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CWPE 1347 & EPRG 1324

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**EPRG Working Paper 1324**

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# Network Procurement Auctions

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A large part of the public infrastructure, such as power systems, road and railway networks, water systems and others, is financed, built and/or operated by private-sector companies (Cantillon and Pesendorfer, 2006; Engel et al., 2013). There are wide variations in how to involve the private sector in infrastructure design. One method is public-private partnerships (PPP) whereas other methods are traditional procurement processes or competitive tender processes (Burger, Philippe, and Ian Hawkesworth, 2011, hereafter procurement/tender processes). The key features of the private sector's involvement are long term contracts, 20 years for example, between the public authority (hereafter auctioneer) and a private company (Engel et al., 1997;

Ofgem, 2009). For the duration of the contract, the private company provides the service in exchange for auctioneer-transfers (hereafter transfer value) that compensate for upfront investments and other costs. Typically, the transfer value is paid for by the consumers, via regulated charges.

In order to foster competition, public contracts are typically awarded via procurement auctions (Klemperer, 2004), which allow companies/bidders to submit a cost (and quality) on the contract(s) that they wish to be awarded. One of the main advantages of using an auction to award a procurement contract is that an auctioneer is given the opportunity to learn about the market's costs of providing and/or operating a complex network. Competition can lead private companies to finance, build and/or operate the service at the most competitive transfer value without loss of quality.

Although procurement auctions have been used as a mechanism for leveraging innovation and competition, they usually have unsatisfactory design features. First, many procurement processes do not allow bidders to propose different network configurations. The network configurations are predefined by the auctioneer. Second, the bidders are not allowed to submit bids on a group of network links (i.e. submit a "package" bid). This is a problem for two reasons: (1) one might ask if the predefined configuration is the optimal configuration; and (2) the bidders cannot gain from synergies between links.

These concerns are seen in many procurement processes, such as the allocation of transmission assets linking offshore wind parks to the onshore electricity grid in the UK or in the allocation of bus routes in Denmark, for instance. Offshore transmission networks are a relevant application for procurement auctions. In 2009, the first round of competitive tenders for offshore transmission licences was launched by the energy regulator, Ofgem. A group of network assets was up for auction. The process was a competitive tender to secure licences to own and operate an individual transmission asset that have been, or are being built by offshore wind park developers following a network configuration pre-determined by Ofgem. It did not include licences to build offshore transmission assets. Hence, the bidders could not propose and build different network configurations. Further, the auction design used did not allow the bidders to submit bids on packages.

The bus tendering model used in Denmark is similar to the model used for offshore transmission. In this procurement auction, bidders bid the cost they need to be compensated for in order to run the route being auctioned. The fare revenue collected goes to the publicly owned traffic planning company Movia who compensate the bus operator for their costs in line with the auction outcomes. In 2012, nine lots, where one lot, for example, contained 11 routes, were up for sale. All routes were predefined by Movia, and prevented bidders from proposing alternative network configurations. Neither did it allow the bidders to submit bids on packages of lots.

Several authors have analyzed the effects of procurement auctions (Dasgupta and Spulber, 1989, Laffont and Tirole, 1993). Together with the increased use of auctions, including package auctions (also called combinatorial auctions), the literature on these subjects has increased substantially (Cramton et al., 2006, Erdil and Klemperer, 2010). However, these papers, along with others, have their focus on the auction design itself. Whether the predefined network is the optimal network and how to let the auction reveal this are questions that have yet to be addressed. We contribute to the literature on procurement auctions by proposing an auction design which will reveal the optimal network. This paper contributes to the literature on network design and auctions by highlighting the motivations and consequences of self-design and package bidding in the area for network procurement. We present an auction where bidders might propose (as well as build, own, operate and finance) different network configurations *and* where bidding for packages is a possibility.

We show that a package clock auction is the most appropriate auction design for auctioning procurement networks. It provides the bidders with the greatest degree of flexibility in identifying alternative bids when there are strong complementarities across the lots being sold. In an auction for individual lots, bidders can end up winning only some of a complementary set of lots and therefore miss out on the opportunity to benefit from synergies, or worse, can end up winning lots that turn out to be useless or unwanted. In a package clock auction, bidders will never be exposed to the situation of winning only a portion of their desired lots. This auction design allows bidders the best opportunity to express their preferences and win those desirable lots in order to maximize their total value. The stage design reduces undersell (i.e. ending up with unsold lots). An activity rule and a pricing rule encourage truthful bidding and can secure or bring the auction closer to efficiency and optimality. Hence, by having a large number of bidder preferences, the package clock auction can bring the auction very close to optimality. We show that the package clock auction will work well when the links and the connection points are divided up into blocks of equal size and price.

Package clock auctions have, famously, been used in practice in telecommunications to sell spectrum licenses where the bidders can combine different blocks/frequencies of the spectrum and submit a package bid, for example, mobile and/or radio, high and/or low frequencies. We take the idea behind the block structure and the auction design and apply it to the area of general network procurement designing[1].

The current auction design closest to ours is discussed in Amaral et al. (2009) which studies the bus tendering models of London and France. Interestingly, the model used in London is a package auction (not a package clock auction) which allows bidders to submit bids on any number of routes and route packages. However, when compared to our paper, Amaral et al. do not discuss models where bidders might propose different network

[1] Note that the block structure and the auction design proposed in this paper are similar to the one used in the sale of spectrum rights. However, the sale of spectrum rights is a revenue raising auction (see Ausubel and Milgrom, 2002) whereas our interest is in procurement auctions, cost decreasing auctions.

configurations. The routes are predefined by the auctioneer, but they can be combined into a package.

Further, and following the tender rules from Transport for London (2013, p. 11/12): "*Each submission must have a compliant bid, but operators may put forward alternatives that they believe would have benefits to passengers and/or London Buses. Alternatives may include options such as use of existing vehicles or variations to the service structure such as routeing or frequency*". Transport for London (2013) contains the actual tender rules for auctioning bus routes in London. The document informs the bidders that alternative configurations may be suggested. However, the auction itself is a so-called "beauty contest" meaning that the evaluation of proposed alternative configurations, as well as other criteria, is highly subjective. Our auction contains a block structure where the bidders' suggestions for alternative configurations are part of the auction itself. This means that in contrast to the beauty contest model the evaluation of the bidders' suggestions is based on a purely objective criterion.

Overall, our block structure together with the package clock auction fills important gaps in the literature.

This paper is organized as follows. Section I presents the package clock auction. In section II, we discuss network designing. Section III illustrates our idea with an example. Then in section IV, we discuss why and how our presented auction could be the way forward and its advantages. Section V contains the conclusion.

## I. The package clock auction

Our main purpose is to show how a package clock auction can be designed in such a way that bidders can propose different network configurations and where bidding for packages is a possibility.

The package clock auction is in two stages, a principal stage and an assignment stage. The principal stage consists of a clock auction and a supplementary round. The clock auction is a sealed-bid multiple round auction in which bidders choose the package of lots that they wish to bid on at prices specified by the auctioneer. In the clock auction, bidders can only submit a bid on one package per round. For all lots with excess demand, the prices are increased in the next round (decreased in a procurement auction). This process is repeated until there is no excess demand on all lots. After the clock auction ends, an additional sealed-bid round (the supplementary round) is held in which bidders can bid on additional packages as well as having the opportunity of improving their bids on packages already placed in the clock auction, subject to an activity rule. In other words, bidders can submit multiple bids on arbitrary packages, but the bid price is limited by an activity rule. The activity rule limits what package bids a bidder can make in subsequent rounds based on the bidder's bids in earlier rounds. Therefore, the activity rule requires bidders to maintain a minimum level of activity throughout the auction. The auctioneer then determines the combination of package bids with the highest value (the lowest transfer value in our case).

The principal stage is followed by the assignment stage: the final step of the package clock auction. The purpose of the assignment stage is to determine how the available lots should be distributed among the winning bidders from the principal stage, and what final price should be paid by each winning bidder for those lots. The stage is designed to give the winners the opportunity to express preferences for specified lots. In this stage, each winner makes bids for lots that are compatible with the amount of lots won in the principal stage. The assignment stage is a sealed-bid auction.

The package clock auction works well when the lots being auctioned have strong complementarities and bidders are allowed to express their preferences for a specific package through a bidding process. The clock auction provides a simple price discovery process and provides a foundation that guarantees the lots end up in the hands of those who value them the most. The supplementary round minimizes the chances of ending up with unsold lots. The assignment stage enables bidders to fully express their preferences for packages of lots. Overall, and most importantly, the package clock auction ensures that bidders are never exposed to the risk of winning only a portion of their desired lots, since bidders are bidding on mutually exclusive packages of lots.

Payments are set using a second-price rule, or in this paper, as illustrated later, a Vickrey-Clarke-Groves (VCG) mechanism (the winner pays the "opportunity cost" of the objects won, and payment depends only on opponents' bids). The VCG mechanism encourages truthful bidding whereas the activity rule eliminates "bid sniping" (i.e. placing a winning bid at the last possible moment) and promotes price discovery. The package clock auction, therefore, has a tendency to return the highest revenue value (lowest transfer value in our case) and allocate the lots in the most efficient way possible.

Ausubel and Cramton (2011a) state that the main weakness of the auction design is its complexity. However, they state that in spite of this, the package clock auction is the most appropriate auction design for auctioning offshore sea shelf, i.e. the area where offshore wind parks are placed, as well as for radio spectrum (hereafter, spectrum).

The package clock auction is particularly appropriate in situations with strong and varied complementarities across lots, and if the objects for sale can be divided up into blocks which bidders can combine and submit bids on. This is why the auction has been successfully conducted for assigning spectrum in several countries over many years (Cramton, 2008; Ausubel and Cramton, 2011a). Therefore, taking the idea behind the spectrum auctions seems like the way forward for the consideration of blocks and packages of bids that have strong interactions – such as different parts of a whole network. In the following sections, we shall demonstrate why.

## II. Network designing

Despite the interest in allowing competitive market participants to be part of large scale infrastructure developments, there remains a reluctance to allow competition into the planning process. In many areas, such as infrastructure for offshore transmission or bus transport, the location of the assets is already decided by the auctioneer before the start of a competitive tender round. This means that the participants will not compete to propose different network configurations. Neither does it allow the bidders to submit bids on packages and therefore, gain from synergies which themselves might substantially depend on a specific network configuration. Moving from a regime where bidders submit bids on a predefined configuration to one where bidders are given the freedom to propose a different network needs radically rethinking, especially when it comes to the definition of objects for sale in the auction.

A spectrum auction is an application of the package clock auction where the freedom to propose different network configurations exists. The spectrum auction bands are divided into blocks and bidders are allowed to submit bids on the objects for sale, and aggregate them in the best way. The bands can be allocated into fixed and mobile services from intervals of MHz, another interval for mobile satellite service and/or broadcasting satellite service. One can transpose these concepts into other network areas where a band can be seen as a specific area in the seabed or inside a city. One area is part of a number of areas which, in sum, is equal to the whole area (“the spectrum”) being auctioned. Hence, there are a number of blocks that bidders can bid on inside the spectrum. This gives the bidders the opportunity to gather a number of blocks to propose the most desired network. Given such freedom to propose different networks, moreover, it also allows for package bidding to ensure that the bidders get the most desired network.

The package clock auction allows bidders to submit bids on a package of lots. It provides the bidders with the most flexibility when there are strong complementarities across the lots being sold. In the case of spectrum auctions, the adjacent geographic areas are often complementary, but bidders can consider different blocks in the same spectrum band as substitutes and submit individual bids. Since links or connection points inside any network can be substitutes as well as complements, there are potentially many different options of various configurations; as is the case for spectrum auctions. In a spectrum auction, one bidder may be interested in fixed and mobile services while others may be interested in broadcasting satellite services. In other network auctions, one bidder may be interested in building one link in one area, whereas other bidders may desire to build more than one link over several different areas. Each bidder has their own optimal network configuration with associated technical requirements. Moreover, different bidders bring to the auction different ideas, properitary technologies, project skills and financial capabilities which impact on the possible network configurations, valuation and cost.

Consequently, one can transfer several concepts and the auction process from the spectrum auction to our general network procurement application. First, we need to clearly define and to divide an area into potential links and connection points and thence into blocks. Typically, an auctioneer provides the areas for the infrastructure investments. For example, Offshore Development Information Statement (ODIS; National Grid, 2011) from the transmission system operator in Great Britain (GB), National Grid, is a document which provides a view of how the national offshore transmission system may possibly be developed in the future. Its aim is to facilitate the development of an efficient, coordinated and economical system of electricity transmission. Interestingly in the area of offshore transmission in the UK and bus transport in Denmark, a link/route is sold as a whole block: a predefined link.

*A. Auctioning predefined links*

Imagine that an auctioneer launches a procurement process where bidders can submit bids on a predefined network. Figure 1 shows such a network where red (R) and green (G) points are connection points through the blue (B) area and the two black lines are the links. The G blocks represent new points on the network that must be connected into feasible connection points on the existing network represented by the R blocks. The figure can be seen as one area out of a number of areas being auctioned where within each area (and across areas) synergies are expected to be significant. The links together with the connection points, as illustrated, are up for auction. Therefore, there are two objects on sale.

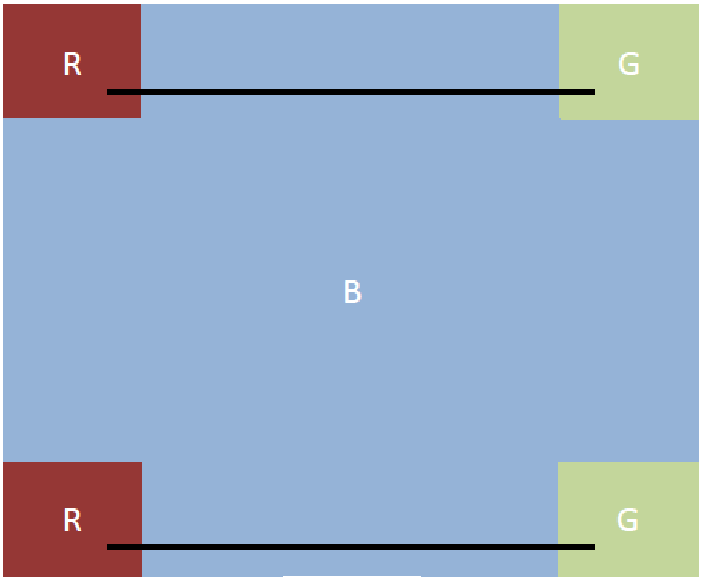


FIGURE 1. A NETWORK DESIGN

First, Figure 1 is one way to design a network. However, it could be that a bidder with a different configuration can benefit from synergies. Second, if there are strong complementarities among lots and the auctioneer does not use a package auction, Figure 1 shows again an example where there is no opportunity to gain from synergies across the area being auctioned. The figure could be a real life example of an offshore transmission network, a bus route network as well as other networks. If this were an offshore transmission network, the wind parks would be on the G blocks and the existing onshore network would be available for connection on the R blocks.

*B. Auctioning non-predefined links*

We need to divide the network area into blocks which are the individual auction lots being bid on. A possible solution is to divide Figure 1 into a set of blocks that for geographic reasons logically belong together. This is shown in Figure 2. Hence, we get two R blocks, two G blocks and 21 B blocks.

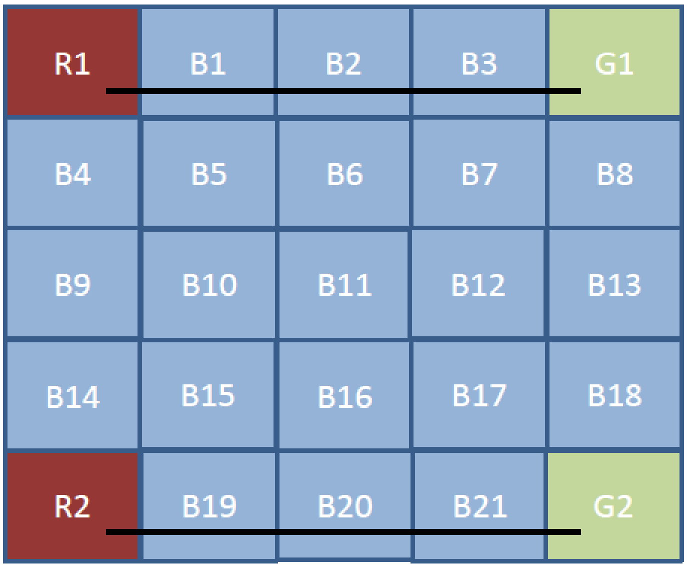


FIGURE 2. FIGURE 1 DIVIDED INTO BLOCKS

Dividing an area into blocks allows bidders to propose different network configurations.

Imagine that Figure 1 is an auctioneer-suggested configuration which is, from the auctioneer's point of view, efficient and optimal. The purpose of this paper is to let the market/the bidders themselves propose different network configurations. However, we need to reduce inefficiency and over-expensive configurations. Consequently, we use the auctioneer's suggestion (Figure 1, hereafter Figure 2) as a possible network and therefore, as a cap on inefficiency and on overly expensive network suggestions (i.e. a feasible starting configuration). This prevents bidders, for example, from proposing expensive configurations by, for instance, proposing to build a network of links over 12 B blocks, when Figure 2 shows that this network can be built using 6 B blocks. Hence, it allows the bidders to submit a package bid on different blocks that in total could be equal to or below the number of blocks allowed to build an optimal network. Using Figure 2 as a possible network, and therefore as a cap, means that we reach at least the design shown in Figure 2. If Figure 2 is not efficient and optimal, the market will tell us so and suggest alternative configurations. In terms of real-life use of our set-up, the blocks could be divided differently. The auctioneer might be the entity who designs the block structure. Importantly, we have a possible network and a cap on inefficiency and on over-expensive network suggestions and an area where bidders, subject to the cap, can propose alternative configurations. Our set-up and block structure gives the bidders this opportunity.

The main goals that we attempt to reach with our auction may be summarized as follows:

- Bidders are given the opportunity to propose different network configurations and so, the bidders are able to propose their most desired network;
- Bidders can submit bids on packages including links and connection points. This helps bidders to obtain their most desired network;
- At least we reach Figure 2;
- The auction should contain a maximum transfer value. This is secured by using Figure 2 as a cap.

Table 1 shows the rules in our auction that reach our main goals. In what follows, we explain and justify each rule.

TABLE 1—THE RULES OF THE AUCTION

(1) Reserve configuration and transfer value are based on Figure 2.
(2) Connection points in R and G areas are divided into blocks, and one block contains one connection point.
(3) Links in B area are divided into blocks of the same size.
(4) There is a maximum number of blocks per link and per connection point. So, there is a maximum transfer value per block and per link and per connection point.
(5) There is a maximum on the number of bids on each block.
(6) Transfer values are paid contingent on winning bidders being able to meet target levels of network availability.
(7) A winning bidder for part of a network has to facilitate interconnection with other parts of the network.
(8) If all blocks are not sold after the principal stage and assets are needed to meet rule 6 after the assignment stage, and if a bidder needs blocks to connect links and connection points, blocks can be sold after the assignment stage at the bidders' lowest cost submitted in the principal stage. If no bid is submitted on a specific object (a R, a G or a B block) in the principal stage, blocks can be sold after the assignment stage at a cost defined after an auctioneer evaluation. Information about unsold assets is not available to the bidders before the end of the assignment stage.

It is not possible to withdraw from the auction after being qualified to bid. However, in the case where rule 8(iii) is necessary, but a bidder refuses to bid on a certain asset, the bidder can withdraw from the auction without forfeiting their initial deposit for that reason. One could have a rule where a bidder can only withdraw from blocks won in the principal stage, if it is not possible to connect a link between two connection points all over the network for sale. Since our aim with this paper is to give bidders the chance to benefit from synergies, rule 8 allows bidders to withdraw completely from the auction. However, this will only be possible if rule 8(iii) exists, but a bidder refuses to bid on the additional block(s) required to make the connection.

Rule 8 secures that a network can be built and at the same time gives the bidders the opportunity to withdraw from the auction if synergies cannot be achieved.

## III. Example

One of the fundamental tasks in designing an auction is to define the lots that are up for sale. For our auction, a lot is a block of a particular size and of a particular value. Specifically, following the set-up above, one block is one lot. Our set-up, including the idea behind the blocks (lots), differs from the one in the spectrum auctions and it is also new to literature. In spite of the differences between our auction and the spectrum auctions, we use the same fundamental idea, and so our auction offers the same advantages as spectrum auctions as well as in the allocation of bus routes and franchise auctions. In order to illustrate how our auction works, we provide an example. In this example, we use the package clock auction and a reserve configuration and transfer value based on Figure 2. The rules of the auction follow Table 1.

Table 2 below describes the type, the number of blocks/lots for sale, the maximum number of blocks/lots (or maximum transfer value which can be given) per R- and G-connection point and per B-link and the maximum number of the same lots available in the auction. The maximum transfer value per B-link is defined by a B-starting point and a B-ending point. The table shows that there are a total of two R lots, two G lots and six B lots on sale (the rest of the blocks [lots] in Figure 2 is intended to increase the freedom in bidding).

TABLE 2—DESCRIPTION OF AVAILABLE LOTS - ILLUSTRATION

| Type | Number of lots for sale | Max number of blocks/lots per link and per connection point | Max number of the same lot (2 means e.g. R2, R2) |
|---|---|---|---|
| R | 2 | 1 | 2 |
| G | 2 | 1 | 1 |
| B | 6 | 3 | 3 |
| **For sale** | **10** | | |

Table 2 shows that Figure 2 is possible. A bidder can suggest two R lots starting from R1 and R2, two G lots and six B lots which connect R and G areas. Interestingly, Table 2 also shows that the auctioneer can accept a network where the two links start from R1 or R2 by a “maximum number of the same lot” equal to two, that is, a bidder can submit bids on two R1 lots (R1, R1) or two R2 lots (R2, R2). However, the auctioneer desires a network which has an exit from both G1 and G2. For B lots, the auctioneer makes it possible to submit bids on a specific B lot three times and therefore, secures certain amount of freedom to propose an alternative cheaper network configuration.

*Eligibility points (an activity rule) and reserve transfer value per lot*: A bidder's eligibility points define the upper limit of lots that the bidder can bid for. In the first round, the number of eligibility points is set by an upfront deposit amount for the bidder. In subsequent rounds, the number of eligibility points is set by the bids placed by the bidder in the previous round. The auctioneer chooses whether or not eligibility can increase after the auction starts. For simplicity, assume that the upfront deposit will not influence whether or not a bidder can stay in the auction. This means that the only barrier that holds back a bidder from staying in the auction is the transfer value of the lot. Assume that a R lot has an opening (and a reserve) transfer value of $10m, a G lot has a transfer value of $20m and a B lot has a transfer value of $10m. Further, assume that the auctioneer with the reserve configuration can get 100 units of capacity. Let the reserve cost be $120m (2*$10m+2*$20m+6*$10m) for 100 units of capacity.

### *A. Principal stage - the clock auction (primary rounds)*

The auctioneer announces round transfer values per lot beginning in round 1 with the transfer values equal to the reserve transfer values. Bidders submit a single package bid in each round consisting of one or more lots in each type (R, G, B). At the end of each round, the auctioneer determines the aggregate demand for each category across all package bids. If the demand exceeds supply in any type, the auctioneer will lower the transfer value for that type and start a new round. The clock auction ends when there is a round in which demand is less than, or equal to supply in all three types.

Following bidder 1, assume that in the first round this bidder prefers the reserve configuration (Figure 2) and therefore, a package of two R lots, two G lots and six B lots. Bidder 1 bids the amount of $120m. For illustration, assume that the clock auction ends after five rounds where bidder 1 drops demand between round three to four and stays at a package of one R lot, one G lot and three B lots until round 5.

TABLE 3—THE CLOCK AUCTION - ILLUSTRATION

| **Round** | **Price per R lot** | **Price per G lot** | **Price per B lot** | **Bidder 1's package bid** | **Promised capacity (units)** | **Bidder 1's bid amount** |
|---|---|---|---|---|---|---|
| 1 | $10m | $20m | $10m | 2 R + 2 G + 6 B | 100 | $120m |
| 2 | $9m | $19m | $9m | 2 R + 2 G + 6 B | 100 | $110m |
| 3 | $8m | $18m | $8m | 2 R + 2 G + 6 B | 100 | $100m |
| 4 | $7m | $17m | $7m | 1 R + 1 G + 3 B | 50 | $45m |
| 5 | $6m | $16m | $6m | 1 R + 1 G + 3 B | 50 | $40m |

*B. The supplementary round*

The supplementary round provides a single round opportunity for each bidder to submit their best offer on all available packages. That is, bidders are allowed to place additional supplementary bids if their preferences have not yet been fully expressed in the clock auction. The supplementary bids will be subject to caps. The caps are linked to a bidder's lowest bid in the final round in the clock auction and (if relevant) to a bidder's bid in the clock auction in the round when the bidder reduced eligibility. Table 4 shows, for example, that bidder 1 placed a bid for a package of one R lot, one G lot and three B lots in round four to five. Bidder 1's lowest bid in the clock auction is $40m submitted in round five. Because $40m is the lowest and last bid in the clock auction, this bid acts as a cap in the supplementary round. Assume that bidder

1 submits a bid of $38m for a package of one R lot, one G lot and three B lots in the supplementary round. Besides this bid, bidder 1 submits a bid for a package of two R lots, two G lots and six B lots. In this case, the supplementary bid for the package of one R lot, one G lot and three B lots acts as a cap on the package bid of two R lots, two G lots and six B lots.

TABLE 4—THE SUPPLEMENTARY ROUND - ILLUSTRATION

| **Package** | **Promised capacity (units)** | **Bidder 1's lowest primary bid for this package** | **Last primary round when bidder 1 was eligible to bid for this package** | **Cap on bidder 1's bids** | **Bidder 1's supplementary bid** |
|---|---|---|---|---|---|
| 1 R + 1 G + 3 B | 50 | $40m (round 5) | 5 (bid for this package) | Uncapped (Bidder 1's final primary bid and was submitted in the last primary round) | $38m |
| 2 R + 2 G + 6 B | 100 | $100m (round 3) | 4 (bid for 1 R + 1 G + 3 B instead) | Capped at bid for 1 R + 1 G + 3 B plus transfer value difference in round 4: Cap=£38m+£45m[1]=£83m | $75m |

*Notes*

[1] Bidder 1 has submitted a bid for extra one R, one G and three B lots and the transfer value for one R, one G and one B lot in round 4 was $7m, $17m and $7m respectively. Therefore, the bidder can add $45m (1*$7m + 1*$17m + 3*$7m) to the capped bid of one R + one G + three B.

### *C. Winner determination*

Winning bids are the combination of valid primary and supplementary bids with the lowest total transfer value.

An example of different bids submitted in the auction is illustrated in Table 5. Thus, for example, bidder 1 might make two separate bids: a bid of $38m for a package of one R lot, one G lot and three B lots; and a bid of $75m for a package of two R lots, two G lots and six B lots. Further, imagine, for example, that bidder 2 and 3 go for the following feasible network configurations.

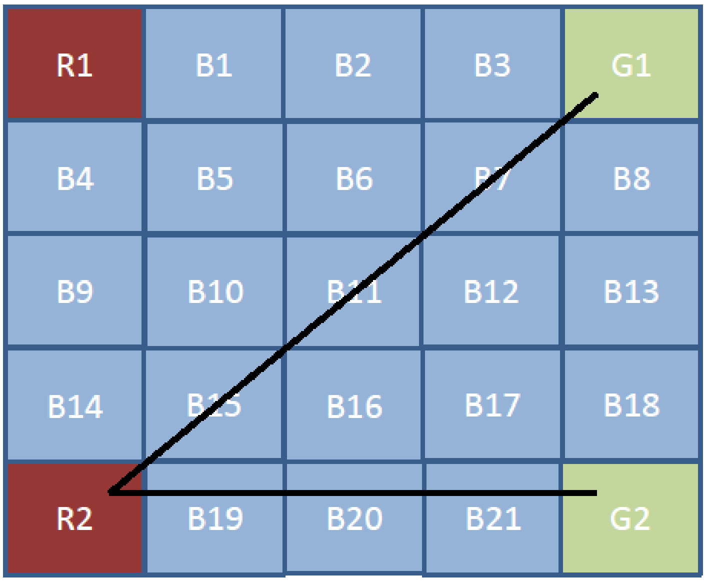


FIGURE 3. ALTERNATIVE NETWORK DESIGN (BIDDER 2'S SUGGESTION)

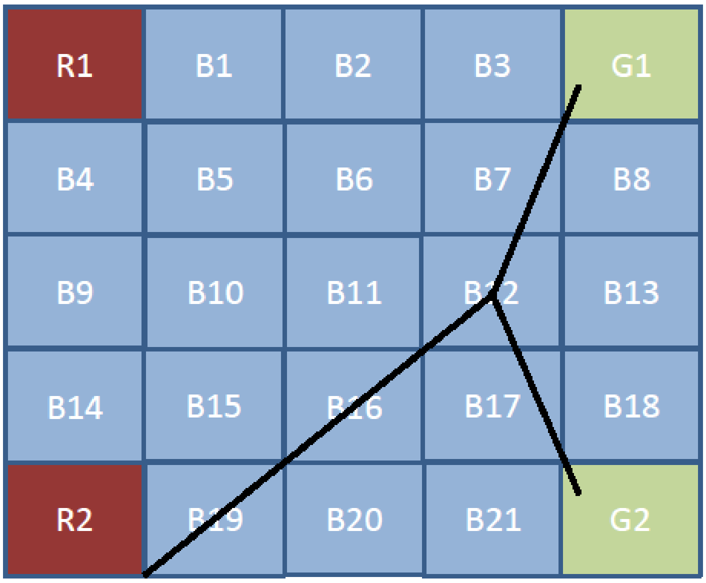


FIGURE 4. ALTERNATIVE NETWORK DESIGN (BIDDER 3'S SUGGESTION)

TABLE 5—ALL BIDS MADE IN AUCTION - ILLUSTRATION

| **Bidder** | **Promised capacity (units)** | **Package** | **Bid amount** |
|---|---|---|---|
| Bidder 1 | 50 | 1 R + 1 G + 3 B | $38m |
| | 100 | 2 R + 2 G + 6 B | $75m |
| Bidder 2 | 100 | 1 R + 2 G + 6 B | $72m |
| Bidder 3 | 100 | 1 R + 2 G + 5 B | $66m |
| Bidder 4 | 50 | 1 R + 1 G + 3 B | $40m |
| Bidder 5 | 100 | 1 R + 2 G + 5 B | $68m |
| … | … | ... | … |

After the supplementary bids round, the auctioneer will determine the winning principal stage bids and the identity of the winning bidders. The goal of the auctioneer is to determine the lowest total transfer value combination which, aggregated or not, gives 100 units of capacity. Table 6 shows lowest value combination. The winner determination process will allocate one R lot, two G lots and five B lots to bidder 3.

TABLE 6—IDENTIFY LOWEST VALUE COMBINATION

| **Winning bidder** | **Promised capacity (units)** | **Package** | **Bid amount** |
|---|---|---|---|
| Bidder 3 | 100 | 1 R + 2 G + 5 B | $66m |

### *D. Base transfer value determination*

The auctioneer will determine an amount payable to the winning bidder in respect of the winning bidder's winning principal stage bid. The amount payable is called the base transfer value that is calculated using the VCG mechanism. Note that, since this auction is a package auction, a base transfer value applies to a winning package and therefore, there is no base transfer value for individual lots.

In Table 7 below, one can see that the base transfer value of bidder 1 winning one R lot, two G lots and five B lots is $68m. That is the value of denying bidder 5 from winning the same package.

TABLE 7—IDENTIFY BASE TRANSFER VALUE

| Winning bidder | Promised capacity (units) | Package | Bid amount |
|---|---|---|---|
| Bidder 3 | 100 | 1 R + 2 G + 5 B | $68m |

Following section I, the principal stage has ended - the winner determination problem is solved, winners are identified (winner in our case), and base transfer value is determined. The principal stage is followed by the assignment stage.

### *E. Assignment stage with one and two winning bidders*

The purpose of the assignment stage is to determine how the available lots should be distributed among the winning bidders from the principal stage. This stage is also used to determine the final transfer value for each winning bidder for the distributed lots. The stage is a sealed bid round. The stage is normally required if there is more than one winning bidder, but can also be used if there is only one winning bidder. This stage ensures that it is possible for a winner to receive contiguous lots. A bidder is not required to submit bids in the assignment stage, but here has the opportunity to secure a desired range of lots, contiguous or not. If there is only one winning bidder, as in our example, the assignment stage works as follows.

Bidder 1 has to be allocated one R lot, two G lots and five B lots. Table 8 shows that bidder 1 prefers a package that includes R2, G1, G2, B7, B12, B16, B17 and B19.

TABLE 8—PREFERENCES FOR RANGES OF LOTS

| Bidder | Package, preferences |
|---|---|
| Bidder 1 | (G1, B7, B12) + (G2, B17) + (R2, B16, B19) |

Because there is only one bidder, bidder 1 does not have to submit a bid in the assignment stage in order to secure a desired package. In this example, bidder 1 will be granted the preferred package.

In the eventuality that there is more than one bidder, the winners in the assignment stage could be chosen by the following rule: the winning bidders from the principal stage submit bids after a possible transfer reduction in the allowed transfer value. The bids are evaluated and ranked by highest possible transfer reduction where the bidder with the highest indicated reduction will win their desired package. Hence, bids in the assignment stage will not be part of the allowed transfer value that the winning bidder will receive to build the desired network, though this bid will be subtracted from the allowed transfer value from the principal stage. The reason is that a bid in this stage is a self-chosen action and shall not be paid by the consumers through the transfer value. In the following we illustrate this rule.

The assignment stage for the situation where there is more than one winning bidder is illustrated below. Instead of Table 7 and 8, imagine Table 9 and 10. Table 9 shows that the base transfer value of bidder 1 winning one R lot, one G lot and four B lots is $47m. Further, the base transfer value of bidder 2 winning one G lot and one B lot is $23m.

TABLE 9—IDENTIFY BASE TRANSFER VALUE – ILLUSTRATION WITH TWO WINNING BIDDERS

| **Winning bidder** | **Promised capacity (units)** | **Package** | **Bid amount** |
|---|---|---|---|
| Bidder 1 | 50 | 1 R + 1 G + 4 B | $47m[1] |
| Bidder 2 | 50 | 0 R + 1 G + 1 B | $23m[1] |

*Notes:*

[1] Assume that someone in the principal stage submitted a bid on these packages, included a promised capacity of 50 units, and that the base transfer value for bidder 1 is $47m and for bidder 2 $23m.

Table 10 shows each bidder's preferences and their bids for the desired lots. Bidder 1 has to be allocated one R lot, one G lot and four B lots. Bidder 2 has to be allocated one G lot and one B lot. In our example, each bidder has submitted a package bid in the assignment stage. Following Table 10, bidder 1 is willing to accept a transfer reduction of $2m to secure its desired package. Bidder 2 is willing to accept a reduction of $1m to secure its desired package.

TABLE 10—PREFERENCES FOR RANGES OF LOTS – ILLUSTRATION WITH TWO WINNING BIDDERS

| Bidder | Package, preferences | Package bid |
|---|---|---|
| Bidder 1 | (G1, B7, B12) + (R2, B16, B19) | $2m |
| Bidder 2 | (G1, B7) | $1m |

Bidder 1 has indicated the highest transfer reduction and will therefore win its desired package. Given bidder 1's preferences - (G1, B7, B12) + (R2, B16, B19), the only feasible network is (G1, B7, B12) + (G2, B17) + (R2, B16, B19). We have the following evaluation criteria:

TABLE 11—IDENTIFY WINNING ALLOCATION – ILLUSTRATION WITH TWO WINNING BIDDERS

| Bidder 1's bids | | Bidder 2's bids | |
|---|---|---|---|
| **Option** | **Amount** | **Option** | **Amount** |
| (B12) + (G2, B17) + (R2, B16, B19) | zero | (G2, B17) | zero |
| (G1, B7, B12) + (R2, B16, B19) | $2m | (G1, B7) | $1m |

Table 11 shows that bidder 1 is awarded (G1, B7, B12) + (R2, B16, B19) and bidder 2 (G2, B17). Interestingly, $1m will be subtracted from bidder 1's allowed transfer value. Bidder's 2 payment is the same as in the previous stage of the auction. Assume that bidder 2 has accepted the suggested split of lots and therefore, chooses not to withdraw from the auction.

### *F. Final assignment and allowed transfer for desired lots*

Table 12 below summarizes the result of the original example where there was one winning bidder. This bidder is allowed to charge a transfer value maximum of $68m for one R lot (R2), two G lots (G1 and G2) and five B lots (B7, B12, B16, B17 and B19).

TABLE 12—WINNING BIDDERS AND ALLOWED TRANSFER VALUE FOR WANTED LOTS

| Winning bidder | R won | G won | B won | Base transfer value[1] | Reduction following the assignment stage[1] | Total transfer value[1] |
|---|---|---|---|---|---|---|
| 3 | 1 | 2 | 5 | $68m | $0m | $68m |

*Notes:*

[1] In the case of more than one winning bidder (Table 9 and 10), bidder 1's total transfer value will be $46m ($47m-$1m) and for bidder 2 it is $23m.

Notice that eight out of ten lots are allocated. Hence, compared to the reserve configuration, a bidder could see an alternative, a more cost efficient configuration.

A key issue going forward is whether our auction design can bring savings by allowing for bidders to propose alternative network configurations and to submit bids on packages of lots. Savings could be estimated by comparing the reserve configuration (two R lots, two G lots and six B lots) and the suggested alternative configuration (one R lot, two G lots and five B lots). The transfer values to be used could be the reserve transfer values ($10m, $20m and $10m) from Table 3. This gives an idea of a potential loss by using a network configuration which is predefined by the auctioneer and where licences only include the rights to own and operate the assets, as in the case of offshore transmission. In terms of saving range, our auction design can reduce the total transfer value by $32m-$52m. The estimation follows Table 13.

TABLE 13 — ESTIMATED SAVING[1]

| Assets | Reverse price | Assets (low) Quantity | (high) Quantity | Low | High |
|---|---|---|---|---|---|
| R | $10m | 1 | 2 | $10m | $20m |
| G | $20m | 2 | 2 | $40m | $40m |
| B | $10m | 5 | 6 | $50m | $60m |
| Total | | | | $100m | $120m |
| Auction Result | | | | $68m | $68m |
| **Savings** | | | | **$32m** | **$52m** |

*Notes:*

[1] From Table 3 and 7.

## IV. Discussion

We show that our block structure and auction could be the way forward for auctioning networks. Importantly, our set-up allows the market to give us a check for optimality and efficiency. This is secured because we give the bidders the opportunity to propose lower cost network configurations and to submit bids on packages, subject to a reserve configuration (a cap on the transfer value), the chosen stage auction design and a VCG mechanism. Hence, the bidders are able to propose and obtain their most desired network. Further, the auctioneer is at least guaranteed the reserve configuration and the related transfer value.

### *A. Why our auction design*

One might wonder whether or not the presented design is feasible. One of the central features of our design is the use of geographical blocks in the bidding process. In the spectrum auctions, the bidders bid for the right to make and install “a link” of carrying capacity through the air. In some cases, our design is straightforward, for example, bus route networks or water systems, road and railway networks in a “more open” landscape. However, in other networks, one could ask whether our design is feasible. For example, in offshore transmission auctions, the bidders bid for a plot of land in the seabed with the seabed terrain that the link may be laid across. The bidders analyse and choose a route for laying and burying the link that minimizes cost. They bid for making, installing and burying the whole link and not only for part of a link. Consequently, the structure of the way that bidders design, evaluate the costs and bid is related to the technical structure of the configuration.

The auctioneer, for example, the GB energy regulator (Ofgem) in the case of GB offshore transmission auctions, needs to define and characterize the product space of the auction and structure of the possible routes of bidding in order to induce a sense of security among the bidders. Then, bidders can structure and assertively make their bids according to the preliminary conceptual configuration of the scheme made by the auctioneer. If the bidders have a more cost efficient way to structure the technology, then there is an incentive for them to suggest alternative configurations, given their freedom to propose different network configurations.

Following on from this, one can say that there are two types of bidders in a network auction – the bidders that follow the auctioneer's suggestion (i.e. Figure 2 configuration) and so a predefined configuration, and the bidders that investigate the environment and analyse possible alternative configurations that are more cost efficient. In both cases, bidding for all or part of the network is possible.

The auction presented in this paper can handle both types of bidders. A reserve configuration can give the bidders a security and confidence in bidding, and they will bid accordingly. The reserve configuration that we have been using throughout the paper is Figure 2. However, one might ask if this is the optimal configuration. Through freedom to propose alternative configurations, one allows the second type of bidders to study alternatives and bid with confidence. The market decides which configuration is the more cost efficient. This is the main distinction from an auction where the links are predefined before start of auction. Without this freedom, bidders submit bids on assets whose location has been already decided. It is true that an auction on predefined links guarantees that the auctioneer controls the transfer values, and that all planned links will be built and used afterwards. Our proposed auction, however, can ensure the same. Rule 1 acts as a cap in favor of cost efficiency and rule 6 secures that all won links and connection points are in use after the bidding process.

If decision-makers are skeptical of this proposed auction, one can design similar auctions without the freedom to propose alternative configurations, and so design an auction with predefined links such as shown in Figure 2. One might consider an auction where this figure is auctioned where one link is one lot and one connection point is another lot. The links could be auctioned as separated links or in a package auction. Depending on the chosen auction, the bidding strategies to consider could be, for example: one link with one connection point, two links and one connection point, all connection points or a bidder that wants to build a whole "figure", for example, the whole of Figure 2. These bidding strategies could be performed in an auction for sale of single objects as well as in a package auction. Some of them will perform better in a single object auction, whereas others will perform better in a package auction (for more information about advantages and disadvantages of the different auction designs, see Binmore and Klemperer, 2002; Ausubel, 2003; Ausubel and Cramton, 2011a).

But why not just auction predefined links, as shown in Figure 2? What is gained from our set-up? First, by auctioning predefined links, the bidders and the auctioneer know precisely what they are bidding for and the network configuration they will get after the auction. Interestingly, given our rules the set-up presented in the previous sections allows for this too. Second, given our block structure, our auction offers all possible bidding strategies, including the bidding strategies mentioned above. Our set-up makes the bidding strategies clearer and more significant. For example, one could imagine an interest from a bidder to combine two offshore closely located links into one larger link. Our auction also allows for this opportunity. We emphasize therefore that the main difference between an auction with predefined links and our set-up is the freedom to propose alternative configurations, e.g. the ability to place the links and connection points where the bidders most prefer.

In areas with complementarities across lots, a package auction is preferable. A package auction can work for auctioning predefined links as well. However, if one uses the "wrong" package auction, then we might have a problem with the auctioneer-announced-prices. In contrast to the package clock auction that includes a supplementary round, a package auction that only includes a clock auction the auctioneer-announced-prices can interfere with the bids submitted. The bidders can end up winning lots that are not needed or can be reluctant to bid because of the announced prices. The design creates an efficiency problem. The package clock auction (with a supplementary round) can eliminate this problem.

*B. Situations where not to use our auction design*

Interestingly for a decision-maker, a link auctioned as a whole block will not perform well in a package clock auction. A package clock auction can be a strong auction design if bidders are allowed to make package bids. However, when the lots for sale are of varying lengths and therefore have different transfer values, including different reserve transfer values, this auction design should not be used for auctioning networks. The auction design works for non-predefined links because the links are divided into blocks of equal sizes and are priced equally (e.g. a G lot with a reserve transfer value of $20m and a B lot with a reserve transfer value of $10m). When auctioning predefined links, whole links, there could be one link with a transfer value of £40m and one link with a transfer value of $20m. With quite different transfer values, the pure package clock auction does not work well. If different length of links were grouped and priced on average, we could end up having unprofitable long links and too expensive short links. However, careful pre-definition of blocks of equal value by the auctioneer can address this, in the same way as spectrum auctioneers (for example, the Federal Communications Commission in the United States or the National Frequency Planning Group in the UK) divide up spectrum band lots. The same can be done by, for example, the Crown Estate (UK) for offshore transmission and Movia (Denmark) for bus routes.

When auctioning whole predefined links, the package clock auction could work, if the auctioneer chooses to subdivide the links into a number of smaller groups of approximately the same transfer value. Placing the links into groups means that an auctioneer can place a reserve transfer value for every group of links of approximately the same length and running a principal stage is possible. However, the more groups there are, the more undesirable the package clock auction is. If further groups are added, then the principal stage becomes sufficiently complex as to make it impractical for bidders to think through the various package combinations. Therefore, in order to reduce the complexity and the uncertainty, it makes sense to use an auction design where lots are sold individually. Another problem is the pre-commitment to financing a whole area which is planned to be built in steps over a number of years. Our auction could be applied to smaller areas where synergies are thought to exist and might work better because of the associated reduction in bidding complexity.

## V. Conclusion

We have presented a block (lot) structure and an auction design where bidders might propose and build different network configurations and where bidding for packages is a possibility.

We have shown that the package clock auction can work well in the market for network designing provided that the links are divided up in blocks of equal financial size; likewise for the connection points.

Interestingly, our auction gives the bidders more options. It gives the bidders a reserve configuration, as illustrated in Figure 2, and if the market can see alternative or more cost efficient configurations, the auction also allows the bidders to propose these alternative configurations. Figure 2 could be the optimal configuration, but our auction will show whether this is true. The market configuration allows this to be revealed.

We have shown that our set-up can provide the bidders and auctioneer the same security as auctioning a predefined configuration by having a reserve configuration. This provides confidence and a cap on costs/a maximum on the transfer values. The freedom to propose alternative configurations can only provide lower costs/transfer values.

When auctioning whole predefined links, the package clock auction could work if the auctioneer chooses to subdivide the links into a number of smaller groups of approximately the same transfer value within each group. However, a higher number of groups make the package clock auction more undesirable. In this situation, it makes sense to use a different auction design.

It is typical that auctioneers need to consider factors other than price (cost in our case). The case for taking factors other than price into account is important, but can be studied independently of the price-only auctions. If non-monetary factors are to be part of the auction, the two-phase multiple factor auction is best-suited for auctioning networks (Ausubel and Cramton, 2011b). The first phase evaluates non-monetary factors, and the second the chosen price-only auction design.

Other added features could improve the auction result, for example, eligibility points, features to secure entry, and to prevent collusion and predatory behaviour (see Ausubel and Cramton, 2011a; Klemperer, 1999).

To conclude, we have shown that it is possible to create a block structure together with procurement auction that can bring the auction result closer to efficiency and optimality.

## APPENDIX. THE RULES OF THE AUCTION

*Rule 1: Reserve configuration and transfer value are based on Figure 2*: This rule ensures that bidders will have a network configuration which they can follow and confidently bid on. The auctioneer can identify feasible bidding strategies and may know the possible cost and outcome of the auction.

Without such rules and conditions, the introduction of the freedom to propose different configurations can be complicated for the bidders and expensive for the auctioneer. Nevertheless, this freedom implies that there may exist different or maybe even more cost-efficient configurations other than a predefined configuration that serves as a cap. The bidders can then bid different suggestions if they see a more cost-efficient way to structure the technology, and so the auction can reach efficiency and optimality.

The auctioneer needs then to define a reserve configuration and a reserve transfer value. Here, we use Figure 2 as a reserve configuration.

Notice, any configuration (i.e. another central configuration) could also be the chosen figure to divide into blocks. The auctioneer decides this.

*Rules 2-3: Links and connection points are divided into blocks*: Similar to spectrum bands, links and connection points will be auctioned on a geographic basis: a subdivision of a number of smaller blocks that can be auctioned off. The bidders will bid for these blocks, and aggregate them so as to best serve their business plans.

We divide the links and connection points into blocks. Due to the lengths of the links and possible differences between lengths, these are divided into blocks of the same financial size. The connection points are divided into blocks where one block contains one connection point. Through this division into blocks, the bidders enjoy the flexibility and freedom to propose different configurations, to mix and to reconfigure their most desired project within the area(s) being auctioned.

*Rule 4: There is a maximum number of blocks per link and per connection point*: Rule 4 is designed to provide some sort of cap which would prevent an over expensive network. For example, it stops bidders from winning a link consisting of 6 B blocks, if it can be built using 3 B blocks. The idea is the same for the connection points. Each block has a reserve transfer value per block, for example $10m per block (and therefore, a maximum transfer value per block of $10m). This means that a link that has a reserve transfer value of $30m cannot end up paying out a transfer value of $60m. This rule imposes a maximum on the transfer values and simultaneously allows the bidders the opportunity to propose different configurations that in total are equal to, or below the reserve transfer value.

*Rule 5: There is a maximum on the number of bids on each block*: If an auctioneer wants to secure diversity inside a network, then rule 5 is important. For example, consider an auctioneer that wants two connection points in G areas, and so, there has to be an exit from both G1 and G2 – one link connected to G1 and one link connected to G2. To prevent bidders from suggesting only one connection from G areas, for example, only an exit from G1, the auctioneer can set a maximum of one bid on each G block. Hence, it is not possible to have two links connected to, for example, G1. This gives the auctioneer a guarantee that bidders will suggest two connection points in G areas. Therefore, a maximum on the number of bids on each block secures diversity.

*Rule 6: Transfer values are contingent on winning bidders being able to meet target levels of network availability*: An optimal network, in the case where the transfer value is to be paid out, depends on coordination between bidders. Three things are of interest to us. First, we want assets that facilitate flow: namely, that they can provide services to end customers. Second, we want a flow through all links and connection points at lowest possible costs, in other words, an optimal network, an optimal use of the transfer value. Third, we want to give all potential bidders the opportunity to participate in the auction, e.g. bidders that wish to bid on whole networks and bidders that only want to build just part of a network. To secure a complete network where all assets are built at the lowest possible cost at the right place, we need bidders in some way to make bids which exploit synergies (i.e. make complete links or blocks of links) or correctly anticipate the interests of other bidders (a bidder interested in connection points anticipates that there are others more interested in bidding for links).

Rule 6 guarantees this. It says that the transfer value will be contingent on winning bidders providing target levels of network availability. Thus, for example, in the area of offshore transmission, the transfer value could be contingent on wind parks being provided with target levels of available transmission export capacity to the onshore grid. Or following our Figure 2 - all desired capacity has to be delivered from connecting R and G areas. The target levels could be assessed after the number of blocks for sale in the auction. This means that all bidders are responsible for securing that all parts of the networks are active in order to claim their part of the transfer value. Thus, even if a bidder builds part of a network, its transfer value may rely on other bidders in the auction delivering their assets. This ensures that bidders cannot bid to partly configure a network which other bidders will not bid to complete.

Rule 6 promotes physical network coordination and the optimal use of the transfer value because transfer values are linked to winning bidders physically being able to provide the service.

The auctioneer decides whether these target levels are likely to be met after the auction. Hence and importantly for the rest of this paper, these target levels are independent of the auction process and will not be discussed further here.

Two points are interesting – the optimal use of blocks for sale and collusion. The optimal use of blocks is secured through competition. Bidders compete for blocks in a procurement auction which promotes the minimum use of blocks/optimal use of blocks. This means that some blocks can go unsold, which in our case, if all target levels are met, is a sign of efficiency and "optimality".

In order to secure something close to an optimal network, the auction has to invite bidders to consider how their bids are likely to "co-ordinate" with those of other bidders. One could say that the auction invites bidders to collude. Collusion is a problem if competing bidders agree up front simply to split the transfer value, having bid uncompetitively on a part of the network. However, the issue may not be significant since a network (that is to say a larger real-life network than illustrated above) offers loop flow possibilities and security value, but does not stop flow on a pathway altogether. However, in order to reduce any possible scope for collusion between bidders, one rule might be that winning bidders for a part of the network have to facilitate interconnection with other parts of the network, and so cannot withhold interconnection ex post. There is a similar rule in the spectrum auctions where different countries co-ordinate to connect the different frequency bands (see Ofcom, 2008). Part of the contracts is the stipulation that the winners of the auction have to facilitate the deployment of systems operating in neighboring countries.

*Rule 7: A winning bidder for part of a network has to facilitate interconnection with other parts of the network*: See rule 6.

*Rule 8: Sale of unsold assets if blocks are needed after the assignment stage*: Imagine the example where two bidders submit bids on blocks in the principal stage. Bidder 1 wins two blocks and bidder 2 wins three blocks. Before the assignment stage, both bidders desire to bid on the same blocks. Assume that the principal stage shows that the reserve configuration is not optimal, that is, the auction leaves some blocks unsold. Further, assume that bidder 2 wins the desired link in the assignment stage, (for example, the upper black line in Figure 2), but bidder 1 needs one block to be allocated the last unsold link, (for example, the lower black line), a block to a connection point. Consider the following situations:

(i) If all blocks are sold after the principal stage, all expected assets can be allocated after the assignment stage.

(ii) If a lower number of blocks are sold after the principal stage, all expected assets can be allocated after the assignment stage.

(iii) If all blocks are not sold after the principal stage and assets are needed to meet rule 6 after the assignment stage, and if a bidder needs blocks to connect assets between R, G and B areas, blocks can be sold after the assignment stage at the bidders' lowest cost submitted in the principal stage. If no bid is submitted on a specific object (a R, a G or a B block) in the principal stage, blocks can be sold after the assignment stage at a cost defined after an auctioneer evaluation. Information about unsold assets is not available to the bidders before the end of the assignment stage.

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