Slot Auctions Can Help Airports Reduce Congestion and Airlines Reach Environmental Targets

by Professor Richard Steinberg

Just before the onset of the pandemic, the ACI World Annual General Assembly announced "the beginning of a new era for slot allocation at airports".

The ACI had updated the Worldwide Airport Slot Guidelines and not before time – more than 200 airports already required slot coordination due to insufficient capacity. Unfortunately, it is clear that these new Worldwide Airport Slot Guidelines will not adequately address the capacity issue. After Covid ends and air travel returns to normal, the slot capacity problem will be back with a vengeance. By the 2030s, global air traffic is predicted to double from pre-pandemic levels.

How should the problem of insufficient slot capacity be addressed? The solution is clear: allow airlines to bid for airport slots.

Virtually all large airports in Europe currently deal with congestion by allocating runway slots to airlines twice a year. The problem is that the way in which they allocate these slots is very inefficient. Under current regulations, if a runway slot is used by an airline 80% of the time over a season, then it has use of the slot for the following season, and in this way the airline can retain the slot in perpetuity.

This rule has led to some wasteful behaviour. Airlines have been known to organise 'ghost flights', i.e., flights with empty planes, so as not to lose valuable runway slots, and to prevent entry by potential competitors.

A market-based approach, in which airlines bid for slots, would be a far more efficient procedure. Economic theory and historical data strongly indicate that slot auctions would result in increased airport capacity, a reduction in flight delays, and decreased flight costs to both airlines and passengers. In particular, with the removal of incentives for airlines to schedule empty aircraft, ghost flights would become phantoms of the past.

There would be a huge additional advantage to slot auctions. By making more efficient use of airport slots, including eliminating the incentive for ghost flights, slot auctions would reduce each airline's overall carbon emissions, moving them closer to environmental targets set by the ESG rating agency Vigeo Eiris. And this would be accomplished while simultaneously reducing airline operating costs.

FIGURE 1 - SIX AIRPORT SLOTS AND FOUR AIRLINES

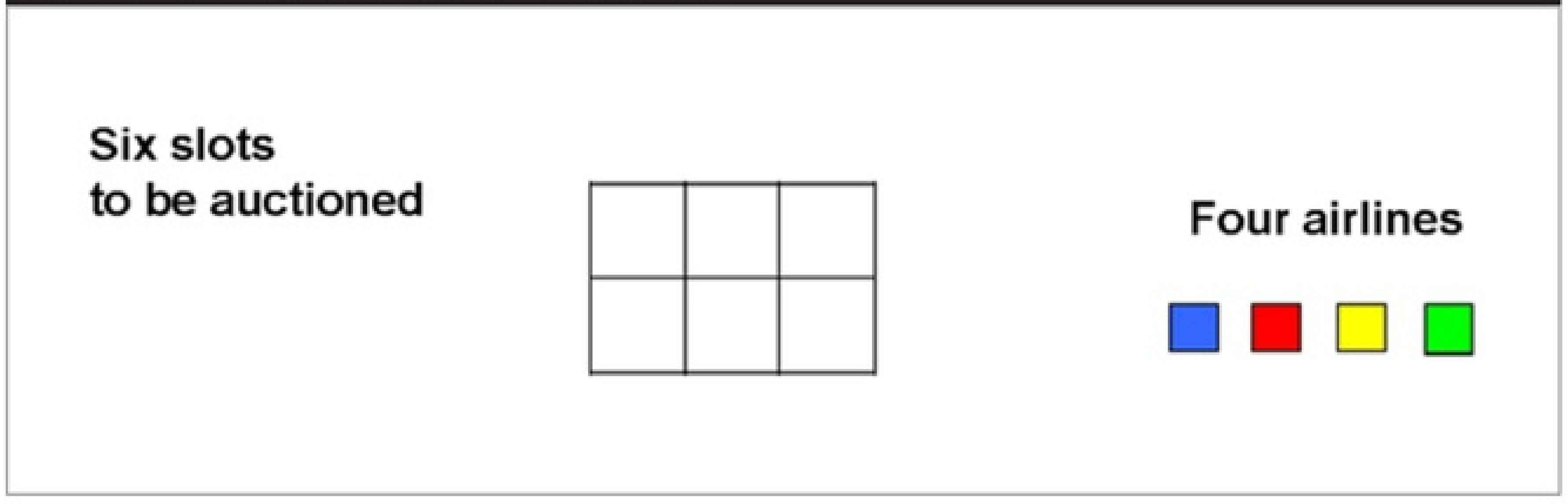
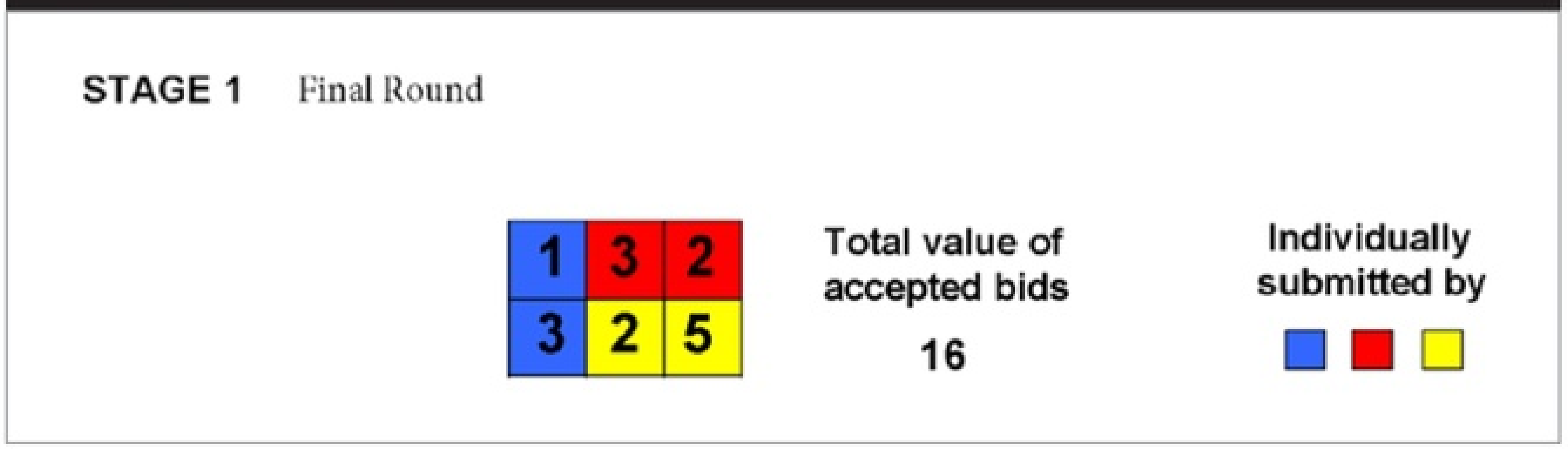


FIGURE 2 - THE STAGE 1 BIDS



HOW, THEN, WOULD SLOT AUCTIONS WORK?

When British Airways requires a slot for a flight departing from London and going non-stop to Los Angeles, it clearly also requires a slot at the Los Angeles airport for the flight's arrival. Likewise, for a Lufthansa flight departing from London and stopping in Frankfurt before arriving in Los Angeles, three slots are required, and for an Air Canada flight headed from London to Toronto, then to Chicago, and finally arriving at Los Angeles, four slots are needed.

In each case, the airline will be reluctant to place separate bids for its two, three, or four required slots because winning some, but not all, would commit it to paying for one or more slots that it doesn't need. In each case, the airline will instead want to bid for a package of slots, that is, an "all or nothing" bid.

Auctions that allow package bids are called combinatorial auctions. Over the past 20 years, combinatorial auctions have been developed for many industries, most notably for the allocation of leases for radio bands for use by telecoms companies for the provision of mobile phone service.

How would a combinatorial auction for airport slots operate? The "standard approach" to combinatorial auctions is to have bidders submit all their bids, including package bids, to the auctioneer, who then attempts to piece them together and accept those bids that maximise auction revenue. This highly complex puzzle, called the winner determination problem, is unfortunately in a class of mathematical problems called NP-hard. What this means is that as the size of the problem—i.e., the number of slots—increases, the time required to determine the allocation increases enormously.

However, there is an alternative to the standard approach to running a combinatorial auction. Cambridge professor Frank Kelly and I developed a combinatorial auction procedure called PAUSE (Progressive Adaptive User Selection Environment), where the auctioneer never faces the winner determination problem. This procedure appears to be especially suitable for the auctioning of airport slots.

PAUSE proceeds in stages. In stage 1, airlines are permitted to bid on individual slots only. In stage 2, airlines can submit package bids that contain two slots. However, each airline must submit its package bid as part of a composite bid, which is a set of non-overlapping bids that cover all the slots in the auction. Of course, an airline is not going to be interested in all the slots in the auction; however, it can fill out its composite bid with previously-submitted bids by any of the bidders. In stage 3, airlines can submit package bids for up to three slots; in stage 4, up to four slots, and so forth, as long as the bids are submitted as part of a composite bid. Each stage can have several rounds of bidding. The point here is that, when the bidding stops, there is no need to solve the winner determination problem. The slot allocation is displayed to all by the final composite bid.

The PAUSE procedure is illustrated with the example below. Figure 1 shows six airport slots to be auctioned, represented as six boxes, and four airlines, represented by the colours blue, red, yellow, and green.

Figure 2 shows the final round of stage 1. The six slots had been auctioned off in six simultaneous auctions, with Blue provisionally winning the two slots on the left at prices 1 and 3; Red, the slots at the top-middle and top-right at prices 3 and 2; and Yellow, the two slots on the bottom-middle and bottom-right at prices 2 and 5. At this point in the auction, Green is not a provisional winner on any slot.

Figure 3 shows the composite bids submitted in stage 2, round 1. Here, Blue, Red, and Yellow have each proposed a composite bid, while Green has decided to stay out of the bidding for now. Blue's composite bid has improved on adjacent bids from stage 1 of 1 from himself and 3 from Red with a package bid of 4.7, and he has filled out the remainder of the slots with bids from stage 1, for a composite bid of 16.7. Red has submitted a composite bid of 17, and Yellow a composite bid of 16.5. Thus, Red's composite bid of 17 is highest and therefore is the one accepted in round 1 of stage 2.

Figure 4 shows the accepted composite bids in each of the three rounds of stage 2. (For simplicity, the losing composite bids in each round are not shown.) In round 2 of stage 2, blue has submitted the highest composite bid for that round of 18, and in round 3 of stage 2, Green has submitted the highest composite bid for that round of 19. Assuming that there is no further bidding in stage 2 after round 3, Green's composite bid is accepted for stage 2, and the auction would continue to stages 3, 4, 5, and 6, where it concludes—although in practice, bidding would likely end considerably earlier. The final accepted composite bid in the auction will display the slot allocation.

By avoiding the winner determination problem, the PAUSE auction procedure is applicable for slot auctions of any size. PAUSE also has several other advantages over other combinatorial auction procedures. One that is especially important is that essentially any additional rules or regulations required by the ACI can be easily accommodated by PAUSE.

The paper that first introduced the concept of combinatorial auctions was written in 1982 and was motivated by an interesting application. The title of the paper was "A Combinatorial Auction Mechanism for Airport Time Slot Allocation." This paper, authored by Stephen Rassenti, Vernon Smith and R.L. Bulfin, was cited by the Royal Swedish Academy of Sciences when it awarded Vernon Smith the Nobel Prize in Economics in 2002.

Why, then, were combinatorial auctions not adopted for slot allocation back in the 1980s? I see three reasons.

FIGURE 3 - PROPOSED COMPOSITE BIDS IN STAGE 2, ROUND 1

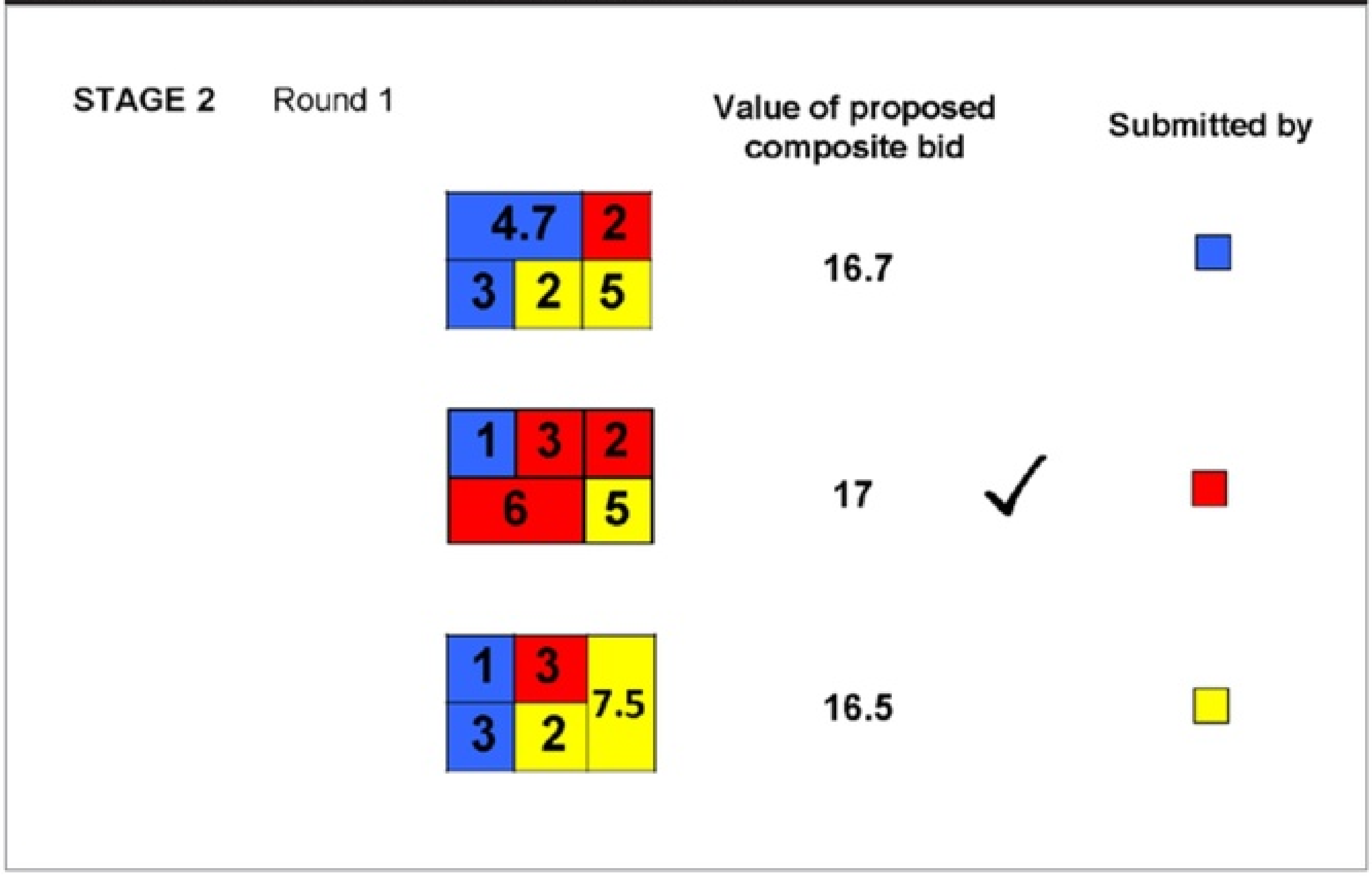
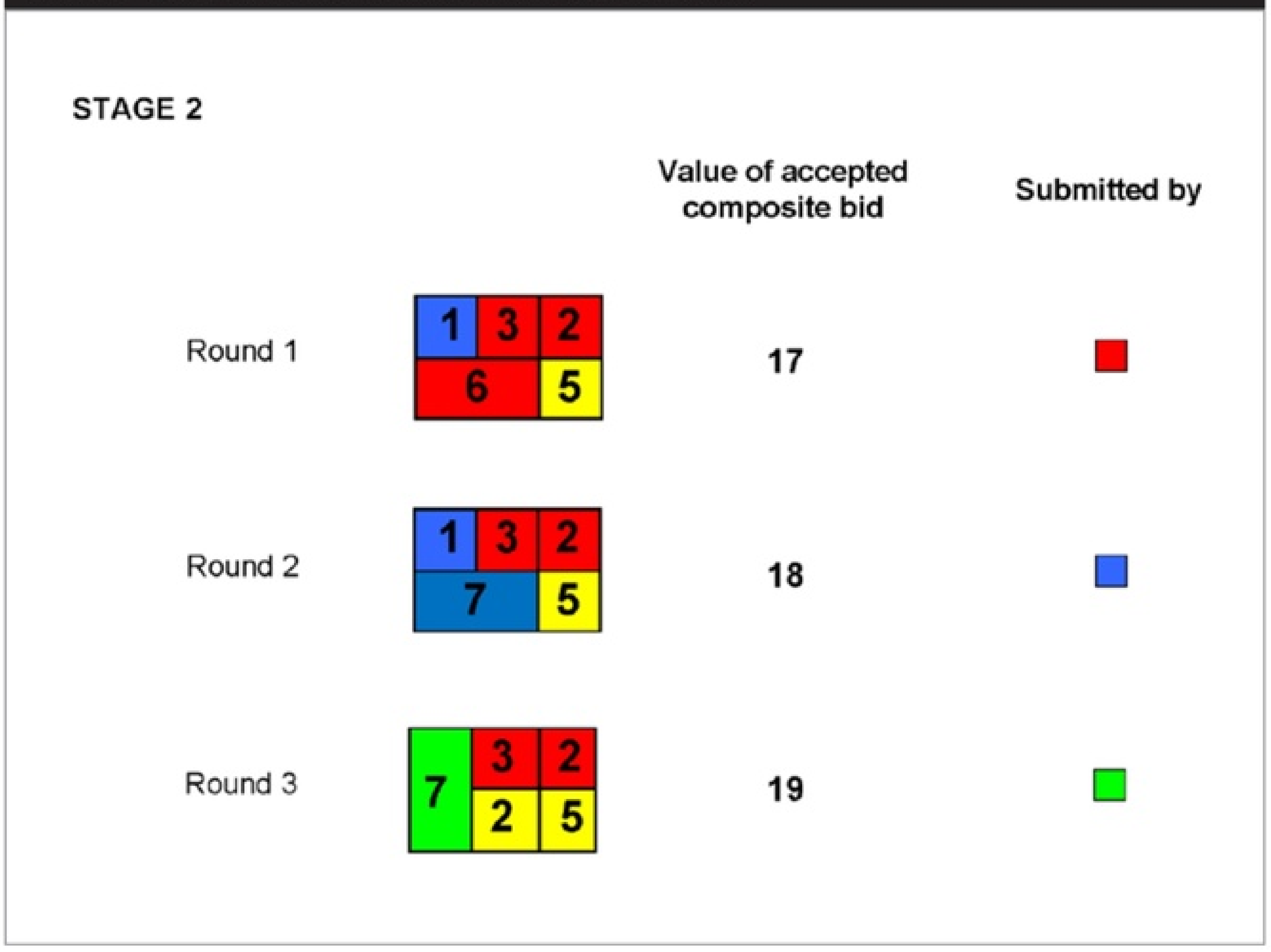


FIGURE 4 - ACCEPTED COMPOSITE BIDS IN STAGE 2, ROUNDS 1, 2, 3



First, the problem of insufficient slot capacity, while already worrying, was not yet critical forty years ago. Second, concerns regarding carbon emissions were barely being discussed at the time. Third, Smith and his colleagues realised that the standard approach for running a combinatorial auction—essentially the only one then available—would work for the allocation of only a very small number of slots.

But times have changed. Slot capacity has now reached a critical stage and airlines are struggling to comply with ESG environmental targets. There is now a combinatorial auction procedure that can handle slot allocation problems of any size. We should no longer put off introducing auctions for airport slot allocation.

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