# IF3140 – Sistem Basis Data
# Recovery System

SEMESTER I TAHUN AJARAN 2024/2025


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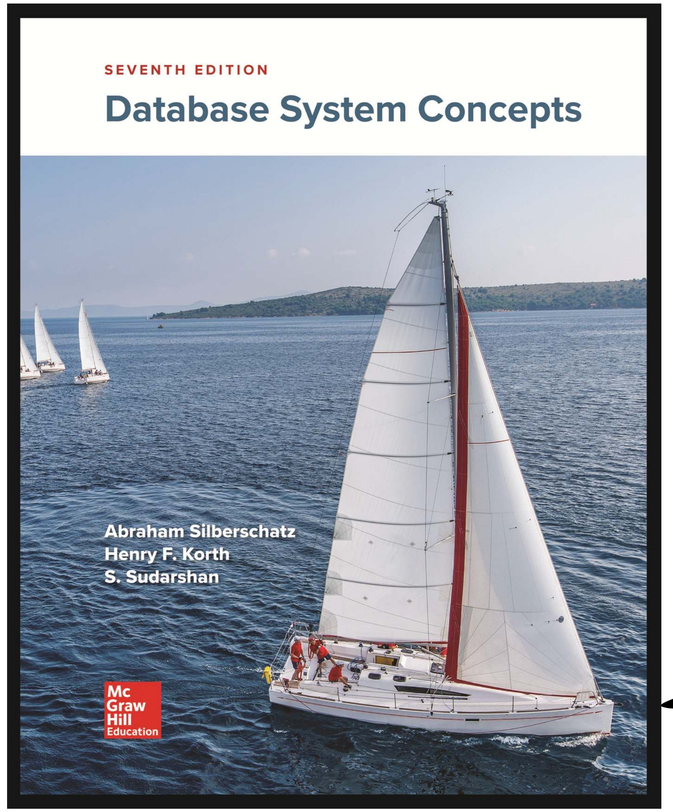


# *Sumber*

Silberschatz, Korth, Sudarshan: "Database System Concepts", 7th Edition

- Chapter 19: Recovery System

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# Objectives

Students are able to:

- Explain kinds of failures that can happen in a database system
- Explain stable storage and recovery task
- Explain when and why rollback is needed and how logging assures proper rollback
- Write a backup plan for a database


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# Outline

- Failure Classification
- Storage Structure
- Recovery and Atomicity
- Log-Based Recovery
- Shadow Paging
- Remote Backup Systems

# Failure Classification

**Transaction failure**

ada aspek logic dr transaksi yg membuat transaksi tidak bisa dilanjut

- **Logical errors**: transaction cannot complete due to some internal error condition
- **System errors**: the database system must terminate an active transaction due to an error condition (e.g., deadlock)

**System crash**

tdk akan menyebabkan secondary storage rusak, yg hilang hny data yg ada di dlm main memory

- **Fail-stop assumption**: non-volatile storage contents are assumed to not be corrupted by system crash
  - Database systems have numerous integrity checks to prevent corruption of disk data

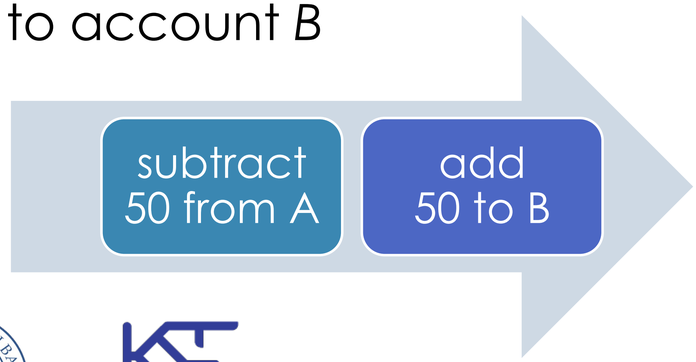
**Disk failure**

kerusakan pd secondary storage, jd ada bagian data yg hilang

- Destruction is assumed to be detectable: disk drives use checksums to detect failures

# Failure Example

Suppose transaction $T_i$ transfers \$50 from account *A* to account *B*




# Recovery Algorithm

**Actions taken during normal transaction processing**

to ensure enough information exists to recover from failures

**Actions taken after a failure**

to recover the database contents to a state that ensures atomicity, consistency and durability

# Storage Structure

- main memory
- cache memory

**Volatile storage:** → semua datanya hilang

- Does not survive system crashes

**Nonvolatile storage:** - disk - tape - Flash memory - non volatile RAM

- Survives system crashes
- But may still fail, losing data → kalau disk crash

**Stable storage:**

- A mythical form of storage that survives all failures
- Approximated by maintaining multiple copies on distinct nonvolatile media
  ↳ duplicate data dr bbrp non-volatile storage

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# Stable-Storage Implementation

- Maintain multiple copies of each block on separate disks
  - copies can be at remote sites to protect against disasters such as fire or flooding.
- Block transfer can result in
  - Successful completion
  - Partial failure
  - Total failure
- Protecting storage media from failure during data transfer
  - Write the information onto the first physical block. → tulis informasi ke copy yg pertama
  - Then, write the same information onto the second physical block. → tulis informasi ke bagian kedua (copyannya)
  - The output is completed only after the second write successfully completes.

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# Protecting Storage Media From Failure

## Find inconsistent blocks:

*Expensive solution*: Compare the two copies of every disk block

*Better solution*: Record in-progress disk writes on non-volatile storage

## Recovery:

If either copy is detected to have an error, overwrite it

If both have no error but are different, overwrite the second block

→ yg dipake primary block

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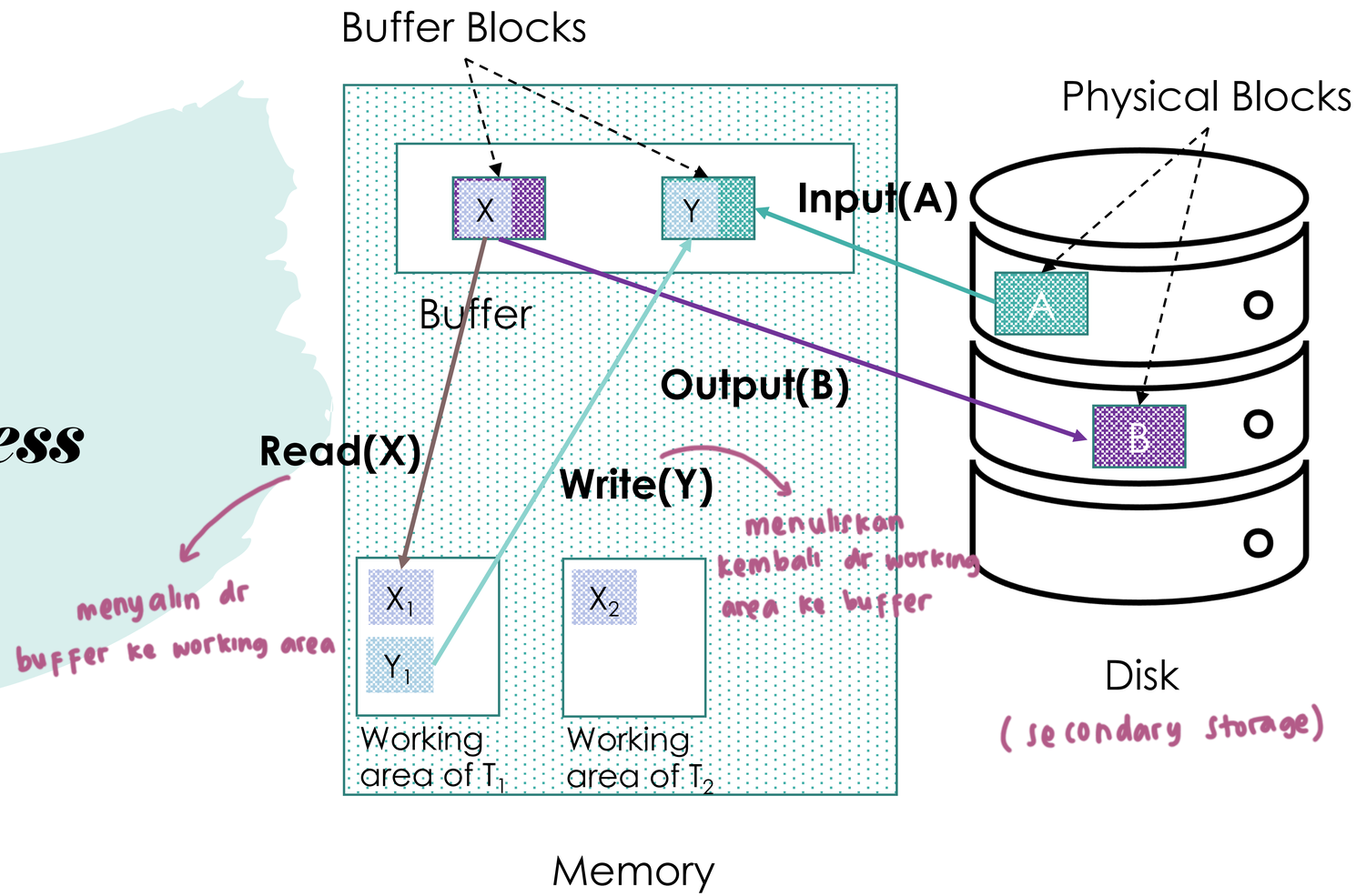
input & output sifatnya seamless

# Data Access

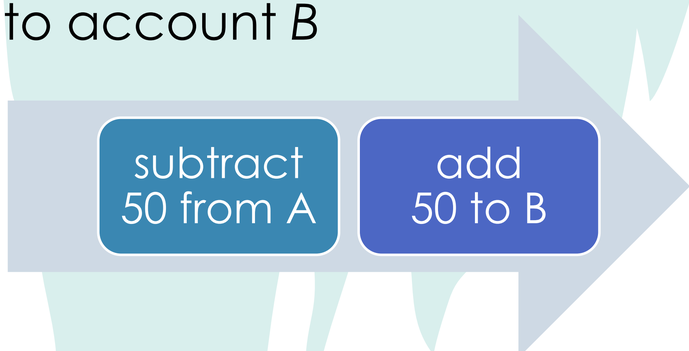


# *Recovery and Atomicity*

**LOG-BASED RECOVERY MECHANISMS** IN DETAIL

LESS USED ALTERNATIVE: **SHADOW-COPY** AND **SHADOW-PAGING**

Suppose transaction $T_i$ transfers \$50 from account *A* to account *B*

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# Log-Based Recovery

Transaction $T_{10}$ transfers \$50 from account *A* to account *B*

Value of A =1000 and B = 2000

mengandung catatan/informasi updating yg terjadi thd data yg terdapat di database

$<T_{10}$ start$>$

$< T_{10}$, A, 1000, 950$>$ substract 50 from A

$< T_{10}$, B, 2000, 2050$>$ add 50 to B

$< T_{10}$ commit$>$

| | |
|---|---|
| A **log** | • A sequence of **log records**<br>• The **log** is kept on stable storage |
| When transaction $T_i$ starts | • $<T_i$ **start**$>$ log record |
| *Before* $T_i$ executes **write**$(X)$ | • $<T_i, X, V_1, V_2>$ log record<br>$V_1$: old val X, $V_2$: new val X |
| When $T_i$ finishes | • $<T_i$ **commit**$>$ log record |

- **Immediate database modification**
  - semua write thdp item diaplikasikan langsung ke buffer block, bs aja dia keoutput ke secondary storage pdhl blm commit
- **Deferred database modification**
  - modifikasi basis data ditunda saat transaksi akan commit
  - semua perubahan pd item dilakukan di private area
  - yg kesimpen ke secondary storage hny updated data yg sdh commited

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# Immediate Database Modification

Update log record must be written *before* database item is written

Output of updated blocks:

- can take place at any time
- order can be different from the order in which they are written

Transaction Commit:

sudah tercatat kalau transaksi ini commit

- A transaction is said to have committed when its commit log record is output to stable storage
- Writes performed by a transaction may still be in the buffer when the transaction commits, and may be output later

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# Immediate Database Modification Example

$T_0$ : transfer 50 dr A ke B

$T_1$ : tarik dana 100 dr C

| Log | Write | Output |
|---|---|---|
| <$T_0$ **start**> | | |
| <$T_0$, A, 1000, 950> | | |
| <$T_0$, B, 2000, 2050> | | |
| | $A$ = 950<br>$B$ = 2050 | |
| <$T_0$ **commit**> | | |
| <$T_1$ **start**> | | |
| <$T_1$, C, 700, 600> | | |
| | $C$ = 600 | |
| | | $B_B$ , $B_C$ |
| <$T_1$ **commit**> | | |
| | | $B_A$ |

$B_C$ output before $T_1$ commits

$B_A$ output after $T_0$ commits

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# Deferred Database Modification

- The **deferred-modification** scheme performs updates to buffer/disk only at the time of transaction commit
  - Simplifies some aspects of recovery
  - But has overhead of storing local copy

# Concurrency Control and Recovery

All concurrent transactions share a single disk buffer and a single log

- A buffer block can have data items updated by one or more transactions

We assume strict two-phase commit

semua lock dihold sampai commit

- i.e., the updates of uncommitted transactions should not be visible to other transactions

tidak akan pernah cascading rollback

Log records of different transactions may be interspersed in the log

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# *Recovering from Failure*

Transaction $T_i$ needs to be **undone**

- Contains the record <$T_i$ **start**>,
- But does not contain either the record <$T_i$ **commit**> *or* <$T_i$ **abort**>.

Transaction $T_i$ needs to be **redone**

- Contains the records <$T_i$ **start**>
- And contains the record <$T_i$ **commit**> *or* <$T_i$ **abort**>

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# Recovering from Failure

**Transaction $T_i$ needs to be undone**

- Contains the record <$T_i$ **start**>,
- But does not contain either the record <$T_i$ **commit**> *or* <$T_i$ **abort**>.

**Transaction $T_i$ needs to be redone**

- Contains the records <$T_i$ **start**>
- And contains the record <$T_i$ **commit**> *or* <$T_i$ **abort**>

**undo**($T_i$) -- restores the value of all data items updated by $T_i$ to their old values, going backwards from the last log record for $T_i$

- Each time a data item X is restored to its old value V a special log record <$T_i$ , $X$, $V$> is written out.
- When undo of a transaction is complete, a log record <$T_i$ **abort**> is written out.

redo only log

ditulis pas rollback udah nemu <Ti start> ; transaksi selesai

**redo**($T_i$) -- sets the value of all data items updated by $T_i$ to the new values, going forward from the first log record for $T_i$

- No logging is done in this case

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# *Immediate DB Modification Recovery Example*

$<T_0$ start>
$<T_0$, A, 1000, 950>
$<T_0$, B, 2000, 2050>

Recovery action:
undo $T_0$
- Log $<T_0$, B, 2000>
- Restore B to 2000
- Log $<T_0$, A, 1000>
- Restore A to 1000
- Log $<T_0$ abort>

$<T_0$ start>
$<T_0$, A, 1000, 950>
$<T_0$, B, 2000, 2050>
$<T_0$ commit> redo
$<T_1$ start>
$<T_1$, C, 700, 600>

Recovery action:
redo $T_0$ and undo $T_1$

redo
- Set A to 950 (new value)
- Set B to 2050

undo
- Log $<T_1$, C, 700>
- Restore C to 700
- Log $<T_1$ abort>

$<T_0$ start>
$<T_0$, A, 1000, 950>
$<T_0$, B, 2000, 2050>
$<T_0$ commit> redo
$<T_1$ start>
$<T_1$, C, 700, 600>
$<T_1$ commit> redo

Recovery action:
redo $T_0$ and redo $T_1$
- Set A to 950
- Set B to 2050
- Set C to 600

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# Checkpoints

Streamline recovery procedure by periodically performing **checkpointing**

Output all log records currently residing in main memory onto stable storage.

Output all modified buffer blocks to the disk.

Write a log record < **checkpoint** *L*> onto stable storage where *L* is a list of all transactions active at the time of checkpoint.

All updates are stopped while doing checkpointing

semua perubahan sblm checkpoint uda tempdate ke secondary storage

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# Checkpoints – On Recovery

karena blm abort / commit

During recovery we need to consider only the most recent transaction $T_i$ that started before the checkpoint, and transactions that started after $T_i$.

- Scan backwards from end of log to find the most recent <**checkpoint** *L*> record
- Only transactions that are in *L* or started after the checkpoint need to be redone or undone
- Transactions that committed or aborted before the checkpoint already have all their updates output to stable storage.

Some earlier part of the log may be needed for undo operations

- Continue scanning backwards till a record <$T_i$ **start**> is found for every transaction $T_i$ in *L*.
- Parts of log prior to earliest <$T_i$ **start**> record above are not needed for recovery and can be erased whenever desired.

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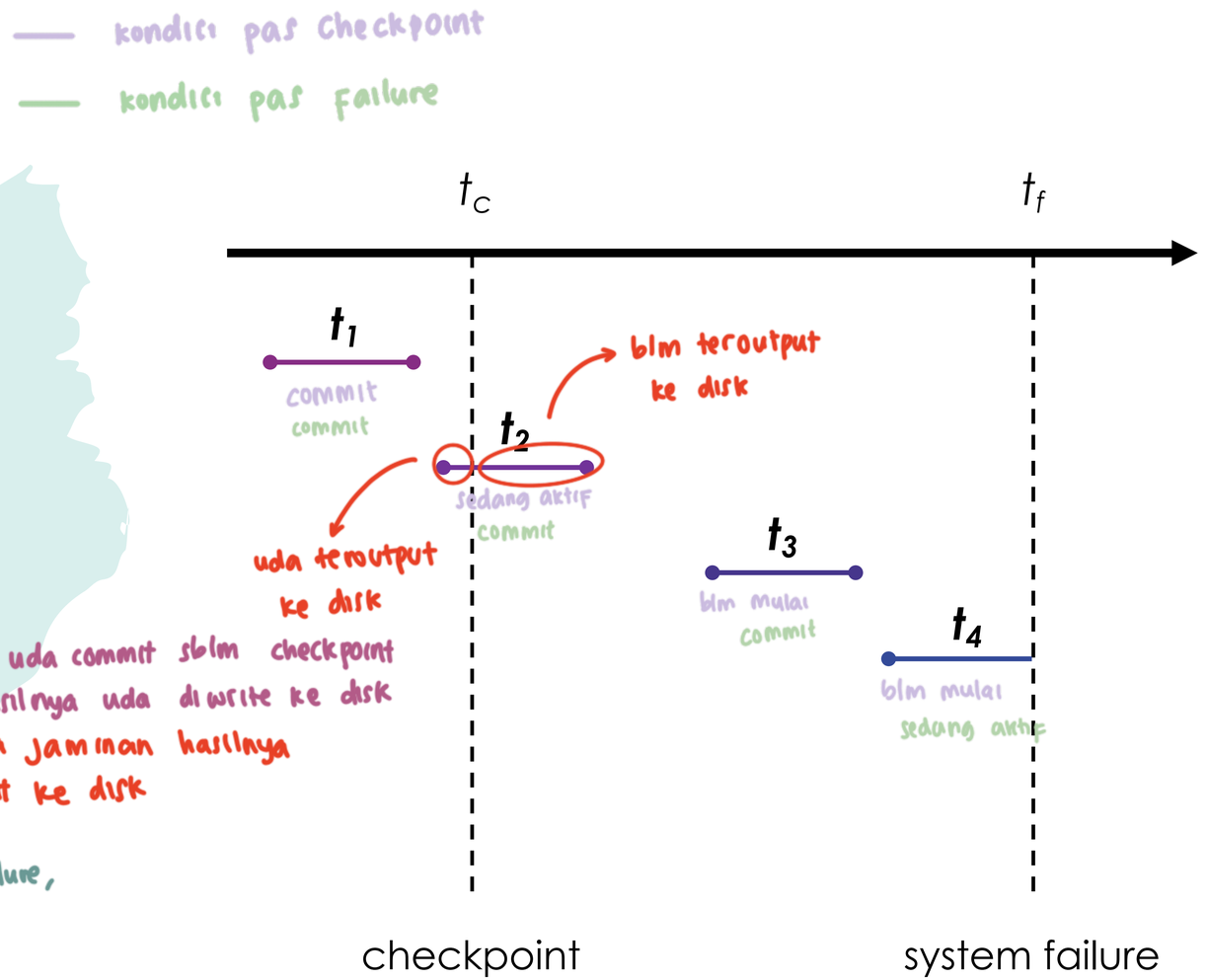
# Example of Checkpoints

$T_1$ can be ignored
$T_2$ and $T_3$ redone.
$T_4$ undone




krn $T_1$ uda commit sblm checkpoint shg hasilnya uda diwrite ke disk

tdk ada jaminan hasilnya teroutput ke disk

uda teroutput ke disk

blm teroutput ke disk

dia aktif saat failure, mk hrs diabort

# Recovery Algorithm

**So far:** we covered key concepts

**Now**: we present the components of the basic recovery algorithm

**Later**: we present extensions to allow more concurrency

# Recovery Algorithm

bukan krn kegagalan sistem

## Logging
(during normal operation)

- <$T_i$ **start**> at transaction start
- <$T_i$, $X_j$, $V_1$, $V_2$> for each update
- <$T_i$ **commit**> at transaction end

## Transaction rollback
(during normal operation)

- Scan log backwards from the end, and for each log record of $T_i$ of the form <$T_i$, $X_j$, $V_1$, $V_2$>
  - Perform the undo by writing $V_1$ to $X_j$, $X_j$ jadi $V_1$
  - Write a log record <$T_i$ , $X_j$, $V_1$>
    - such log records are called **compensation log records** = redo only log records
- Once the record <$T_i$ **start**> is found stop the scan and write the log record <$T_i$ **abort**>

# Recovery Algorithm – Recovery from Failure

**Redo phase**

- replay updates of **all** transactions, whether they committed, aborted, or are incomplete

**Undo phase**

- undo all incomplete transactions

# Recovery Algorithm – Recovery from Failure

**Redo phase**

**Undo phase**

Find last <**checkpoint** *L*> record, and set undo-list to *L*.

Scan forward from above <**checkpoint** *L*> record

- Whenever a record <$T_i$, $X_j$, $V_1$, $V_2$> or <$T_i$, $X_j$, $V_2$> is found, redo it by writing $V_2$ to $X_j$ Xj jd V2
- Whenever a log record <$T_i$ **start**> is found, add $T_i$ to undo-list
- Whenever a log record <$T_i$ **commit**> *or* <$T_i$ **abort**> is found, remove $T_i$ from undo-list

kalau uda selesai redo, isinya undo-list hanya transaksi yg incomplete

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# Recovery Algorithm – Recovery from Failure

Redo phase

Undo phase

Scan log backwards from end

Whenever a log record $<T_i, X_j, V_1, V_2>$ is found where $T_i$ is in undo-list → transaction rollback

- perform undo by writing $V_1$ to $X_j$.
- write a log record $<T_i, X_j, V_1>$

Whenever a log record $<T_i$ **start**$>$ is found where $T_i$ is in undo-list,

- Write a log record $<T_i$ **abort**$>$
- Remove $T_i$ from undo-list

Stop when undo-list is empty, i.e., $<T_i$ **start**$>$ has been found for every transaction in undo-list

After undo phase completes, normal transaction processing can commence

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# *Example of Recovery*