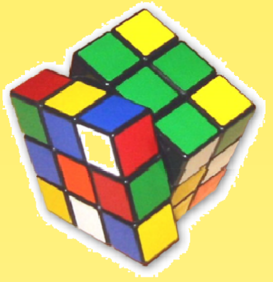
The Netherlands Research School for Transport, Infrastructure and Logistics
TRAIL

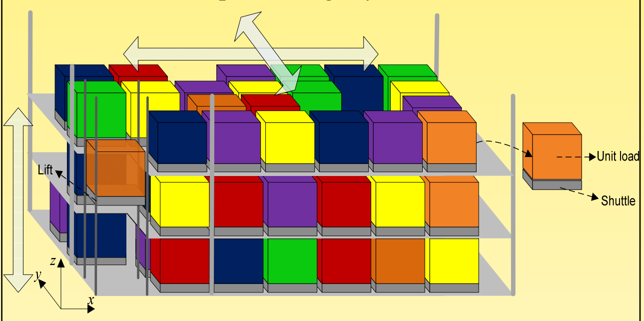
OPTIMAL CONFIGURATION OF A PUZZLE-BASED COMPACT STORAGE SYSTEM

Nima Zaerpour, Yugang Yu, Rene de Koster
Rotterdam School of Management, Erasmus University

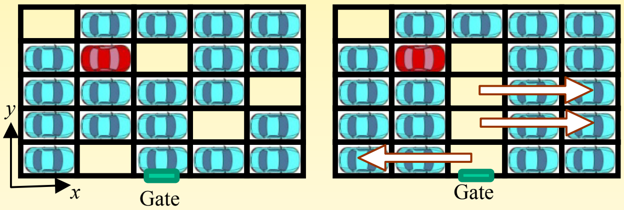


Introduction

• Puzzle-based compact storage system



• Work mechanism



A retrieval request — A solution

Objective

• **Research question**: How to optimize dimensions of a puzzle-based storage system, leading to the minimum response time in a random storage policy.

•**Assumptions**:

1.The system capacity is a known positive constant.

2. A random storage policy is assumed.

• ***Theorem***. *The minimum retrieval time of a random unit load stored at location (X, Y, Z), can be estimated by the following equation:*

$$RT(X, Y, Z) = \max\{X+Y, Z\} + Z, \qquad (1)$$

if the utilization of the system does not exceed $(V'-\max\{L,W\})/V'$, *where* V', *L, and W represent the capacity of the system in number of storage locations, the number of columns in each level, and the number of rows in each level, respectively.*

A random retrieval location can be denoted by (X, Y, Z) where X, Y and Z refer to coordinates in x-, y- and z-directions respectively.

Mathematical model

Min ERT, (2)

subject to:

$l \times w \times h = V$, (3)

decision variables: $l > 0$, $w > 0$, $h > 0$,

where l, w, and h (length, width, height of the system) are the decision variables. All the dimensions are expressed in time units. V represents the volume of the system in cubic time unit. Constraint (3) makes sure the given capacity is achieved.

Methodology

• The model is non-linear and mixed integer; however, we can optimally solve it by splitting it into several solvable sub-models

• In order to solve the model we have to derive ERT in Equation (2). The expected retrieval time for any puzzle-based system with a given capacity can be calculated as follows:

$$ERT = \int_{t=0}^{\max\{w+l,h\}+h} t f(t)\,dt \qquad (4)$$

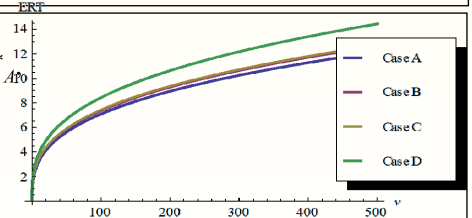
where, t represents the retrieval time for any retrieval location. $f(t)$ represents the probability density function of retrieval time t.

• Calculation of ERT can be done into four different complementary cases, each referring to a specific configuration of the system:

Case A: $h \le w$, case B: $w < h \le l$, case C: $l < h \le l+w$, case D: $l+w < h$.

Findings and conclusions

The following figure give ERT^*_A, ERT^*_B, ERT^*_C, and ERT^*_D as a function of V.



The solution of case A ($h \le w$) gives the minimal ERT for the Model.

$$h^*(V) = 0.874461 V^{1/3} \qquad (5)$$

$$l^*(V) = w^*(V) = 1.069374 V^{1/3} \qquad (6)$$

N. Zaerpour
Rotterdam School of Management, Erasmus University
T: +31-10-40 82 619; Nzaerpour@rsm.nl

TU Delft — Delft University of Technology

UNIVERSITY OF TWENTE.

Erasmus Universiteit Rotterdam

TU/e Technische Universiteit Eindhoven University of Technology

Radboud University Nijmegen