Does class-based storage reduce travel time?

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Warehouses

An automated warehouse

A manual warehouse

- Types: manual order picking, AS/RS…
- Functions: store and retrieve products

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Aisle details

I/O point (depot)

unit load / pallet with stored products

rack

S/R machine

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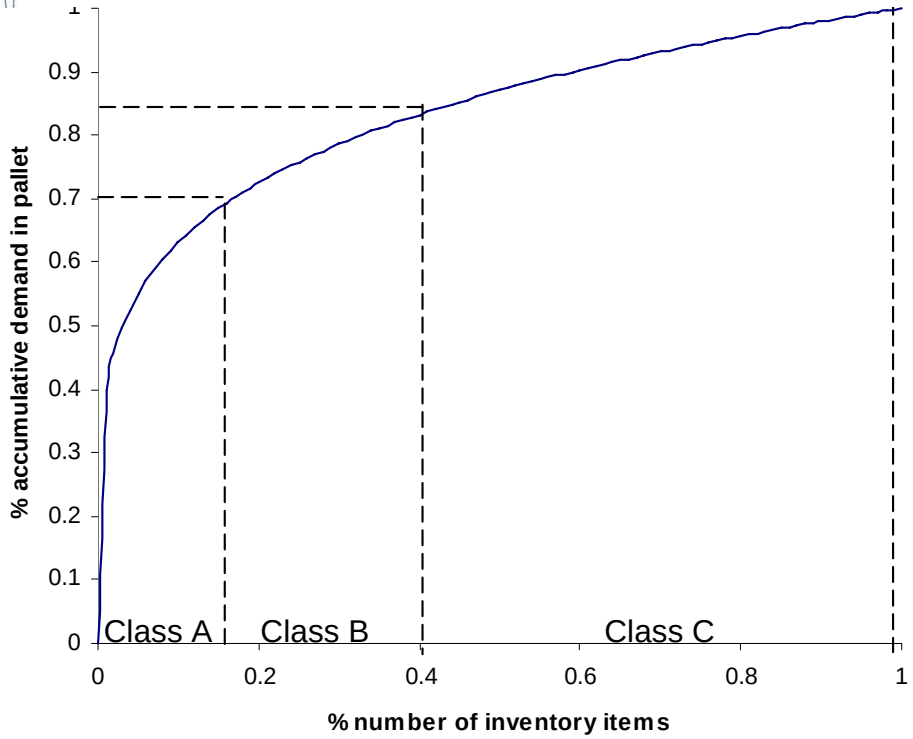
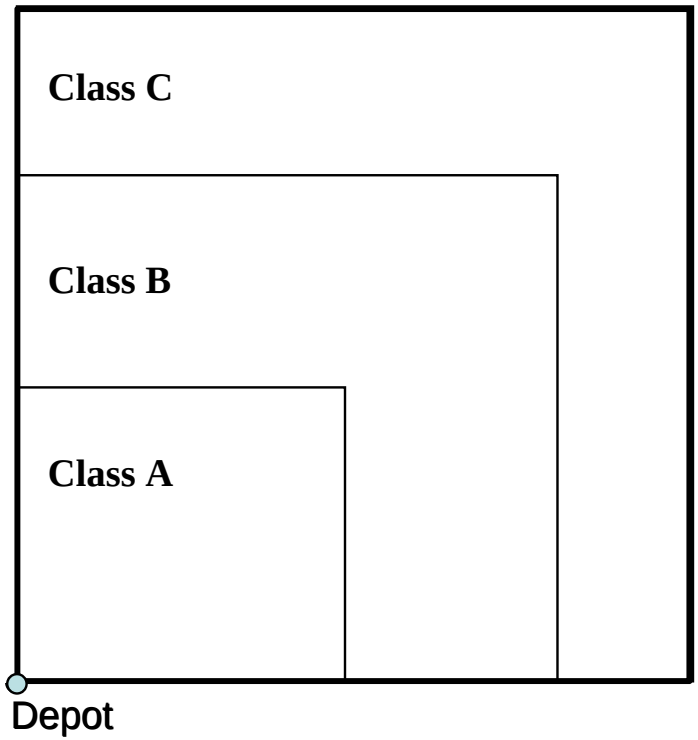
Storage policy



(a) ABC Curve

Side view of a rack



(b) ABC class-based storage areas

- Where to store products in a rack to minimize travel time?
- Use ABC demand curve!
  => ABC-class based storage policy

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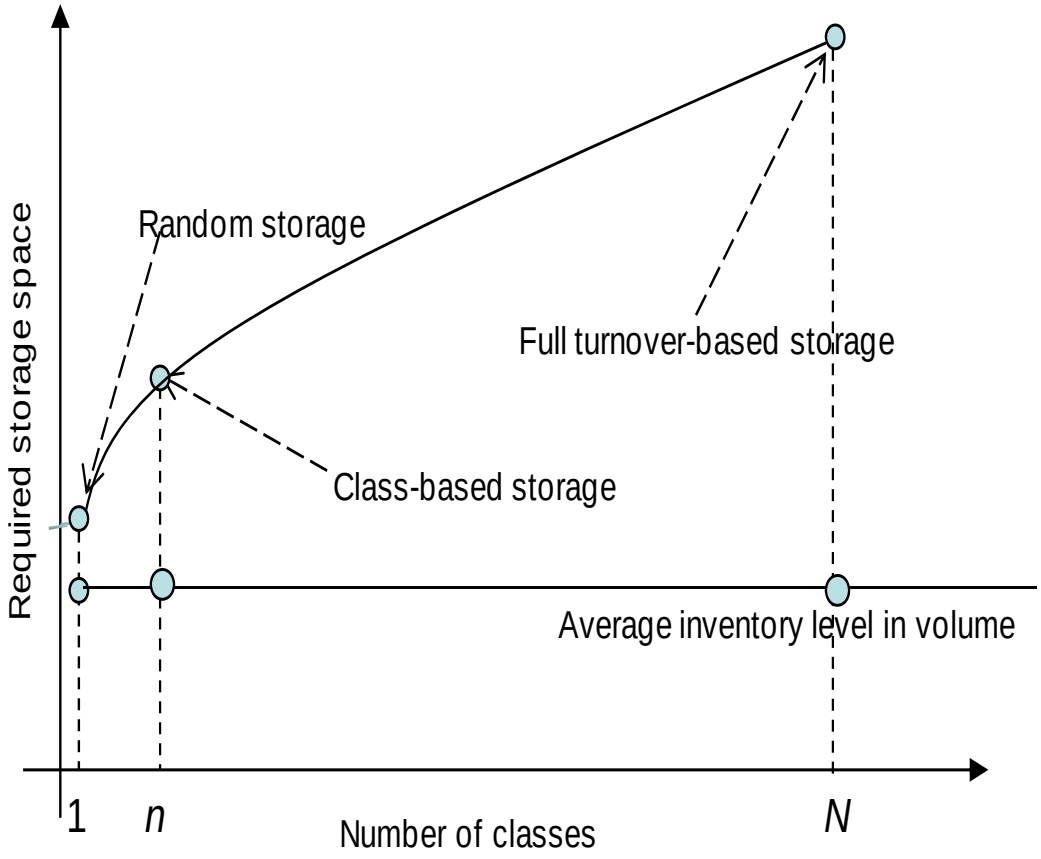
Required storage space as a function of *n*



- Required storage space is not constant
- It is a function of the number of classes and the replenishment policy

a trade-off exists

For class-based storage: more storage classes

- reduce travel time, because fast movers are closer to the depot
- increases travel time, because more storage classes require more space

Main question and objective

- Does an increase in the number of classes *n* reduce the travel time if the required storage space is considered?
- Research objective

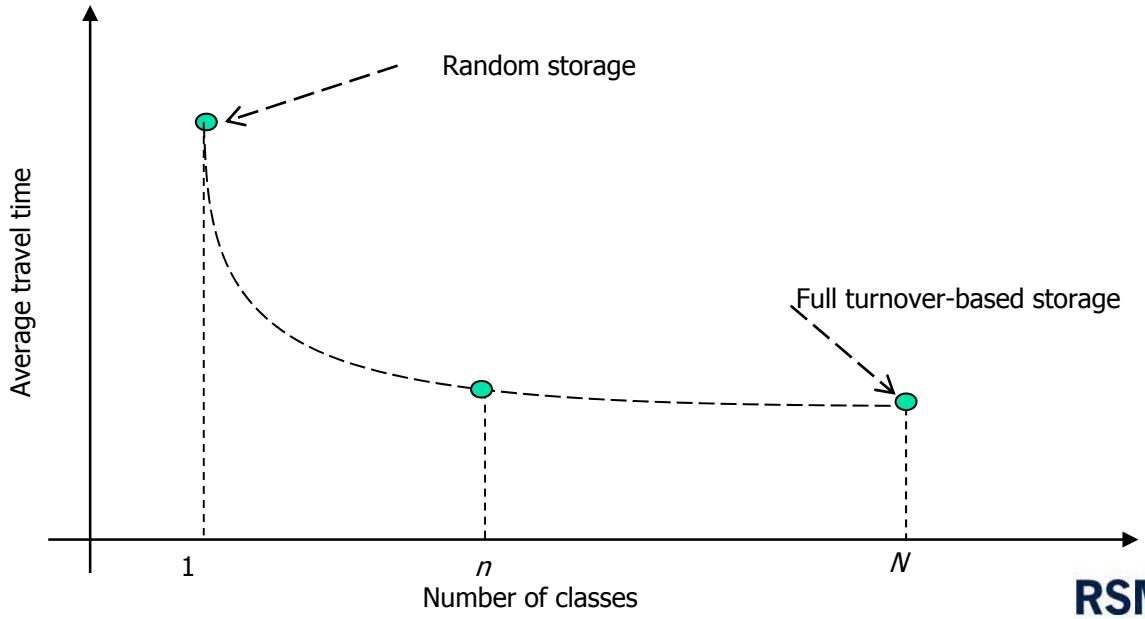
-find the new travel time model

(considering required storage space as a function of *n*.)

In literature

- The more classes, the shorter the travel time…

(e.g., Graves et al., 1977; Linn and Wysk, 1990, page 41; Eynan and Rosenblatt, 1994; Lee and Schaefer, 1997, page 16; Wen et al., 2001; Lee and Elsayed, 2005, page 1786; De Koster et al., 2007; Gu et al., 2007).



N : number of product types; n: number of classes

In literature

- Some researchers notice the impact of # storage classes on required storage space (Graves et al., 1977; ..),
- However the joint effects in this trade-off are not well-researched.

In practice

- 2 to 4 classes are commonly used in practice.
- Practical experience does not match the above theory very well.

How to find travel time $T(n)$?

1. find required storage space $A_k \; k = 1, \ldots, n$

2. develop travel time $T(n)$

Travel time model

- Assumptions:
- an automated storage/retrieval system (AS/RS)
- storage rack is "square" in time.
- depot is at the lower-left side of the storage rack.
- single-command mode .
- pickup/deposit time is ignored.
- turnover frequency of each product type is known and constant.
- simple EOQ-replenishment model
- ABC demand curve.

Step 1. Required storage space (A_k)

Possible influencing factors?

-# classes (n)

-# product types (N_k) per class

-shape (s) of the ABC curve

-parameters in EOQ-replenishment models (e.g., K=the ratio of order cost and holding cost)

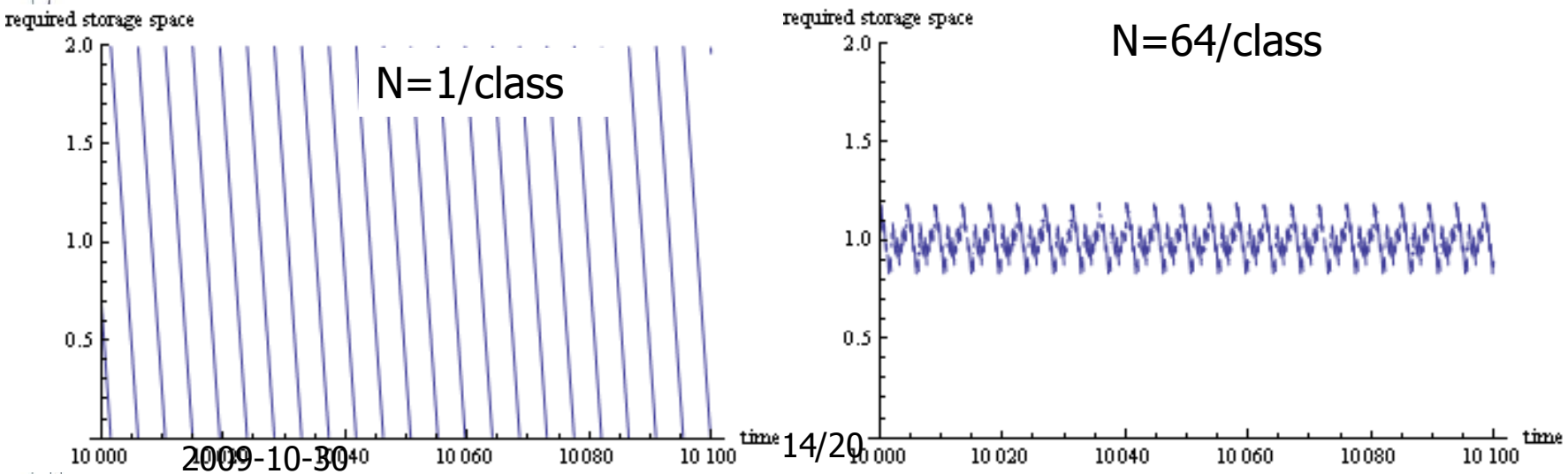
-initial inventory levels of products

Required storage space

1: Monte Carlo simulation of storages within 1 class

2: Find empirical relation between storage space and *s, K, N*

Let K=10, s=1….



Step 2. Travel time model

$\Lambda(k)$ – the turnover of products in class k

t_k – average of travel time of products in class k

i_k – *percentile of the last product in class k in all N products*

$$\min T_n = \frac{\sum_{k=1}^{n} t_k \Lambda(k)}{\sum_{k=1}^{n} \Lambda(k)}$$

Subject to:

$$A_k = A_k(i_{k-1}, i_k, N), \quad k = 1,..n$$

$$N(i_k - i_{k-1}) \geq 1 \qquad k = 1,...,n$$

$$i_n = 1 \text{ and } i_0 = 0$$

Decision variables:

$$i_k, \; k = 1,...,n-1 \text{ and } n$$

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Algorithm

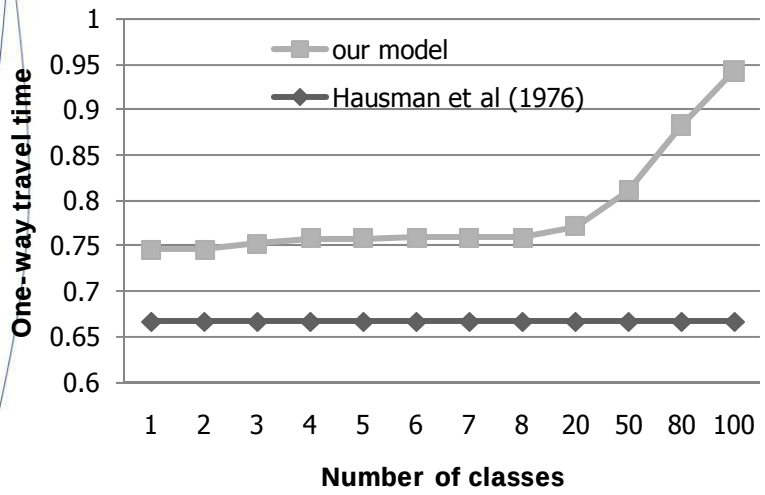
1: for n=1,…,N

2: solve the model

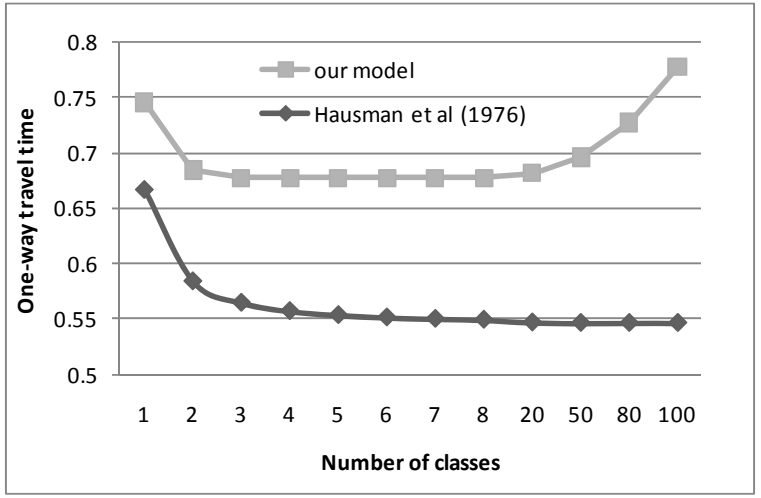
3: output the minimum T(n) and the optimal boundary of each class

4: select the optimal n

Results: travel time $T(n)$



Case 1: for 20%/20% demand curve

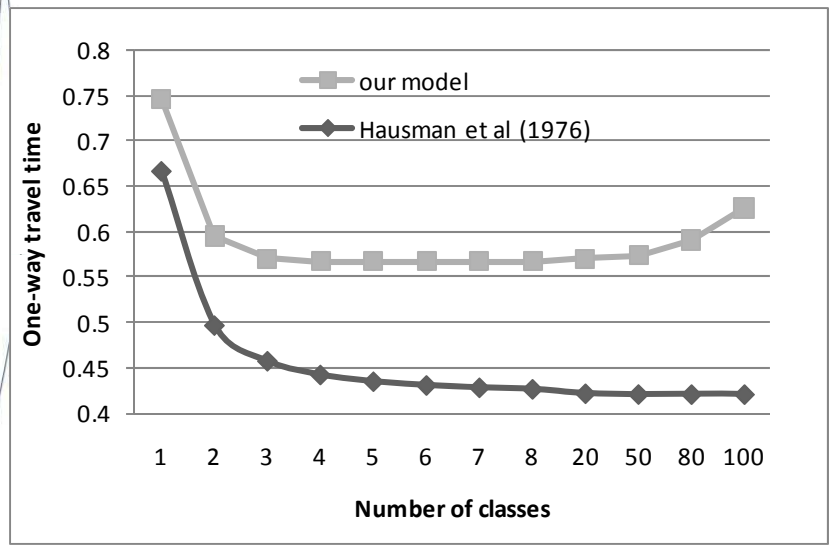


Case 2: for 20%/50% demand curve

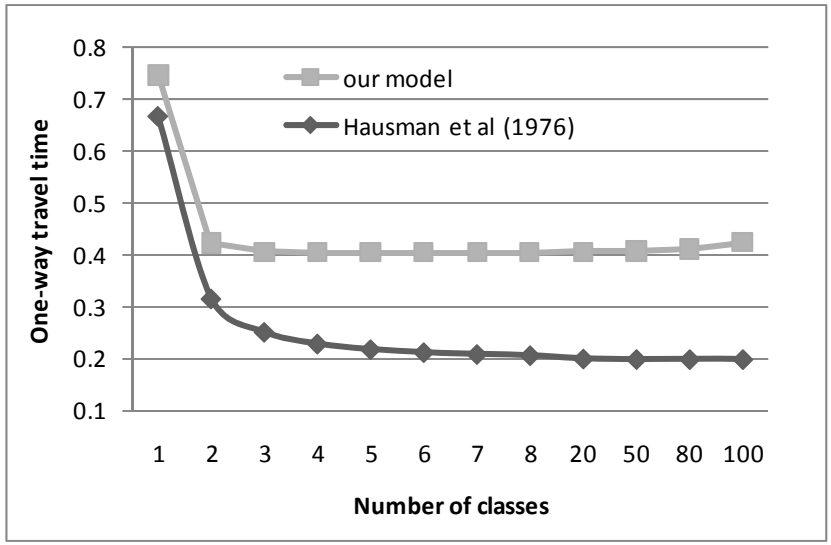
Case 1: system performance deteriorates when the number of classes increases

Case 2: 3-class based storage is the optimal!!

Results: travel time $T(n)$



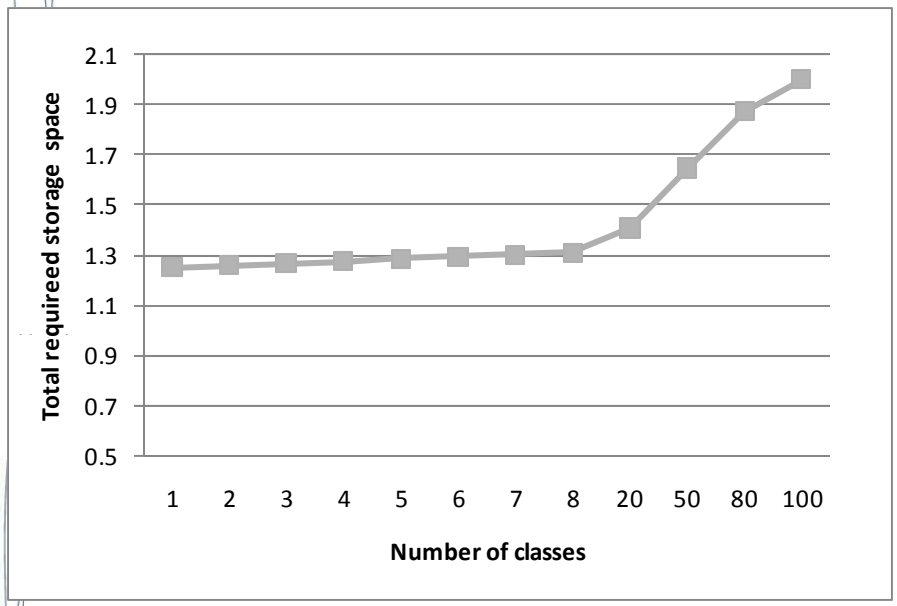
Case 3: for 20%/70% demand curve



Case 4: for 20%/90% demand curve

-Cases 3&4: 4 classes are the optimal!
-3 classes normally provides the (near-) shortest travel time
-the relative error of the previous research is large, especially when *n* is large!!

Results: required storage space



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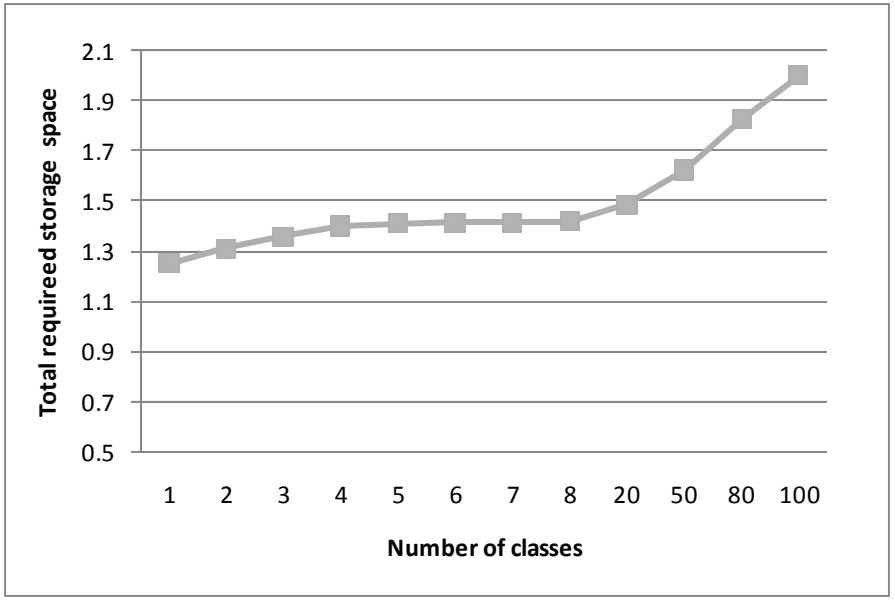

Case 4: for 20%/90% demand curve

-The required storage space is an increasing function of *n*. The space is between 1 to 2.

-With the increase in *n*,
when n is small, the increasing rate of case 1 is relatively high, but when n is large, the increasing rate of case 4 is relatively high.

Conclusion

- We theoretically show that 2- to 4-class based storage is optimal for common ABC demand curves: 20%/50%-20%/90%.
- We provide an explanation as to why n ($n \geq 4$) classes are rarely implemented in practice: poor performance.