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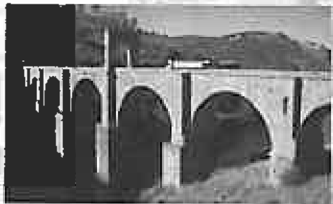

Roman arched bridge across river Tajo in Alcántara / Spain

Bridge LCC - New tool for life-cycle-costs for bridges

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International Scanning Tour

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1. Introduction
2. Calculation requirements
3. Basic calculation criteria
4. Life cycle model
5. Redemption model
6. Software LCCB (LZKB)

Summary

2

Holistic perception of cost trends of a construction over its whole expected service life

- Planning costs } start of life cycle
- Building costs } start of life cycle
- Cost of maintenance during service life cycle period
- Unexpected costs (optional)
- Cost of demolition at the end of life cycle

Life cycle costs

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Predominant investment
- after building phase
- during utilisation

Generally cost optimisation only for building phase

Only reliable cost available are production cost = construction cost
➔ hence reference base of further costing

Actual targets of optimisation

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Choice of system, quality of material and construction impact level of expense during utilisation phase decisively

Targets of strategic planning of structure at budgeting
- ➲ to aspire maximum of service life
- ➲ to aim for minimum of costs
- ➲ to meet function without restriction

Planning strategy

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Roman arched bridge across river Guadiana in Mérida / Spain

1	2	3	4	5	6

REQUIREMENTS
ON CALCULATION MODEL LCCB (LZKB)

6

Creation of a consistently applicable tool of calculation for life cycle cost of a **single** bridge

Possibilities of application:

- Comparison of bridges
- Comparison of versions
- Optimisation of planning
- Checking of costs
- **Redemption**
- Leasing of bridges

Program targets

- *Redemption guideline ÖBB 2006*
- Calculation of **redemption cost** by intervention on buildings, when initiator **is not** upholder **or** with change of upholder.
- Calculation of **maintenance costs** for old and new **building** is **basis** of calculation of **redemption costs.**

Redemption guideline

- **Adaption** of tabular values for special cases using <u>matching coefficients</u>
  - Variance of construction guidelines
  - **Exceeding of normative** defaults
  - Consideration of material technology
  - Experiments **with new** material
- ***Guideline RVS 15.01.11 – Quality criteria for planning bridges***
  - Adaptability for road **bridges**
  - Additional criteria

Matching coefficients

Factors for reduction **and** re-evaluation

- **Theoretical service life m [years]**
- **Annual maintenance costs p [%]**

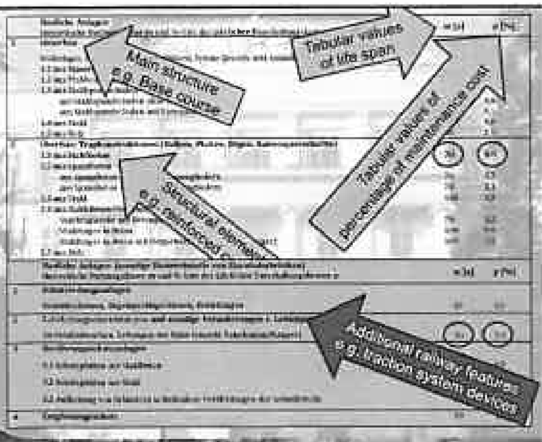
Application

- **New** material technology
- **Experimental** projects
- **Accreditation**
- **Assessment** of alternative offers

Groups of bridge construction elements

- **Structure** base (foundation)
- Structure
- **Level of utilization**
- **Equipment**

Extension according to guideline RVS 15.01.11



Tabular values – m [a] and p [%]

Negative impact on structure may require **adjustment of concrete quality.**

Less than 3,5 cm concrete covering is not permissible.

- Concrete covering → <u>tabular values</u> **for** $d_{concrete}$ = [illegible]
  $m_{concrete} = 70\,Years \quad p_{concrete} = 0{,}8\,\%$
  $k_m = 1{,}00 \qquad k_p = 1{,}00$
- **<u>Increase</u> of concrete covering:**
  → higher durability ⇒ positive impact
  → **more** concrete and reinforcement ⇒ negative impact
- Increase **> 3,5 cm – 6,0 cm → new** <u>correction factors</u>
  $k_m = 1{,}10 \; and \; k_p = 0{,}85 \; for \; d_{concrete} = 6{,}0\,cm$

Matching coefficient – durability of structure

Medieval Ponte Vecchio across river Arno in Florence / Italy

1 | 2 | 3 | 4 | 5 | 6

BASIC CALCULATION CRITERIA

- **Base** → redemption guideline **ÖBB**
- **Commitment of parameters** → safeguarding comparability of projects
  - **Fixed interest rate** of capitalisation → ***4 % p.a.***
  - **Fixed values** *m* and *p* **are dependent on structure and construction**
    - ➢ Theoretical **service** life (life span) ***m [a]***
    - ➢ Percentage **of annual** maintenance costs ***p [%]*** based **on building cost and** construction cost **respectively.**

- Calculation **based on** ***CONSTRUCTION COST*** ➔ **only reliable well-established** value
- **Construction cost K_B** contain:
  - **Production cost of** construction **units**
  - **Related miscellaneous** works
  - Clearance **of traffic, site** protection
  - Generation **of execution** documents/plans
  - **Difficulties for third** parties

- Non-recurring **administration cost** K_V (fixed **10%** of K_B) contain:
  - **Work in** advance, preliminary and construction draft, **awarding of contracts**
  - **Check of statics/plans, site management**
  - **Test and** measuring **devices, vehicles,** test loading
  - Administration, accountancy

- **Building cost K_{er}** contain:
  - Construction cost K_B
  - Non-recurring administration cost K_{VB} fixed with **10%** of K_B
- $K_{er} = K_B + K_{VB} = 1{,}10 * K_B$
- K_{er} → Calculation basis of percentage ***p*** for annual maintenance cost

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- **Dismantling cost K_A** contain:
  - ➢ **demolition cost in the course of** replacement K_{rA}
    → fixed with 20% of K_B
  - ➢ **administration cost of demolition** K_{VA}
    → fixed with **10% of** K_{rA} (2% of K_B)
- $K_A = K_{rA} + K_{VA} = 0{,}22 * K_B$

- **Annual maintenance cost K_{JU}**
  - Calculated as overall fixed percentage **p** of building cost K_{er} according to tabular value **p** [%] in redemption guideline
  - $K_{Ju} = p * K_{er} \rightarrow K_{er} = K_B + K_V = 1{,}10 * K_B$
    $K_{Ju} = p * 1{,}10 * K_B$
- Annual maintenance cost K_{Ju} are handled as **annuity**

Annual maintenance cost K_{JU} 19

Roman aqueduct Pont du Gard across river Gardon near Nimes / France

4

LIFE CYCLE MODEL

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- **Life cycle cost** are calculated for one single life span
- Calculation of LCC with only three input parameters ***p*** [%], ***m*** [a] and ***C_C*** [€]
- Calculation methods used
  - *Cash value method*
  - *Final value method*

Philosophy of life cycle cost calculation 21

$$LCC_B^{cv} = C_B = C_C * 1{,}10$$

$$LCC_M^{cv} = \frac{1}{q^m} * C_{aM} * \frac{q^m - 1}{q - 1} = \frac{1}{q^m} * C_C * 1{,}10 * p * \frac{q^m - 1}{q - 1}$$

$$LCC_D^{cv} = \frac{1}{q^m} * C_D = \frac{1}{q^m} * C_C * 0{,}22$$

$$\sum LCC = LCC_B^{cv} + LCC_M^{cv} + LCC_D^{cv}$$

$$LCC_B^{fv} = q^m * C_B = q^m * C_C * 1{,}10$$

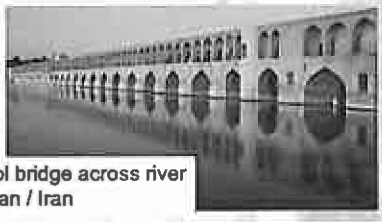
$$LCC_M^{fv} = C_{aM} * \frac{q^m - 1}{q - 1} = C_C * 1{,}10 * p * \frac{q^m - 1}{q - 1}$$

$$LCC_D^{fv} = C_D = C_C * 0{,}22$$

$$\sum LCC = LCC_B^{fv} + LCC_M^{fv} + LCC_D^{fv}$$

Building cost
$C_B = C_C + C_{AC} = C_C * 1.10$
Annual maintenance cost
$C_{aM} = C_B * p = C_C * 1.10 * p$
Dismantling cost
$C_D = C_D + C_{AD} = C_C * 0.22$
Life cycle cost $LCC^{cv}{}_{fv}$
Interest factor $q = 1 + z = 1.04$
Accumulation factor q^m
Discounting factor $1/q^m$
Calculation factor of annuity with payment in arrear $q^m - 1 / q - 1$
Percentage of annual maintenance cost according to building cost p [%]
Theoretical service life m [a]
Construction cost C_C [€]

Calculation of life cycle cost 22



Safavid Si-o-se Pol bridge across river Zayandeh in Isfahan / Iran

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REDEMPTION MODEL

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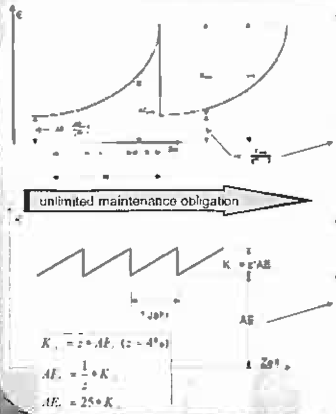
Base → unlimited maintenance obligation.

Cause → transfer of maintenance cost when change of upholder takes place.

Cost → compensation as redemption debit amount to or from next upholder.

Philosophy → when bridge is up for next replacement at end of service life, from capitalised maintenance cost after subtraction of replacement cost a certain amount of capital keeps remaining, which has to meet the liabilities of next replacement by return on capital employed during next following service life.

Philosophy of redemption cost calculation 24



- Maintenance cost of replacement E_{ern} consists of the replacement cost K_{ern} and the socket capital AB at point in time of next renewal: $E_{ern} = AB + K_{ern}$
- Annual maintenance cost K_{JU} are constant.
- Capitalised maintenance cost AE_U should yield interest income to cover ongoing annual maintenance cost K_{JU}

Maintenance cost of replacement

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SOFTWARE LZKB (LCCB)

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- Decision between software *Java* and *Excel*.
- Justification for Java:
  - Computer language independent of platform
  - Software library and pattern
  - Individual user interface and graphs
  - Software exempt from charges
  - Computer-oriented language
  - Source code needed for changes
  - Compatible with all systems software
  - Each kind of calculation possible
- Software package "basis" and "factors"
- Licence bound to hard disk of computer

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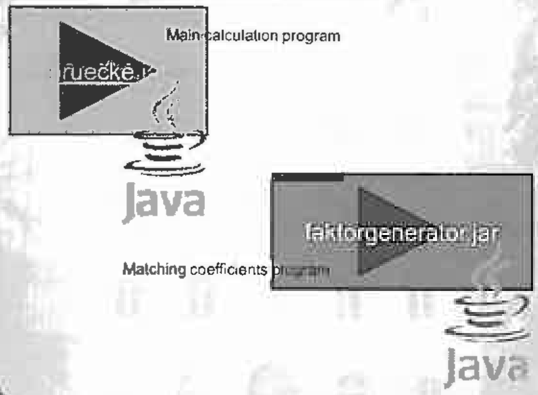

bm**v**it

Thank you for your attention

New software **LZKB (LCCB)**

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