On selectivity and accessibility

*An earlier article in CARGO SYSTEMS on a means of measuring the trade-off between storage density and accessibility of different kinds of container handling plant has prompted this reply**

The long evolution process of the various container yard systems, has left four basic survivors, namely chassis, frontlifters, straddle carriers and rubber tyred or rail-mounted yard cranes. A recent article in CARGO SYSTEMS ("Selection process," March 1991, pp35-7) reviewed a methodology proposed by Itsuro Watanabe for comparing RTGs and straddles based on a so-called selectivity index (SI).

However, the SI would appear to be based on arbitrary assumptions. It has no easy interpretation, is too complex mathematically and, as a result, could be said to muddle the picture instead of clarifying it. We would like to suggest an alternative and much simpler selectivity (or accessibility) index. Despite its inherent simplicity, we feel it serves better the purpose of cross-system comparisons.

A question of access

Firstly, a quick clarification of some basic concepts is warranted. "Selectivity" seems to be the wrong term. Selectivity, or the ability to select a required box, is mainly a function of operating policy which determines which box is required. It is not specifically related to the physical configuration of the yard stacks. For example, if export boxes are block-stowed by destination port and by weight, then, for the purpose of vessel loading, the stack provides perfect selectivity of required boxes, regardless of the stack configuration. An alternative term, accessibility, better conveys the concept of being physically able to access boxes.

The effectiveness of yard storage relates primarily to the convenience of accessing boxes with a minimum movement of machines, especially the avoidance of re-handling (shifting or shuffling) of other boxes which block this access. For example, all the boxes in a wheeled yard (assuming the chassis are parked either side of a central aisle and are not block-parked) or at the top tier of a stack (ground) system can be directly accessed. These boxes have a perfect *accessibility* (editor's note: Watanabe gives such containers a maximum SI of 1, or unity).

In order for an index to be useful, it should accurately reflect an underlying association in the mind of the user. It should be expressed in physical units or, at least, directly relate to them. This is the case in most port indices which measure yard productivity (TEU/yard acre) or handling productivity (Vessel moves/gang hour). Even if an index is expressed as a ratio or percentage, the base or the target value to which it relates is quite clear (berth utilisation).

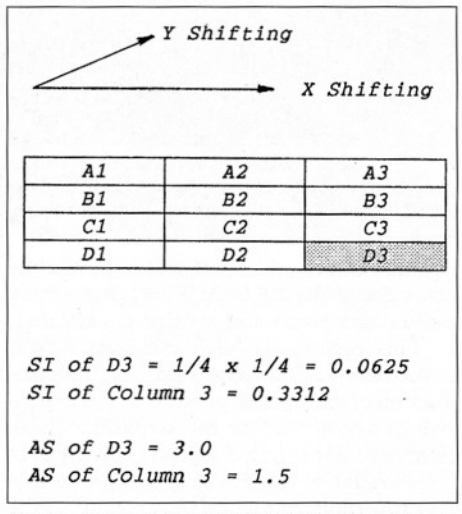

Fig 1 - accessibility and "selectivity" compared

Density or convenience

Obviously, storage density and handling convenience are the two main counteracting factors in any yard system. An index which assesses storage effectiveness should relate directly to this density versus handling convenience trade-off. The SI does not directly relate to this relationship but only focusses on the convenience side.

The SI is based on an arbitrary scoring system, that is two two types of shifting and a multiplication methodology, viz:

- *X* shiftings that do not involve long travel
- *Y* shiftings that do involve long travel.

Each *X* and *Y* shifting is accorded a different selectivity multipier based on the "difficulty" involved in the shiftings. The scores themselves, however, seem arbitrary. For example, accessing box *C2* in Fig. 1 requires an *X* and a *Y* shifting which are worth 1/2 and 1/3 multipliers respectively using the SI methodology. But does *Y* shifting really reduce the box selectivity by 17 per cent compared to the *X* shifting (SI decreases from 50 per cent to 33 per cent)? Why multiply the scores? Does box *D3* with a score of 1/16 involve the equivalent of 16 shiftings?

Height	Density	Total shiftings	Average shiftings
1	1	0	0
2	2	1	0.5
3	3	3	1
4	4	6	1.5
5	5	10	2
h	*h*	*1/2 h (h-1)*	*1/2 h (h-1)*

Indexing and simulation

Instead of trying to capture several characteristics in one index, it would be better to rely on a detailed operational simulation. This can better depict the impact of different operating policies including the stochastic nature embedded in any yard system. Only a simulation can encompass the intricate relationship between the many policy and physical variables.

It hardly needs saying that shifting is directly related to the operational policy. For example, in many terminals which operate 1 over 3 RTGs, the export boxes are blocked with an average stack height close to 4, while the import stacking height averages 2.5 to minimise shifting. The "length" of a shifting is a function of the availability of a close-by open space, which can be best described by probabilistic modelling.

Having regard to all this, we suggest an alternative index to measure accessibility of various yard systems based on the idea of avoiding shifting (re-handling). Yard moves can be divided into productive moves, when the box is directly loaded/unloaded to a vehicle, and unproductive moves, involving the preliminary "digging" required to uncover a box which lies underneath other boxes, called shifting (or "shuffling").

In the most convenient situation, when each box has its own direct access, no shifting is required, so the average number of shiftings per box is simply zero. Stacking 2-high requires no shifting for the upper box and 1 for the lower one, or an average of 0.5. 3-high results in a total of 3 shiftings or an average of 1; 4-high involves a total of 6 shiftings or an average of 1.5, and so on. Note that the simplicity is a result of our rule against differentiating various types of shiftings (unlike the SI).

Hence, our "accessibility index" is simply the average number of shiftings per handled box (AS). Simple algebra proves this point (see table).

TS = Total number of shiftings per stack
$= 1/2\ h\ (h-1)$

AS = Average number of shiftings per box handled
$= 1/2\ (h-1)$

h = storage height (h > 1).

A preliminary assessment of the inherent trade-off between density and accessibility is, in essence, the overall objective of the proposed indexing system. The definition of accessibility index helps this assessment.

An increase in stacking height (density)

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of one tier will result in:
- Increase in the number of shiftings (TS) by h
- Increase in the average number of shiftings (AS) by 0.5.

Alternatively, in relative (percentage) terms, an increase in density by 1/h percent will result in an increase in AS by 1/(h-1) percent. For example, a transition from a 1 over 4 configuration (h = 4) to 1 over 5 (h = 5) will result in a d ensity gain of 25 per cent (from 4 to 5), to be set against an AS increase of 33 per cent (from 1.5 to 2.0). This trade-off is quite transparent to any operator. Storing 25 per cent more boxes at the yard will increase the "price" of handling them as measured by unproductive moves by 33 per cent.

Feasibility assessment

The simpler definition of accessibility can also be used to conduct a "quick and ready" feasibility assessment for increasing/decreasing storage height. In the above example, an operator considering moving from a 1 over 4 to 1 over 5 configuration, regardless of the yard machine, has to figure out the average cost of a shifting and compare it to the value of the land saved due to the higher storage density.

For example, if the annual turnover ratio per slot is 50 (dwell time of 7 days) and the average cost of a shifting is, say, $10, the increase in cost per move will be roughly $3.3 (33 per cent) or the annual equivalent of $165 (3.3 x 50). Only if the annual space lease cost equals $660 per slot or higher (25 per cent of $660 is $165), will the operator be better off increasing the storage density.

Space costs/TEU should be measured against the cost of extra shuffling

This calculation is very preliminary, obviously, and is intended only to provide an order of magnitude guide. The most problematic assumption in the calculation is that of perfect randomality in access to boxes. For a better indication of the feasibility of this venture there is, obviously, a need to better define the machine cost, stacking policy, access probabilities for each box, desirable service levels (acceptable waiting times) and so on.

The burden of this article is that no selectivity or accessibility index can be a substitute for a detailed operational simulation, to obtain a proper evaluation of different yard systems. An indexing system can provide only a very rough and preliminary guide and it should be simple to calculate and easy to comprehend. We believe our proposals meet these essential criteria. □