Process Flexibility
Business Process Lifecycle

**Evaluation:**
- Process mining
- Analytics/Warehousing

**Design:**
- Business Process Identification & Modelling

**Analysis:**
- Validation
- Simulation
- Verification

**Enactment:**
- Operation
- Monitoring
- Maintenance

**Administration & Stakeholders**

**Configuration:**
- System selection
- Implementation
- Test & Deployment

*07/03/2018*
Business Process Flexibility

- **BP Flexibility** is the ability of a BP to address changes in the context or operating environment.
- Changes can be:
  - Foreseen
  - Unforeseen
- Addressing includes:
  - Varying or adapting those BPs that are affected by changes
  - Retaining those parts not affected
Flexibility Types

- 4 types or approaches:
  - By design: design-time specification of strategies to address foreseen changes
  - By deviation: small deviation from “as-is” BP to handle occasional unforeseen changes
  - By underspecification: similar to 1st but the addressing is handled at run-time (strategy not known or not generally applicable)
  - By change: actual process adaptation & evolution to handle both occasional and permanent unforeseen changes
BP Specification for Flexibility

- **Imperative/procedural** approach: precise definition of how BP tasks must be executed
  - Flexibility achieved by adding execution paths
- **Declarative** approach: focuses on what must be done and not how
  - By default, all execution paths are allowed
  - The more constraints are provided, the more execution paths are filtered
  - Constraints are relations between tasks
  - Both mandatory & optional constraints are allowed
  - Flexibility achieved by removing or weakening constraints
BP Specification for Flexibility

**Imperative approach**

\{[A,B]\}

**Declarative approach**

\{[A], [A,A], [A,B,A], [A,B,B], \ldots\}

A should precede B
Flexibility by Design

- Model alternative execution paths at design-time to anticipate for foreseen changes at runtime
- Each foreseen change maps to selecting one alternative path
- Realisation options (most common):
  - parallelism,
  - choice,
  - iteration,
  - Interleaving (execute tasks in any order but not concurrently),
  - multiple instances (of a task),
  - cancellation (of a task now or in the near future)
Flexibility by Design

- Workflow patterns cover all possible options
- Realisation options thoroughly studied at imperative approach
- Equally applicable to declarative approach through the use of less constructs/constraints
- Realisation options can be differently implemented
  - E.g., deferred vs. exclusive choice
- Drawbacks:
  - Model complexity increases
  - Impossible to model unlimited or unknown alternative cases
Flexibility by Deviation

- Temporally **deviate** from prescribed execution sequence to **accommodate changes** in operating environment at runtime
  - Swap task order between “register patient” and “perform triage” in a clinical emergency situation
- Actual process definition is **not altered** or the tasks included in it
- Just execution sequence of particular instance is modified
- Realisation options:
  - Vary actual tasks to be executed (from those enabled)
    - Imperative: **apply deviation operations**
    - Declarative: just **violate optional constraints**
Flexibility by Deviation

- Deviation operations:
  - **Undo task A**: shift control at moment before execution of A. Does not always imply that task actions are undone or reversed.
  - **Redo task A**: re-execute task A without shifting control. Small example: re-enter data that have been wrongly provided
  - **Skip task A**: pass control to the next task from A. Skipped task is not compensated. Quite useful in emergency situations with the skipping of non-critical tasks
  - **Create additional instance of A**: to run in parallel with process instances created on the moment of task instantiation. Flexibility can be controlled by limiting the number of concurrent task instances running in parallel. Example: do a separate reservation for a set of people in trip arrangement
Flexibility by Deviation

- Deviation operations:
  - **Invoke task A**: initiate task not enabled & executed in current execution. The thread of control is not altered. Example: an additional task, not foreseen, should be executed to check if provided data are fraudulent in a reviewing insurance claim process instance. Then, next task in order normally takes place.

- Deviation operations can be differently implemented

- Additional requirements for each operation could be provided
  - E.g., A can be undone only when A has been previously executed

- Should identify which operations have been performed in the execution trace. Different ways can be used to perform this
  - Undo operations can be logged either explicitly or by just removing affected task from execution trace
Flexibility by Deviation

Before skipping B
Trace: [A]

After skipping B
Trace: [A, “skip B”]
Flexibility by Deviation

- **Drawbacks:**
  - Who decides about performing which deviation operations & what knowledge does he/she have available for this?
  - Not all operations may have realizations
  - Some tasks might be difficult to undo their effects
  - Not suitable for cases where more drastic changes must occur at process structure & process replanning is actually needed
Flexibility by Undespecification

- When all execution paths cannot be defined in advance, it is required to dynamically add them as process fragments at runtime, thus executing incomplete process definitions.
- BP model is not modified at runtime but just missing information is filled in for undefined parts.
- More suitable for BPs where it is known beforehand which points need to be adjusted. Content for these points is not yet known. Also suitable when overall BP structure is fixed but different parts are designed and controlled by different work groups.
- Incomplete process definition contains underspecified placeholders. Their content is specified when executed.
Flexibility by Underspecification

- Two types of placeholder enactment exist:
  - Late binding: select one process fragment from the candidate ones to realize placeholder. Candidate list is fixed.
  - Late modelling: An existing process fragment can be selected or a new one can be specified. Subsumes former type.

- Process fragments are stored in a repository

- Two moments for realization can be exploited:
  - Before placeholder execution: either when process instance is commenced or before the placeholder is executed the first time
  - At placeholder execution
Flexibility by Underspecification

- Placeholders can be realized once or multiple times. Two realisation types exist:
  - Static realisation: initial placeholder realization is used for all subsequent placeholder executions
  - Dynamic realisation: placeholder is realized for each execution

- Drawbacks:
  - When should a new fragment must be created instead of using available, candidate ones?
  - Manual or automatic construction of new fragment?
  - Cannot perform adaptation for BP points not foreseen
Flexibility by Underspecification

Before realization

After realization

Process fragment
Flexibility by Change

- Events cannot always be addressed by small temporal deviations from prescribed process definition
- Process replanning must be performed
- Either some process instances are modified or even the process model (process evolution)
- One or more currently executed process instances must be migrated to new process definition
Flexibility by Change

- Variation points:
  - **Effect/Impact of change**: changes are performed at the instance or model level.
    - Momentary change (instance level)
    - Evolutionary change (process model level)
  - **Moment** of allowed change at instance or model level:
    - Entry time: changes performed only when instance is created. For evolutionary changes, only new instances are affected (old stay with previous model)
    - On-the-fly: changes performed at any point in process execution. Momentary changes map to customizing modified instance. Evolutionary changes are propagated to both new and old instances. Old instances must be migrated.
Flexibility by Change

• Variation points:
  ◦ Migration strategy: indicates the handling of instances impacted by evolutionary change
    • Backward recovery: instances are aborted
    • Forward recovery: instances are aborted, possibly compensated and restarted
    • Proceed: changes are ignored by old process instances
    • Transfer: instances are transferred to respective state in new process definition

• Drawback:
  ◦ Can always old instances be migrated?
  ◦ Which migration strategy to choose from?
  ◦ When should we move to an evolutionary change?
  ◦ More time consuming than performing small deviations
Flexibility by Change

Initial Model

A → B → C

Extend

A → B → D → C

Reduce

A → C

Relink

A → B ← C
Flexibility Spectrum

Design

Change

Deviation

Underspecification (Late binding)

Underspecification (Late modelling)

BP Definition Completeness

full

partial

design-time

runtime

Flexibility Configuration
## Flexibility Work Comparison

<table>
<thead>
<tr>
<th></th>
<th>ADEPT</th>
<th>YAWL</th>
<th>FLOWer</th>
<th>DECLARE</th>
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<tbody>
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<td>Choice</td>
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<td>Iteration</td>
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<td>Interleaving</td>
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<td>Multiple Instances</td>
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<td>Cancellation</td>
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<td>Undo</td>
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<td>Invoke task</td>
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<td>Violation of optional constraints</td>
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<tr>
<td>Late binding</td>
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<td>Late modelling</td>
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<td>Static, before placeholder</td>
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<td>Dynamic, before placeholder</td>
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<td>Static, at placeholder</td>
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<td>Dynamic, at placeholder</td>
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<tr>
<td>Momentary change</td>
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<td>Evolutionary change</td>
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<td>Entry time</td>
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<td>On-the-fly</td>
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<td>Forward recovery</td>
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<td>Backward recovery</td>
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<td>Proceed</td>
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<tr>
<td>Transfer</td>
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Challenges

- Support for all types of flexibility
- Accommodate for additional perspectives:
  - Organisational
  - Information
  - Application
- Use process mining to discover adaptation logic in system supporting deviation and/or change operations
Change Operations

- **Change patterns** on control-flow of a BP have been proposed
  - Focus on high-level BP adaptation
  - Are associated to **pre- & post-conditions** to guarantee **soundness** of resulting model
- **Change support features** were also proposed
  - Guarantee that changes are performed in a **correct and consistent** way, **change traceability** is enabled and **process changes facilitate** users
- Both can be used for **evaluating approaches in BP adaptation**
- Not all BP aspects have been covered (**data flow, resources**)

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### Change Patterns

- **Two main categories:**
  - **Adaptation patterns**: modify BP at model or instance level by applying **high-level operations** (e.g., activity insertion); can be applied at the whole BP schema. **Low-level operations** are not considered due to lack of abstraction & not guaranteeing model soundness.
  - **Patterns for changes in predefined regions**: allow participants to complete information for unspecified BP parts during runtime.

<table>
<thead>
<tr>
<th>Structural process change</th>
<th>Adaptation Pattern</th>
<th>Patterns in changes to predefined regions</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Anticipation of change</td>
<td>NO</td>
<td>YES</td>
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<tr>
<td>Change restricted to specific regions</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>

- Application area

<table>
<thead>
<tr>
<th>Application area</th>
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</thead>
<tbody>
<tr>
<td>Unanticipated exceptions, unforeseen situations</td>
</tr>
<tr>
<td>Address uncertainty by deferring decisions at runtime</td>
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</table>
Adaptation Patterns

- **Insert Process Fragment**
  - Design choice: where to embed the fragment
    - serial inclusion between succeeding activities by some approaches
    - others allow insertion of fragment between two activity sets that meet certain constraints (e.g., parallel or conditional insert)

- **Delete Process Fragment**
  - Straightforward (single design choice)
  - Different realizations:
    - Physically delete the fragment from the model
    - Replace fragment with silent/empty activity
    - Fragment embedded in conditional branch with condition equal to FALSE
Examples

Insert process fragment

If d>0

Delete process fragment
Adaptation Patterns

- **Move Process Fragment**
  - Design choice: where to embed fragment
  - Can be realized as a sequence of delete & insert
- **Replace Process Fragment**
  - Can be realized as a sequence of delete & insert
- **Swap Process Fragment**
  - Can be realized as above patterns or with two moves
- **Extract SubProcess**
  - Extract process fragment from one model and encapsulate in a separate sub-schema/model
  - Add hierarchy level to simplify schema or hide information from users
  - Implemented through graph aggregation techniques
Examples

Extract SubProcess
Adaptation Patterns

- **Inline SubProcess**
  - Opposite to Extract
  - Flattens hierarchy of process (to e.g. reduce levels)
- **Embed process fragment in a loop**
  - Could be realized through combining patterns for adding process fragment, inserting & deleting control dependency
- **Parallelize Process Fragments**
  - Parallelize fragments which were sequentially executed
  - Realized through either inserting & deleting control dependency or moving process fragment patterns
Examples

Inline SubProcess
Adaptation Patterns

- Embed process fragment in conditional branch
  - Can be realized via inserting process fragment and adding & deleting dependency control
- Add control dependency
  - A control edge is added to the model
  - Ensure that use of this pattern meets certain pre- & post-conditions
  - Can be associated to attributes (e.g., transition conditions)
  - Additional parameters might be needed for different types of controls (loop backs, synchronization of parallel activities)
Examples

Embed process fragment in conditional branch
Adaptation Patterns

- Remove Control Dependency
- Update Condition
  - Update transition conditions
  - Correctness of condition must be checked (e.g., all workflow relevant data elements are present in the process model)
- Copy Process Fragment
Examples

Remove control dependency

A + X B

A + X D

B + E

C + E

D

C + E

A + X B

A + X D

B + E

C + E

D
Patterns for Change in Predefined Regions

- Late Selection of Process Fragments
  - Realize a particular activity based on predefined rules or user decisions or a combination of the first two options

- Late Modelling of Process Fragments
  - Model selected parts of process model at runtime
  - Design choice for selecting process fragments from repository, from specific set or by newly defined activities or process fragments
  - Design choice for applying the same modelling constructs at build-time or by further considering more restrictions
  - Design choice for performing realization: at process instantiation, placeholder activity enablement or certain process state is reached
  - Design choice for working with an empty template or adapting an existing predefined template
Patterns for Change in Predefined Regions

- Late Composition of Process Fragments
  - **On-the-fly** composition of fragments from repository by also inserting appropriate control dependencies
  - **Interleaved routing** workflow pattern as a special case
  - **Exact decisions** about control flow are deferred at runtime
  - An activity might be executed **multiple times** (vs special case)
- Multi-instance Activity (also workflow pattern)
  - Decision about how many instances to create can rely on design-
    or run-time knowledge. Latter should be available before activity
    execution or when activity is enabled
Example – Late Modelling

Process Model Level

Empty Template

Process Instance Level

A → C → D → ?
F1. Version Control & Instance Migration

- No Version Control:
  - Manual copy of model generated to be modified
  - Current model modification:
    - Running instances are either withdrawn or
    - Remain associated to modified model
  - Can lead to inconsistent states, deadlocks or runtime errors

- Version Control:
  - Running instances remain associated to old model, new instances are mapped to new model
  - Alternative: controlled migration of selected instances to new model
  - Alternative: uncontrolled migration -> inconsistencies & errors
F2. Support for Instance-Specific Changes

- Unplanned changes at instance level are addressed through high-level patterns or low-level primitives.
- Uncertainty handled by keeping process parts unspecified until runtime.
- Instance changes are permanent or temporary (valid for a certain time period – e.g., current iteration of a loop).
F3. Correctness of Change

- To avoid runtime errors, different criteria are introduced for moving instances to new model to reassure compliance.
- Additionally, formal constraints depending of the respective formalism must be considered.
F4. Traceability & Analysis of Changes

- Change patterns or primitives must be entered into a change log.
- Change analysis & mining become easier when high-level information is stored → continuous process improvement.
- An execution log is enough for traceability concerning changes in particular process regions.
- Logs can be enriched with semantic information covering the reasons & context of changes.
F5. Access Control for Changes

- To avoid security issues wrt. the misuse of the change capabilities, authorization should be enabled:
  - Only particular users can change process model or instances
  - More coarse-grained granularity maps to authorizing single change patterns.
  - Authorizations can also depend on the object to change (e.g., object type – model vs instance or sets of process models attributed to particular process designers)
F6. Change Reuse

• Change reuse must be exploited to avoid spending time in finding the same solution to the same problem
• This can be supported by annotating changes with contextual information and storing them in logs
  ■ Contextual information maps to matching similar situations
    • User is presented only with solutions to those situations
  ■ For predefined region changes, historical cases must be presented to users & frequent, re-occurring pattern realizations must be stored as templates
**F7. Change Concurrency Control**

- Concurrent changes at instance level concerning process structure & state must be dealt with
  - Can lead to errors or inconsistencies (e.g. violating state constraints) if performed in an uncontrolled manner

- Ways to address:
  - Forbid concurrent changes (strict due to long-term locks required)
  - Allow concurrent changes on structure or state
    - Pessimistically or optimistically

- Could also need to address concurrent changes both at model & instance level
## Change Support Features

<table>
<thead>
<tr>
<th>Change Support Feature</th>
<th>Scope</th>
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</thead>
<tbody>
<tr>
<td>F4. Traceability &amp; Analysis</td>
<td>M+I</td>
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</table>

### No version control – old model is overwritten
- 1. Running instances cancelled
- 2. Running instances remain

### Version control
- 3. Co-existence of old/new instances, no instance migration
- 4. Uncontrolled migration of all instances
- 5. Controlled migration of compliant instances

1. Traceability of Changes
2. Annotation of Changes
3. Change Mining
4. Uncontrolled migration of all instances
5. Controlled migration of compliant instances

1. Changes are restricted to authorized users
2. Application of single change patterns is restricted
3. Authorizations depend on object to change
## Change Support Features

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<tr>
<td>F2. Support for Instance-Specific Changes</td>
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<td>F6. Change Reuse</td>
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<tr>
<td>F7. Change Concurrency Control</td>
<td>M+I</td>
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</tbody>
</table>

1. Unplanned changes
   a. Temporary
   b. Permanent
2. Preplanned changes
   a. Temporary
   b. Permanent

1. Uncontrolled concurrent changes
2. Concurrent changes prohibited
3. Concurrent changes of an instance’s structure & state
4. Concurrent Changes at instance & model level
Recommended Reading