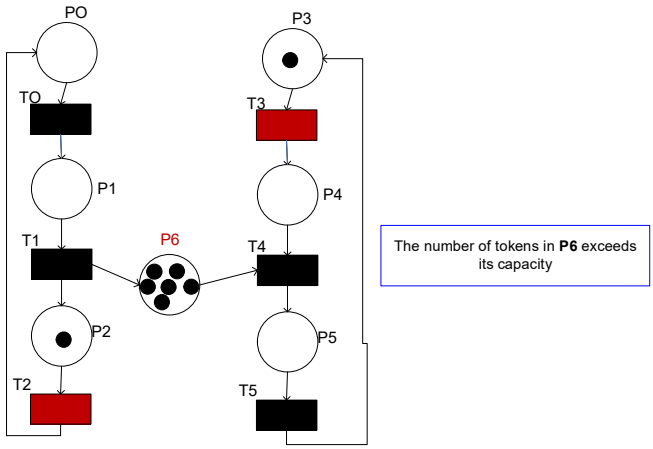


Boundedness

***Verification Heuristic**: Check the absence of overflow, i.e., the number of elements in some communication channel or resource exceeds a finite capacity [35]*

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 M_0. If the Petri-Net is not *bounded*, overflow exists in some place [42]. *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**:

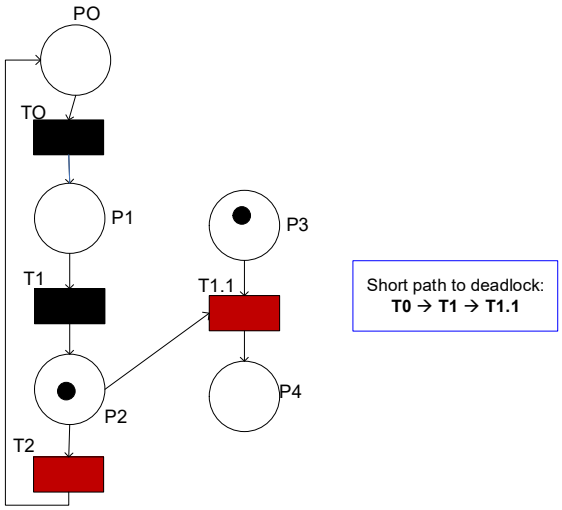


Liveness

***Verification Heuristic**: Check the absence of paths to deadlocks [35], e.g., it may occur when an alternative flow does not return to the main flow, does not finish the scenario, or is not treated/handled*

Indicator: Path to *deadlock*

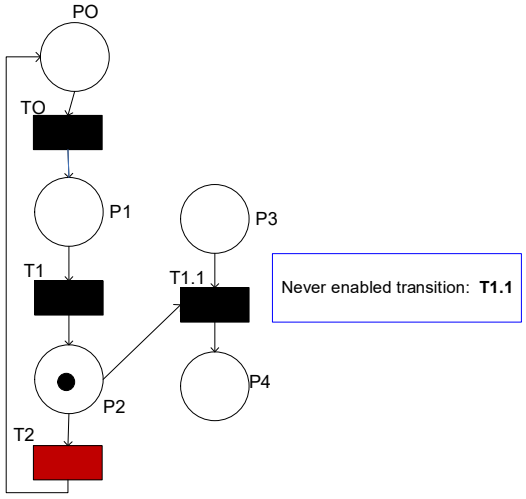
- **Detection Method**: Check whether the Petri-net contains a *short path* (consecutive transitions) that blocks the execution of the Petri-Net, i.e., the Petri-Net is not *deadlock free*. *Reachability analysis* can reveal short *paths* to *deadlock*.
- **Fix Recommendation**: Check whether there are 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 [42]*

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 [42].
- **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:**