HANDLING CONDITIONS ON LOTS IN TENDERS

Bachelor assignment

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ABSTRACT

Tendering in lots is strongly encouraged in the most recent EU directives on public procurement. However, unconditionally tendering in lots may suppress dependencies between lots, resulting in failing to achieve maximum value for money for the taxpayer.

Conditions on lots allow buyers and suppliers to express dependencies between lots, enabling them to attain cost-effectiveness and impact procurement policy opportunities. These conditions have been effective in private procurement, as shown by anecdotal success cases. However, use is limited in the public sector, despite showing that significant advances in attaining value for money and policy opportunities can be made. The research objective of this thesis is to tackle the potential problem drivers behind the limited use of conditions in the public sector to encourage future use. Four main problem drivers emerge; lack of knowledge on the benefits of conditions, difficulty of formulation and optimization and ambiguity regarding legality of implementing conditions.

To tackle these problems, a study of literature and practice cases is conducted, enumerating conditions that may add to either buyer or supplier procurement objectives. After that, the difficulty of formulating these conditions as mathematical programming problems is analysed, after which their respective methods of optimization and associated software are explored. Finally, the legality of these conditions is considered.

Ultimately, numerous reasons to employ conditions emerge, they can add value to various socioeconomic procurement policy objectives for both buying and supplying parties. Many conditions are relatively easy to formulate for procurers using mathematical programming, where computational complexity is hardly ever troublesome. Software packages such as Excel's built-in solver can be used as a hands-on alternative to more expensive commercial software packages for optimizing combinations of conditions.

The EU directive on public procurement provides limited clarity on the legality of conditions. Deriving from the conditions that are explicitly mentioned in the directive, analysis provides that many conditions are presumably legal in EU- public procurement. Finding that conditions on lots in tenders are relatively easy to handle, the path for increased future use in tenders by contracting authorities is paved.

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1 INTRODUCTION

The average spend on tenders as a percentage of government expenditure is around 30% in OECD countries (OECD, 2015). The sheer volume of these tenders may give public contracting authorities the ability to support broader government objectives. Increasingly, governmental bodies view public procurement as a means of leveraging strategic policy (European Commision, 2011), for instance to facilitate SME participation in tenders. The EU obliges contracting authorities to tender in lots, otherwise requiring a justification not to tender in lots in an effort to reduce large contract values that are seen as obstacles by SMEs.

In the Netherlands, around 6% of tenders are divided into lots (TenderNed, sd). These divisions allow contracting authorities to pursue social and economic procurement objectives to some extent, such as facilitating SME participation. However, simply tendering in lots without adding conditions to them potentially supresses full social- and economic value for money for contracting authorities.

Dividing into lots and applying unconditional bids on these lots effectively divides tenders into many small segments where lots are independent of each other. However, lots can only be considered as independent when suppliers cost for one or more lots is independent of how many of them they are awarded, where their cost for supplying an additional lot is constant. Next to that, they can only be regarded independent when the contracting authorities are indifferent about the allocation of winners, disregarding strategic interest and implications. In practice; these considerations cause lots to be hardly ever independent of each other, illustrating a potential loss in value for money in the status quo when tendering in lots.

In practice, suppliers experience dependencies in the awarding of the number of lots they wish to receive. Any supplier can submit their most competitive bids only when they can formulate these dependencies on the bidding sheet. Dependencies between lots exist whereas supplying parties are unable to express these in unconditional bids on multiple lots. Buyers may experience dependencies between lots in their strategic interest. For instance; they may have a motive for a great number of winning suppliers, in order to preserve competition and limit supplier liability. This consideration cannot be handled in normal tenders divided into lots; as they cannot constrain the allocation of bids. A step in the direction to impact policy and maximise value for money may be to promote the use of conditions on lots, so that these dependencies can be expressed by buyers and suppliers.

Limiting supplier liability by adding conditions

Consider a simple example where there are two bidders for three lots, as shown in table 1. In a normal tender divided into lots, bidder 1 will win lots A, B and C at a combined cost of €30. However, the contracting authority may have natural incentive to limit supplier liability, in order to preserve future competition and mitigate collusion risks. When introducing the condition that no bidder can win more than 2 lots, a new allocation is given, as highlighted in table 1. The added cost for the contracting authority is €1, due to bidder 2 winning lot A. This premium of €1 represents a small fraction of tender cost (€31). In this case, the contracting authority may be well-willing to add this premium to limit supplier liability.

Allocation before adding condition, Total spend: **€30**			
	Lot A	Lot B	Lot C
Bidder 1	10	10	10
Bidder 2	11	12	13

Allocation after adding condition, Total spend: **€31**			
	Lot A	Lot B	Lot C
Bidder 1	10	10	10
Bidder 2	11	12	13

Table 1: Adding a condition to limit supplier liability

Suppliers can experience economies of scale or capacity constraints, linked to the number of lots they receive. These associations cannot be fully expressed in unconditional bids on multiple lots. A result of this is that the contracting authorities are unable to benefit from potential lower prices that may be introduced by suppliers when they can reflect these dependencies in their bids. Allowing suppliers to express their interest in these complementary lots by stating that they wish to be awarded both lots or none allows them to submit more competitive bids, mitigating the exposure problem of being awarded a number of lots outside their capacity. Alternatively, buyers themselves may wish to introduce dependencies between lots to deliver social- and economic procurement policy objectives by using conditions, such as facilitating SME participation, preserving competition or reducing supplier liability.

There are many conditions that can provide value for money to both social- and economic opportunities. The use of conditions on lots is however minimal in public procurement, while use in private tenders has created evident success cases in the past. The root cause to this lack of use of conditions may be attributed to several problems. The aim of this thesis is to tackle these problems by classifying the difficulty of handling conditions on lots in public procurement for contracting authorities, increasing familiarity and resolving problems that may be the basis to the rare use in public procurement. Assessing the difficulty of handling conditions will be done regarding several aspects; analysing the benefits of conditions, difficulty of formulation and optimization and the legality of using conditions.

1.1 PROBLEM STATEMENT

In advance of the 2014 EU directives on public procurement, the European Commission constructed a *problem tree for the modernisation of public procurement* (European Commision, 2011), displayed in figure 1. Evaluating the directives introduced in 2004 they find areas wherein there may be opportunities to: “improve further the existing public procurement environment and enable the full potential of the Internal Market for public procurement to be realized.”

Two of the problem areas that are described as causes to the internal market of public procurement not achieving its full potential are “insufficient cost-efficiency of procurement” and “missed opportunities for society and sub-optimal cost efficiency of procurement”, through which “the best value for money is not achieved”. Numerous problem drivers that are root to these problems are described, several of which remain (to some degree) after the introduction of the most recent (2014) EU directives.

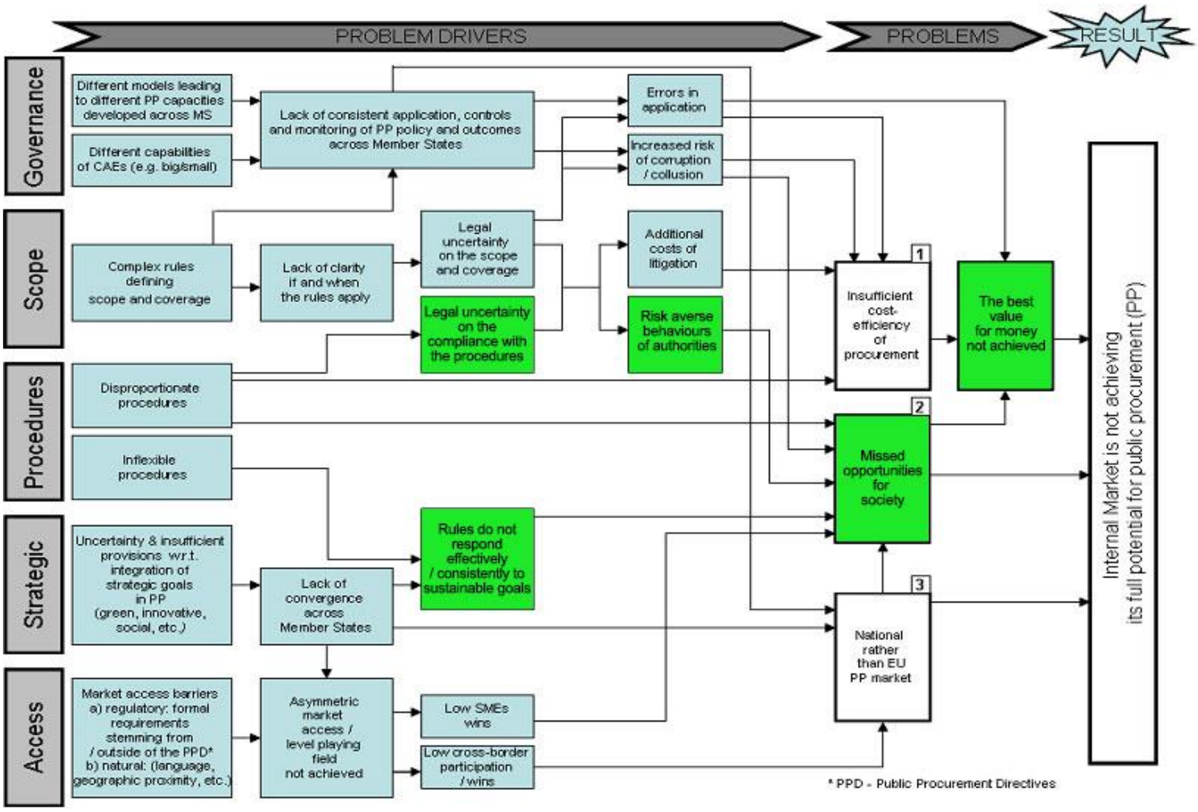


Figure 1: Problem tree for modernisation of public procurement (Impact Assessment European Commission 2011)

The result in the problem tree may be viewed analogous to the market not achieving full potential due to the lack of use of conditions on lots, because dependencies on lots are not regarded in regular tenders. Several of the problem drivers (highlighted in figure 1) can be tackled by implementing conditions or by creating awareness on the applications of effective conditions, an example is illustrated in the introduction, allowing suppliers to reflect dependencies between lots potentially results in more competitive bids, achieving better value for money.

An area in which the problem drivers persist to inhibit the full potential of the market for public procurement is the (lack of) use of conditions on lots. Theory and private procurement practice show that the use of conditions on lots in tenders may realize currently untouched benefits on reaching cost-efficiencies in procurement and effecting opportunities for society, wherein the benefits with respect to this technique are plentiful. There are numerous examples of significant savings made in procurement spend by adding conditions BRON, next to that conditions may add to social policy in public tenders extending their effectiveness to effect opportunities for society next to achieving better value for money.

Moreover, the substandard use and awareness of conditions in public procurement is illustrated by the presence of the numerous software solutions for implementing advanced conditions that are used by private companies, and the fact that the conditions are only minimally touched upon in the 2014 EU directive on public procurement, article 46 allows limiting the number of lots awarded to any winner.

There seems to be a discrepancy between the potential and current use of conditions on lots, inhibiting the key EU procurement objective: achieving value for money for taxpayers. The core problem is derived from the previous arguments: Conditional purchasing is rarely used in the public sector. Several problems may be root to its limited use. One of these is that the contract authorities are simply not aware of the broad range of conditions; and the benefits they carry. While the procurers may be familiar with the notion of conditions; formulating them to a tender is another task. The formulation requires mathematical programming, which may be unfamiliar to buyers. After formulating, these conditions require optimization to find the optimal allocations, for which there are numerous software solutions that may be similarly unfamiliar. Furthermore, the problem tree in figure 1 shows legal uncertainty as one of the problem drivers, which may cause risk-averse behaviour and a box-ticking approach; inhibiting innovative approaches to tenders such as conditions on lots.

Conditional purchasing is rarely used in the public sector	• Available conditions may not be directly discernible for the procurer; they may be unfamiliar with the benefits that conditions may have to attain economic- and social procurement objectives
	• Methods of formulating conditions may be unknown
	• Methods of optimizing conditions may be unknown
	• Legal uncertainty on the use of conditions may cause risk-averse behaviour and lack of use.

Table 2: Research problems

1.2 RESEARCH QUESTIONS & METHODOLOGY

In section 1, problems that may be root to the limited use of conditions by public procurers were found. This thesis will tackle those problems, but only after displaying the benefits that conditions can have towards influencing the objectives as seen in section 1.2, to stress the foundation for the use of conditions. The problems and corresponding research questions are displayed in table 3.

Research problems	**Research questions**
Available conditions may not be directly discernible for the procurer; they may be unfamiliar with the benefits that conditions may have to attain economic- and social procurement objectives	(2 + 3) Which conditions, that fit societal, technical or economic policy can be applied to tenders?
Methods of formulating conditions may be unknown	(4) How can these conditions be formulated for optimization, and how can they be solved accurately?
Methods of optimizing conditions may be unknown	(5 + 6) What is the required optimisation method and estimated cost for implementing a specific condition?
Legal uncertainty on the use of conditions may cause risk-averse behaviour and lack of use.	(7) Is the use of conditions legal?

Table 3: Research questions

The second chapter will cover the benefits of using conditions, to effectively pursue value for money for society the benefits of using conditions in pursuing value for money will be described. This will be done by demonstrating how conditions can add to fulfilling procurement policy; such as economic policy in limiting supplier liability and collusion, next to the contribution of conditions to achieving societal goals such as increasing SME participation or encouraging local bidders. These illustrations are retrieved from literature or empirical evidence showing the advances that conditions make towards achieving value for money optima. Furthermore, the effect of increased expressiveness for suppliers on tender cost will be studied. By tackling these topics using examples from literature and tender practice, a list of conditions that can be used for tenders will be enumerated.

To stress the importance of modelling conditions to the award procedure, inferior design methods of achieving procurement policy will be demonstrated and compared in chapter 3.

To implement these conditions, they must be formulated as (multiple) constraints in mathematical programming problems. These formulations differ vastly, as we will discover by analysing how similar problems can be expressed as mathematical programming problems in chapter 4.

These conditions may differ vastly in the required methods of optimization. These methods differ in complexity, which affects the potential to find allocations that are global optima, and the necessity for using advanced software. This complexity will be analysed in chapter 5

There are numerous software solutions that allow the procurer to resolve combinations of conditions on a tender. These range from more hands-on approaches such as Excel's Solver to private software solutions that allow contracting authorities to translate implement these tenders and their respective conditions easily. To examine the added value of these private software solutions, several interviews will be conducted. These will introduce a valuation of the cost-effectiveness of

Next to that, we will demonstrate the implementation of these conditions in Excel's add-in Solver. The demonstration of the use of these software solutions should allow contracting authorities to make the trade-off between choosing software for handling conditions.

In the prior chapters, legality of conditions will be assumed, whereas they may not coincide with procurement law. Procurers fear for litigation is one of the key areas inhibiting cost-efficiency (European Commision, 2011). Therefore, the most recent EU directives on public procurement will be used to analyse the legality of each condition, as domestic law varies more greatly.

1.3 SCOPE

Public contracts are generally awarded in the common format of tendering (Soudry, 2004); the (reverse) first-price sealed auction. In this procedure, each bidder submits bids on one time-interval independently, not knowing bids of other participants, where the contract is awarded to the lowest cost, or most economically advantageous bidder. This thesis solely regards this method of tendering, as other tender formats may differ in implications on conditions, strategy, policy and formulation- and optimization methods.

This thesis will focus mainly on EU public procurement objectives and guidelines, assessed through the EU impact assessment (2011) and directives (2014) on public procurement, as worldwide public procurement targets and laws vary greatly. For instance, the US promotes set-asides for SMEs in tenders, whereas the EU public procurement objectives target equal access opportunities for SMEs and large enterprises (GHK, 2010), creating differences in legality and the potential use of conditions. The legality of the conditions tackled will be disregarded until chapter 7, where their respective legality will be assessed guided by the 2014 EU directives on public procurement.

1.4 RESEARCH OBJECTIVE

Ultimately the objective of this thesis is to give public procurers insight in the difficulty of handling conditions. Removing obstacles that prevent them from using conditions, and providing guidance on how to handle conditions may cause public procurers to implement them and obtain more value for money. The results may therefore be interesting to public procurement authorities as conditions can significantly contribute to impact public procurement objectives constructed by the European Commission (appendix D), as shown in chapter 3 of this thesis.

2 INFERIOR METHODS: DEFICIENT DESIGN RESULTING IN INEFFICIENCY

There is a clear distinction in efficiency between applying conditions before and at the award procedure. In this chapter, we will demonstrate that implementing conditions before the award procedure is suboptimal from an economic perception, so that the necessity of adding them in the award procedure instead of the bidding sheet becomes apparent.

Achieving the objective of limiting supplier liability may be done in several ways. One includes limiting the number of lots that a supplier can bid for on their bidding sheet, which does not restrict the award procedure itself. An alternative method of achieving a similar outcome is by introducing a condition in the award procedure. This condition maximizes the number of lots that can be won by any supplier in the award procedure itself. The difference is that the latter method generates a larger solution space: the number of submitted bids is greater, which generates a more probable chance of lowering total tender cost for the buyer. The former method, not using conditions, is a suboptimal method from an economic outlook, where the number of bids submitted is restricted prior to the award procedure.

Two different methods of applying conditions before the award procedure are covered.

1. Consider scenario 1 in table 4 where bidders are restricted to bid on a maximum of two lots, fitting the former method, and the latter scenario 2 where bidders are restricted to winning a maximum of two lots. In scenario 1, bidder 1 decides to bid only on lots A and B, because it is indifferent about winning any two lots, and bidder 2 decides to bid on lots A and C, excluding their highest cost bid for lot B. This combination amounts to a total procurement spend of 33. In scenario 2, their expressiveness increases, allowing them to bid on all lots, as they are constrained to win only two in the award procedure. Scenario 2 benefits the procurer as their desired outcome of limiting supplier liability (more than one winning supplier) is maintained while cost decreases.

Scenario 1, spend: **€33**			
	Lot A	Lot B	Lot C
Bidder 1	**10**	**10**	*10*
Bidder 2	11	*15*	**13**

Scenario 2, spend: **€31**			
	Lot A	Lot B	Lot C
Bidder 1	10	**10**	**10**
Bidder 2	**11**	15	13

Table 4: Increasing supplier's expressiveness lowers cost

2. Restricting the number of lots won by any supplier can be done in several ways. One of these is to introduce sequential bids for lots, where a supplier is excluded from bidding in subsequent rounds when they have won the maximum allowed number of lots. It is easy to spot that this creates an inefficient allocation. Bidders are excluded from bidding in farther rounds, whereas they may have submitted the lowest cost bids for lots in those rounds.
The described inefficiency follows a principle similar to the one demonstrated earlier, where decreased supplier expressiveness heightens cost. Consider Table 4 again, where in scenario 1, bidders would be constrained to stop bidding after they have won two lots. Lot A, B and C would be awarded sequentially. In this case, bidder 1 would be excluded after winning both lots A and B, granting lot C to bidder 2. Now scenario 2, where bidding is constrained only in the award procedure, where a maximum of two lots can be assigned to one supplier. Impacting the same the objective of limiting supplier liability by limiting the number of lots that can be bid on, the spend is lowered while in this case maintaining the objective of limiting the number of lots won.

The key takeaway from these examples is that the number of bids should not be restricted. The previous examples illustrate that the use of these simple, less burdensome methods of applying conditions on the bidding sheet instead of the award procedure are deficient from an economic perspective. This stems from the fact that they limit the expressiveness of suppliers and the number of potential tender outcomes prior to the allocation, therefore potentially heightening tender cost for the procurer, whereas they could have been efficient by adding conditions, which adhere to the exact same procurement objectives, only in the award procedure stage of a tender.

3 THE BENEFITS OF AVAILABLE CONDITIONS

Normally the objective function of public contracting authorities (CAs) is to award by selecting the lowest-cost or most economically advantageous bids for each single lot available in a tender. Conditions directly constraint the solution space for the objective function in the award procedure of a tender. These constraints are likely to result in an increase in direct spend. However, the increase in allocation cost does not imply that conditions always increase spending. Consider the situation where a supplier wishes to implement the condition of not being awarded more lots than they can supply. In theory, this would increase cost for the CA, as the number of bids in the solution space reduces. However, this expression by the supplier may have caused them to bid on more lots; as they will not be awarded a number outside their capacity; ultimately increasing competition and reducing cost.

This is an example of an economic condition that increases expressiveness for the supplier, resulting in lower cost bids. Conditions may also impact opportunities for society, such as creating a lower bound on the number of winning suppliers to promote small supplier participation. The benefits of a wide array of conditions will be covered in this chapter, after which a list of conditions will be constructed, so that their difficulty of formulation, optimization and legality can be assessed.

3.1 USING CONDITIONS TO PURSUE ECONOMIC PROCUREMENT POLICY

Conditions can be used to support economic policy. They may be used to aid the fight against corruption, preserve competition and improve (indirect) cost-efficiency. The conditions contributing to economic policy will be tackled in this section.

3.1.1 PRESERVING COMPETITION FOR TENDERS AND LIMITING SUPPLIER LIABILITY

Competition for tenders encourages innovation and reduces the risks of collusion. Lock-in represents the scenario where the procurer ends up locked in with one winning supplier. This short term (one-time) competitiveness for a tender is beneficial only once. However, when works, good or services are expected to be tendered for more frequently in the future, the present allocation may have significant adverse effects on competition. The present tender outcome may cause smaller parties that are dependent on the tender to go out of business, not returning and therefore reducing competition for future tenders.

Division into lots are a significant step in preserving competition, because the chance of a greater number of winning suppliers increases, as smaller suppliers see great contract values as obstacles in bidding (Pwc, London Economics, Ecorys, 2011), and specific lots may fit better to local suppliers. The chance of lock-in does however remain. Conditions that reduce the potential occurrence of lock-in include introducing lower bound on the number of winning suppliers or an upper bound on the number of lots that they can win, so that supplier liability is limited. In the first of a recurring tender, these conditions is likely to increase tender spend, but that increase could is unlikely to outweigh the potential negative lock-in and supplier liability effects. Next to that, the use of dual sourcing is empirically proven to: reduce informational asymmetries between suppliers, inducing more aggressive bidding in subsequent tenders, and give the procurer more leverage over non-contractible dimensions of product quality (Lyon, 2000).

3.1.2 Minimizing the incentive for collusion: Aiding the fight against corruption

There is limited theory with regards to the optimal number of lots that should be tendered for, however, (Linthorst, Telgen, & Schotanus, 2008) describe several factors that may influence the degree of bundling for goods and services. These include dependencies, economies of scale, competition and purchasing effort.

The likelihood of collusion occurring changes with the types of bidders (large/small, incumbent/entrant) and the number of lots, and thus the initial degree of bundling into lots by the buyer. A prescription that emerges from literature is that the number of lots should be smaller than the number of participants (Klemperer, 2004). Where this is not the case, competition may be hampered resulting in a greater incentive for collusion and inefficient allocations.

A key general procurement objective of the European Commission (table 2) is to aid the fight against corruption and collusion in public procurement. The division of contracts into lots influences participation, competition and therefore the incentives for collusion in tenders. The division ultimately determines the potential for splitting it among competitors; or the potential for agreeing on explicit collusive measures to inflate tender prices (Grimm, Pacini, Spagnolo, & Zanza, 2006), where a larger number of participants generally results in more competition and less incentives for collusion.

Aiding the fight against corruption may be enhanced by introducing conditions on these lots. The general prescription is to increase competition for lots, making collusive allocations more difficult. In the previous section conditions that may increase competition were described, they may be fit to reduce collusive incentives as well.

In unconditional tenders in lots, small suppliers may have incentive to collude with each other, due to the exposure problem. In unconditional tenders with many lots, their limited effective capacity will cause them to bid on a constrained number of lots, resulting in arranging to division in their bids on lots with other small suppliers. By allowing these suppliers to express the maximum number of lots they can handle, they will submit more bids increasing competition and reducing the incentive for collusion. Therefore: reducing the exposure problem by increasing suppliers’ expressiveness increases competition for lots, reducing the incentive for collusion.

3.2 Impacting opportunities for society with conditions

One of the specific objectives of the 2011 EU impact assessment on public procurement is to take full advantage of all opportunities to deliver the best possible outcomes for society. In line with this desire, the contribution of conditions to social procurement objectives will be explored in this section.

3.2.1 Increasing SME participation in public tenders

First and foremost, one of the key points that is include in the 2014 EU Directive is that facilitation of the participation of SMEs (small- and medium sized enterprises) in public procurement. Contracting authorities may already encourage the facilitation by splitting a contract into lots, because high contract values are commonly an obstacle to SMEs (GHK, 2010). The aim of facilitating participation can be strengthened significantly by adding conditions to the award procedure. From the buyers perspective, conditions may be introduced that limit the competitiveness of large companies or facilitate the participation of SMEs. Alternatively, allowing SMEs to express their capacity allows them to submit more bids, competing for more lots.

A simple constraint to promote SME participation may be to introduce an upper bound on the number of lots that any supplier can be awarded. By limiting the size of winning procurers, the aptitude for a larger number of winning to suppliers to increases. Accompanied by that increased room for participating suppliers is the possibility for SMEs to be competitive for those lots, facilitating their participation. If the size of lots is heterogeneous, a condition effecting similar results may be to constrain the winning monetary volume of lots.

Alternatively, increasing supplier expressiveness causes small suppliers to submit a greater amount of bids. Permitting suppliers to state the maximum number of lots or the maximum volume they wish to be awarded allows them to submit more bids, increasing their competitiveness and likelihood of winning, as shown in section 3.3.

3.2.2 Facilitating social integration

Reserving for entrants, minimum number of winners, maximum number of lots

Another societal goal that may be realized more effectively by using conditions is the promotion of social integration. The directive (article 36) mentions that “social businesses whose aim is to support the social and professional integration of disabled and disadvantaged persons, such as the unemployed” can play a significant role. However these may not be able to win contracts in regular tender conditions. Therefore, the directive (article 36) states “it is appropriate to provide that member States should be able to reserve the right to participate in award procedures for public contracts or for certain lots thereof to such workshops or business to reserve performance of contracts to the context of sheltered employment programmes.”

To facilitate this, indirect constraints similar to the conditions for the promotion of participation by SMEs can be used. Article (20) of the directive states that the right to participate can be reserved to economic operators who promote social integration. In practice, this allows procurers to reserve a fraction of specified lots of a tender to such economic operators. However, from an economic perspective this may not be most efficient, as we will show in chapter 3. More sensible would be to introduce a condition that these economic operators win at least the specified number of lots in the award procedure, so that their most competitive bids can be awarded to win.

3.3 Reducing cost-efficiency by allowing conditions that increase supplier expressiveness

The previous exampled only included conditions implemented to target buyer objectives, such as limiting supplier liability or preserving competition. Another means of adding value and mitigating supplier problems is to increase supplier expressiveness by allowing them to introduce conditions reflecting their respective capacity and cost drivers. Expressive bids allow suppliers to fit their bids to their cost and capacities; offering their most economically advantageous bids without facing the risk and uncertainty of being awarded a number of lots outside their capacity, or at prices that do not fit their cost in economies of scale. In this section, we will introduce some of these conditions and show how they can help mitigate problems of uncertainty and help achieve economically efficient allocations.

When conditions are added, the solution space of the objective function that minimizes cost is constrained. In theory, this means that adding a condition that is subject to the objective function will never potentially lower cost. However, this hypothesis may be false with respect to the potential implied reduction of cost for suppliers that is not directly reflected in the cost of their bids. The implied reduction of cost is realised in subsequent tenders, or by increasing the expressiveness for the supplier, by allowing them to add conditions to the award procedure, this addition potentially lowers the value of bids or increases the number of bids in advance of the allocation.

3.3.1 Mitigating exposure risk

An example of this implied reduction of cost is the limitation of the exposure risk by adding constraints. Small scale suppliers face exposure risk when bidding for a number of lots greater than they can supply, or outside their expected capacity. This results in small-scale suppliers submitting a lower number of bids than the potential number of winnings bids from them, or it may result in submitting high prices for all lots.

The exposure risk can affect small and large suppliers. Large suppliers face the risk of bidding on a lot not knowing if they will receive the other that they included in the calculation of the height of their bids, which may be lower due to the presence of economies of scale.

Table 5 regards exposure risk for smaller suppliers. Consider scenario X where supplier 1 can bid competitively on either lot A or B exclusively for the same price. Due to their limited capacity, they are unable to submit both lots, where they suffer significant additional cost when they win a second lot. Therefore, supplier 1 decides to submit a bid for just lot A, due to the risk of being exposed to winning more lots than their capacity if they submit on both. Supplier 2 can bid on lots A and B, albeit the bid for lot A being more competitive for them. The result of this is that the total cost of the tender is €13.

Solutions to reducing this exposure problem include the possibilities for bidder 1 to express that they wish to win a maximum of one lot, prior to the award procedure. By introducing this condition, the total number of lots that they bid for will increase, and in theory reduce cost by increasing competition for lots. In scenario Y, bidders may express the maximum number of lots they wish to be assigned in the award procedure. Bidder 1 is indifferent about winning either lot A or B, they bid €4 on both, expressing that they wish to be awarded a maximum of 1 lot, restricted by their capacity. This simple condition is an example that has lowered the total spend by increasing the number of bids.

Scenario X, spend: **€13**			Scenario Y, spend: **€11**		
	Lot A	Lot B		Lot A	Lot B
Bidder 1	**4**	x	Bidder 1	4	**4**
Bidder 2	7	**9**	Bidder 2	**7**	9

Table 5: Illustrating exposure risk

3.3.2 INTRODUCING DISCOUNTS

Suppliers may seek to introduce discounts for various reasons. For instance, consider a tender where fixed cost is relatively high compared to marginal cost for all suppliers. A supplier may seek to offer progressive discounts where each additional lot won provides a discount, because supplying additional lots becomes marginally less expensive.

Similarly, they may offer business volume discounts where a certain monetary volume of awarded business allows a supplier to offer a discount on their bids. An example of this can be a threshold above which they can add an extra vehicle, or extra personnel which may contribute to a lower cost tender, that they can express through adding discount conditions.

3.3.3 INTRODUCING PACKAGE BIDS FOR SUPPLIERS

Suppliers may be well-willing to submit lower prices for combinations of lots when the cost for supplying the sum of the lots in the combination is lower than supplying the distinct lots. This difference may stem from a sizable fixed cost investment that is required to serve any of the lots, whereas the marginal cost for supplying another lot decreases.

When tendering unconstrained single lots where complementarities exist, bidding suppliers may not bid competitively because of the exposure problem that occurs. The cost structure for supplying a multitude of lots depends on the combination of lots they are awarded. Because they bid on one of the lots unaware of winning their complements, they risk of being exposed to winning only one of the lots out of the package that reflects their true bid value. This risk may cause them to refrain from bidding aggressively (Dimitri, Pacini, Pagnozzi, & Spagnolo, 2006).

Consider Table 6, Bidder 1 has a cost scheme, where fixed cost is high and marginal cost is low, allowing them to bid aggressively on a package of lots, so that they can fully express positive complements. This demonstrates the maximum effectiveness of package bids, as in theory the exact cost structure can be portrayed in the package bids of any supplier.

In section 3.3.1, a condition that solves the exposure problem of being awarded too many lots was introduced: allowing the suppliers to express an upper bound on the number of lots that they wish to be awarded. This is a solid condition that solves the potential exposure problem, however, true synergies can be fully expressed by allowing the suppliers to submit bids in packages.

Negative complements between lots can be expressed by submitting a higher bid for a combination of lots. Consider table 6, where the bids by bidder 2 are shown. The package (A, B) allows them to convey the negative complements for them when being awarded both lots A and B, allowing them to submit competitive bids on both lots A and B, because they will not be awarded the package of lots. When package bids would be prohibited, bidder 2 would only bid on one of the two lots; lowering the total number of bids and the competition for lots, potentially increasing lot prices.

	Lot A	Lot B	Package (A, B)
Bidder 1	10	10	15
Bidder 2	10	10	99

Table 6: Expressing complements between lots by allowing package bids

Standard package bids are prone several risks, such as lock-ins, predatory bidders or lock-in suppliers. These can be countered by introducing counter-measures on the bidding sheet, such as maximum obligatory standalone bids or additional maximum package discounts. They are described in appendix E.

3.4 List of conditions

In the previous chapters, the respective potential benefits of conditions for buyers and suppliers have been discussed, shaping a list of conditions in Figure 2. In the next chapter, these conditions will be formulated as mathematical programming problems and constraints, so that their complexity and methods of solving can be assessed. Next to that, the implementation of these conditions on the bidding sheet will be analysed.

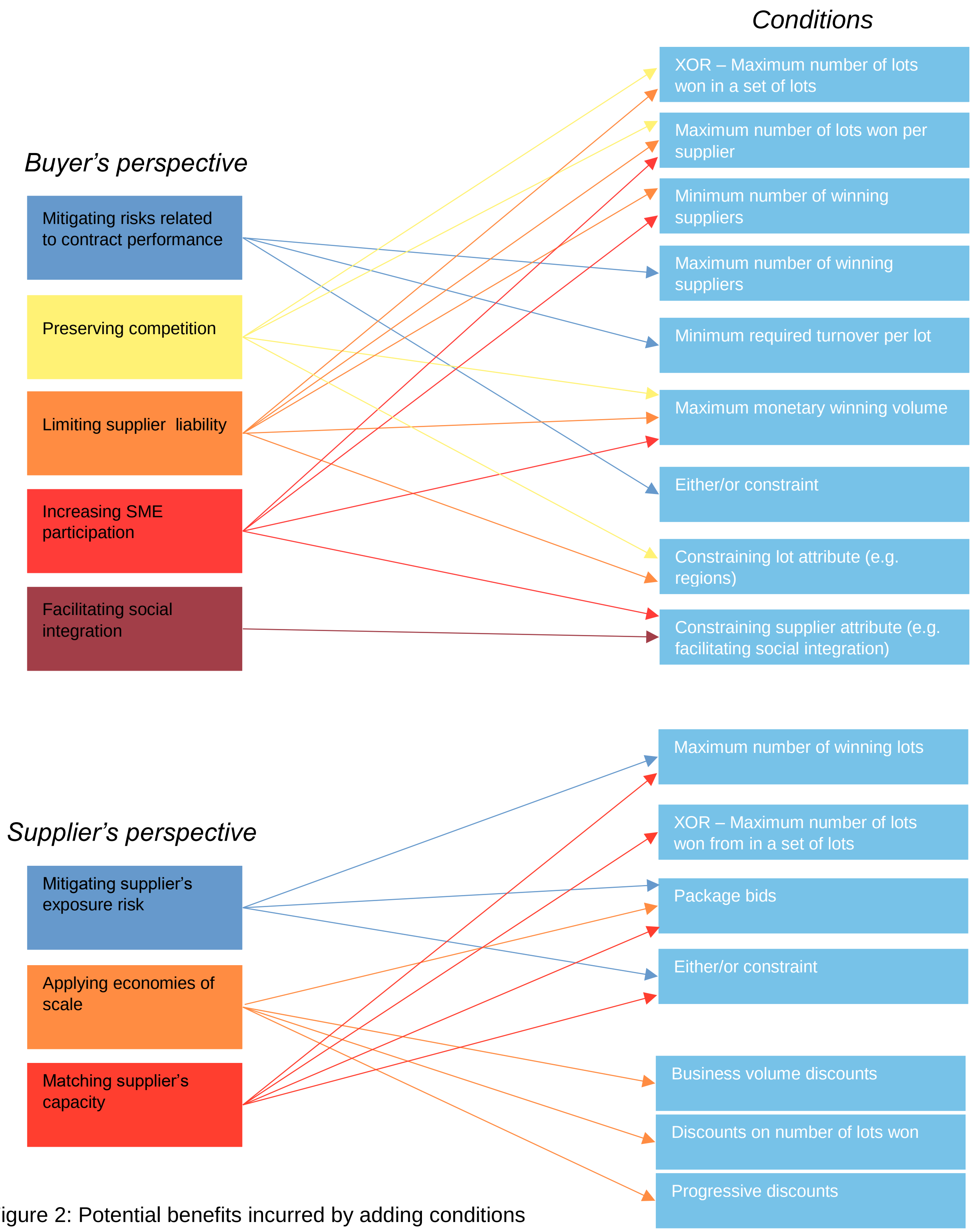


Figure 2: Potential benefits incurred by adding conditions

4 FORMULATING CONDITIONS TO THE AWARD PROCEDURE

As illustrated in the previous chapters, the introduction of conditions in the award procedure may be beneficial for procurers towards realising procurement objectives. Mathematical optimisation can be used to select the combination of lowest cost bids while constrained by conditions that are introduced by the buyer or supplier. These conditions vary in methods and difficulty of optimisation. The methods of optimisation will be explored in this chapter, while the difficulty and complexity will be discussed in chapter 5 and 6.

4.1 LINEAR PROGRAMMING FOR CONDITIONS ON SINGLE LOTS

Conditions on lots can be formulated as mathematical optimisation problems, where an objective function is subject to constraints. For tenders, the objective function is most often to award on lowest cost, or another score. The objective function seeks to minimize this target function, while being constrained by conditions. Some conditions can be formulated in a linear programming problem, where the objective function is linear, constituting no products of variable values.

4.1.1 OBJECTIVE FUNCTION AND MANDATORY CONSTRAINTS

Most tenders use a procedure in which lots are tendered separately, where no bids can be placed on combinations of lots and awarding is done to the lowest cost bids. In this case, the set of suppliers I submits a corresponding set of bids J. These bids can be programmed mathematically as an integer linear programming model. In an unconstrained tender where, finding the lowest cost combination of bids can be formulated as follows:

$$\mathrm{c} = min \sum_{i \in I} \sum_{j \in J} p_{ij} x_{ij}$$

Where p_{ij} is the price offered for lot $j \in J$ by supplier $i \in I$, and x_{ij} is the assignment variable. The sum of the product of variables p_{ij} and x_{ij} determines the prices for a combination of bids.

The goal is to multiply a value of x_{ij}, 0 or 1 with a value of p_{ij} greater than 0, wherein each lot is assigned to at least on supplier, and where every lot is won by at most one supplier. In the coming sections, all conditions will be treated as integer programming problems, but there is a distinction between simple and hard problems, as explained later on in section 4.6. Therefore the values of x_{ij}, 0 or 1 will be constrained to 1. Next to that, constraint (1) is mandatory, so that each lot is won exactly once.

$$\sum_{i \in I} x_{ij} = 1, \qquad \forall j \quad (1)$$

4.1.2 FORMULATING SIMPLE CONDITIONS

Several conditions can be introduced that constrain the objective function of minimizing cost of the linear programming problem. One of these constraints may be the desire from the procurer to limit the number of lots that a bidder wins. Constraint (2) ensures that the sum of winning bids for any supplier is less than the specified number z_1.

$$\sum_{j \in J} x_{ij} \leq z_1, \qquad \forall i \quad (2)$$

Another condition that may be added is an XOR constraint, which states that the awarding of two specific lots is mutually exclusive, which may stem from strategic interest. Constraint (3) specifies that the sum of two lots assigned to a specific supplier, in this case lots 1 and 2, cannot exceeded 1; removing the option of any supplier *i* winning both lots.

$$x_{i1} + x_{i2} \leq 1, \qquad \forall i \quad (3)$$

Additionally, the procurer's intention could be to limit the suppliers in their winning monetary volume, that is the sum of the price of winning bids. In constraint (4), the sum of winning bids by any supplier cannot exceed a value of z_2, which decreases the probability of suppliers winning a great volume and locking-in the procurer.

$$\sum_{j \in J} p_{ij} x_{ij} \leq z_2, \qquad \forall i \quad (4)$$

Constraining turnover, the procurer may wish to introduce a minimum on the turnover of suppliers, for each awarded lot, where t_i is the turnover of supplier *i*. In constraint (5), the procurer introduces the condition where the turnover of the company must be at least two times greater than the value of the lots awarded to them.

$$2 \sum_{j \in J} p_{ij} x_{ij} \leq t_i, \qquad \forall i \quad (5)$$

4.2 HARD INTEGER PROGRAMMING FOR CONDITIONS ON SINGLE LOTS

Several conditions require the use of logical constraints for implementation. Integer programming (IP) is a suitable method of optimization that allows the tenderer to express these logical constraints. Consequently, difficulty of formulation and complexity of optimization increases. This distinction in formulation will be discussed in 4.6, whereas the difference in complexity will be discussed in section 5.

4.2.1 ADDING CONSTRAINTS SUBJECT TO THE OBJECTIVE FUNCTION

For various reasons, the buyer can choose to constrain the number of suppliers to any minimum or maximum value. By introducing conditions (1) and (2), the number of winning suppliers is limited to a maximum of z_3. The combination of these conditions guarantee that if the sum of all lots x_{ij} is greater than 0 (or: they are allotted an amount great than 0) for any supplier in *I*, y_i must be assigned the value of 1 for supplier *i*, with M_1 being any number greater than the number of lots in *J*. Condition (2) ensures that the sum of these allotments for all suppliers is smaller than the specified maximum number of suppliers z_3. The essential difference between the IP- and LP formulation is that $y_i \in \{0, 1\}$, instead of being assigned a continuous value.

$$\sum_{j \in J} x_{ij} \leq M_1 y_i, \qquad \forall i \quad (1)$$

$$\sum_{i \in I} y_i \leq z_3\,, \qquad (2)$$

4.2.2 Constraining supplier attribute

Contracting authorities may be inclined to restrict any accompanying values for lots or suppliers. An example may be to introduce a minimum bound on the number of winning suppliers promoting social integration. Consider a binary constant $n_i \in \{0, 1\}$, assigned value 1 if the supplier is such an organisation, and value 0 if they are not. The method of implementing this condition is similar to the method used for creating a lower bound on the number of winning suppliers, except for the addition of n_i in (4), multiplying it with the number of winners variable y_i. Causing the number of organisation that facilitate social integration to be at least z_4.

$$\sum_{j \in J} x_{ij} \geq y_i , \qquad \forall i \ (3)$$

$$\sum_{i \in I} y_i n_i \geq z_4, \qquad (4)$$

4.2.3 Either/or conditions

Either/or conditions may be expressed by buyer or specific supplier interest. From the buyer's perspective, these conditions may stem from strategic interest. For example, buyers may wish to concentrate the market on some lots. On the other hand, either/or constraints allow specific suppliers to mirror capacity constraints. For example, they have to win a number of three lots to be profitable, or none at all. Examples of these either/or constraints include:

- A supplier can either win at least 2 lots, or none [1]
- A supplier must win at least 2 out of these 4 lots to win any at all [2]

To model a condition similar to [1], constraints (5) and (6) are added. These ensure that for any supplier *i*, either constraint (5) or (6) is valid, by adding the variable y_i. In this case, a value of 1 for variable x_{ij} never satisfies both conditions, rendering it an unattainable allocation.

$$\sum_{j \in J} x_{ij} \geq 2 - M_1 y_i , \qquad \forall i \ (5)$$

$$\sum_{j \in J} x_{ij} \leq M_1(1 - y_i) , \qquad \forall i \ (6)$$

To satisfy condition [2], similar constraints (7), (8) can be added to the objective function. Any supplier is allowed to win either at least 2 lots out of 4 specified lots, else they will not win any of those lots.

$$x_{i1} + x_{i2} + x_{i3} + x_{i4} \geq 2 - M_1 y_i, \qquad \forall i \ (7)$$
$$x_{i1} + x_{i2} + x_{i3} + x_{i4} \leq M_1(1 - y_i), \qquad \forall i \ (8)$$

4.2.4 Constraining lot attributes for suppliers

Alternatively, binary variables can be used to constrain lot attributes in the award procedure. One of these lot attributes can include the region of a lot. Suppose a tenderer divides in four regions, wishing to limit supplier liability for each region. Therefore, they decide to introduce a lower bound on the number of winning suppliers for all regions: at least two suppliers must win per region.

A set J_r contains all lots *j* in a region *r*. Consider variable $y_{ir} \in \{0, 1\}$, assigned a value of 1 if supplier *i* wins any lots in region *r*, else it is 0. The values for y_{ir} are generated in constraint (10). To minimize the number of winners in a region; constraint (11) is introduced. In this case, the minimum number of winning suppliers in any region must be 2.

$$\sum_{j \in J_r} x_{ij} \geq y_{ir}, \qquad \forall i, \forall r \quad (9)$$

$$\sum_{i \in I} y_{ir} \geq 2, \qquad \forall r \quad (10)$$

4.3 Package bids

Packages of lots may be introduced by either the buying or the supplying party. They allow the parties to express (negative) complements between lots. These use of packages is advantageous for positive complements between lots, when fixed cost is high compared to the marginal cost, because the cost of supplying an additional lot because marginally lower. The introduction of package bids may be beneficial to both smaller and larger suppliers as they may risk being offered too many or too few lots respectively, which they may limit by bidding on packages fit to their capacity precisely.

In section 2, several methods of avoiding problems that may occur with the introduction of package bids were mentioned. These methods, such as a maximum discount percentage of package bids vs standalone bids do not alter the award procedure as they can be introduced on the bidding sheet itself:

- Obligatory standalone bids
- Standalone bids vs package bids, fixed discount rate
- Standalone bids vs package bids maximum discount rate
- Fixed package or variable – set by buyer vs supplier
- Maximum number of lots in any package

Next to that, package bids themselves do not restrict the outcome of the award procedure. They simply require a different formulation of the award procedure and conditions, which may be subject to the conditions used earlier, therefore we will formulate this function separately.

4.3.1 Formulating package bids in a programming problem

The nature of the objective function of package bids is different from the previous LP- and IP-problems. The objective function c sums the product of the price of a bid of a combination of items in bid *j* by supplier *I*, p_{ij}, and the assignment of those bids x_{ij}. The standard package bids can be formulated as an LP-problem:

$$\mathrm{c} = \min \sum_{i \in N} \sum_{j \in M} p_{ij} x_{ij}$$

They are subject to a mandatory constraint (1), where A_{kij} is lot *k* in bid *j* by supplier *i*. The constraint specifies that each item *k* is present in the assigned lots.

$$\sum_{i\in N}\sum_{j\in M} a_{ij}^{k}\, x_{ij} \geq 1, \qquad \forall k \in K \;\; (1)$$

The method of applying conditions to this award procedure differs from bids on single lots. For instance, the maximum number of lots that any supplier can win, is given by condition (2). Herein, the combinations of the number of lots won in packages is considered.

$$\sum_{k\in K}\sum_{j\in M^{i}} a_{ij}^{k} x_{ij} \leq W\,, \qquad \forall i \in N \;\; (2)$$

As seen with standalone bids, the use of logical constraints requires integer linear programming. Similar to standalone bids, the maximum number of suppliers *S* is given by creating an upper bound on the sum of winning bids, introducing constraints (3) and (4).

$$\sum_{j\in M^{i}} x_{ij} \geq M_1 y_i\,, \qquad \forall i \in N \;\; (3)$$

$$\sum_{i\in N} y_i \leq S, \qquad (4)$$

4.4 DISCOUNTS ON LOTS

Discounts may be introduced by suppliers so that that they can better express (dis)economies of scale and capacity constraints. One of these discount conditions can be formulated as an IP-problem, where the objective function is the product of the sum of assignment variables and the discounted values for lots, introduced by suppliers. Three types of discount conditions will be formulated:

- Business volume discounts, discounts based on the awarded monetary volume
- Discounts on the number of lots won
- Progressive discounts with a linear or exponential increase in discount height

4.4.1 TIERED DISCOUNTS (BUSINESS VOLUME DISCOUNTS)

Suppliers may wish to offer (negative) discounts based on the monetary value of the lots that they can be assigned through their original bids. For instance, for an allotted bid value above $1000 they receive a discount of 30%, in line with a specific discount schedule, such as illustrated in table 7. These business volume discounts may be fitted to specific cost structures of suppliers, where in the lower example of table 7, a value above $600 may reflect significant savings for instance.

Alternatively, negative discounts may be implemented by using negative discounts values. These can be introduced to express negative volume synergies. For instance: a threshold above which an extra employee or vehicle must be hired.

Sum winning bid value $	Percentage discount
Upper bound (u_{ik})	d_{ik}
500	0,10
600	0,20
1000	0,30

Table 7: Business volume discounts for a supplier *i*

These tiered discounts differ with the previously formulated integer programming problem. In the former objective function, the goal was to minimize the sum of assignment variables for each lot and the bids for these lots. In the case of business volume discounts, the goal is to minimize the discounted values for the volume of bid value by each supplier. We formulate the IP-problem where the discounts and ranges may differ for each supplier, based on (Sadrian & Yoon, 1994).

This objective function is formulated as follows, where V_{ik} is the monetary volume awarded to supplier *i* in the range up to u_{ik} with discount rate d_{ik} for discount range *k*.

$$\mathrm{c} = min \sum_{i \in I} \sum_{k \in K} (1 - d_{ik}) V_{ik}$$

This function is subject to several mandatory constraints, the first of which is constraint (1), which guarantees that the monetary volume in the ranges is equal to the product of the price p_{ij} offered for the lots j by supplier i and their assignment $x_{ij} \in \{0, 1\}$.

$$\sum_{j \in J} p_{ij} x_{ij} = \sum_{k \in K} V_{ik} \qquad \forall i \in I \ (1)$$

Another mandatory constraint is (2), which states that the monetary awarded volume for supplier I in range k must be smaller than or equal to the product of the presence in that range ($S_{ik} \in \{0, 1\}$), and the upper bound value in that range (U_{ik}).

$$V_{ik} \leq u_{ik} s_{ik} \qquad \forall i \in I, k \in K \ (2)$$

The next constraint (3) ensures that the volume for supplier i in the next discount range k is greater than or equal to the product of the presence of supplier i in that range (S_{ik}) and the upper bound of the range (U_{ik}).

$$V_{i,k+1} \geq u_{ik} S_{i,k+1} \qquad \forall i \in I, k \in K (k \neq K) \ (3)$$

Together with constraint (4), constraints 1 to 3 ensure that the bid values are placed in the correct discount segment specified by the upper bound U_{ik}.

$$\sum_{k \in K} S_{ik} = 1 \qquad \forall i \in I \ (4)$$

The above constraints are mandatory to construct the condition of business volume discounts. The conditions mentioned in previous section can be added to this objective function in the same way, except for the bounds on monetary awarded values.

4.5 NONLINEAR PROGRAMMING FOR DISCOUNTS ON LOTS

Previous conditions only regarded (integer) linear programming models, where constants such as monetary volumes or prices offered for lots were multiplied with the assignment variables. For certain discounts schemes, the objective function depends on the number of lots won. This changes effects another change: the required use of non-linear programming, where the objective function consists of multiplied variables constrained by linear variables.

4.5.1 PROGRESSIVE DISCOUNTS

One of these non-linear mathematical programming problems includes discount schemes based on the number of lots won. When tendering homogenous lots, progressive discounts may be introduced to fit to suppliers' economies of scale, to reflect the marginal cost incurred for supplying additional lots.

When using quantity discounts in combination with bidding on single lots – e.g. each additionally awarded lot may be accompanied with a 2-percentage point lowered total cost for the supplier, requires the use of quadratic programming, because the quantity discounts alter the objective function itself; the bid value changes with the number of lots won.

$$\mathrm{c} = min \sum_{i \in I} \sum_{j \in J} p_{ij} x_{ij} \, (1 - r_i d_i)$$

$$r_i = \sum_{j \in J} x_{ij} \, , \qquad \forall i \in I$$

Where d_i is the discount rate for supplier *i*., and r_i the number of lots won by supplier *i*.

These progressive discounts assume equal linear marginal cost for additional lots supplied; which will hardly ever reflect supplier's cost structure. An option that allows suppliers to mirror their economies of scale fully is to allow them to submit package bids.

4.6 DISTINCTION BETWEEN INTEGER- AND LINEAR PROGRAMMING

Previously similar computational complexity for (integer) linear problems was assumed, where all were treated as integer programming problems. However, some problems can be easily constrained into linear programming functions. In this case, the objective function is the same, but the requirement is made that variables are all continuous.

The value of x_{ij} will ultimately amount to be either 0 or 1, where a value of 1 means the assignment of lot *J* to supplier *I*. However, LP-problems must be constrained continuously, therefore x_{ij} is restricted to be greater than 0 and smaller than 1 in constraints (1) and (2).

$$x_{ij} \geq 0, \qquad (1)$$

$$x_{ij} \leq 1, \qquad (2)$$

To ensure that each lot *j* is won at least once in total, the objective function must be subjected to another constraint (3), where the sum of bids from all supplier for lot *j* is greater than 1. Simultaneously constraint (3), together with the minimization objective function guides the values of x_{ij} to be integer values, where conditions (2) and (3) ensure values of 1 in case of assignment and condition (1), together with the minimization function guides the other values of x_{ij} to 0. Next to that, condition (4) is introduced, so that every lot has at most one winner.

$$\sum_{i \in I} x_{ij} \geq 1, \qquad \forall j \quad (3)$$

$$\sum_{i \in I} x_{ij} \leq 1, \qquad \forall j \quad (4)$$

Now that these values of these variables are continuous, the integer linear programming problems can be relaxed to be solved as LP- problems. However, as mentioned in section 4.2, several conditions cannot be relaxed into LP-problems due to the requirement of non-relaxable binary variables required for logical constraints.

4.7 FORMULATING CONDITIONS ON THE BIDDING SHEET

Using conditions on lots requires transparency, so that conditions introduced by buyers are effectively communicated to suppliers, and that all suppliers have equal chances to express their capacities and economies of scale. In a tender divided into lots, a bidding sheet will may look similar to figure 3, where suppliers can indicate a price offered for each lot they are interested in. Conditions can quickly complicate and extend the bidding sheet.

Lot number	Price offered
1	€
2	€
3	€
4	€
5	€
6	€

Winning business volume (€)	Discounts offered (%)
€ _____	%
€ _____	%
€ _____	%
€ _____	%
€ _____	%
€ _____	%

Condition \ Lot	1	2	3	4	5	6
1	X		X			
2		X		X		
3						
4						

Figure 3: Examples of implementing conditions on bidding sheet

When designing a tender intending to implement conditions on lots, the conditions have to be formulated on the bidding sheet, or the tender notice. Conditions introduced by buyers, such as a maximum of lots awarded to any supplier, or the minimum turnover required per lot won can be stated in the tender notice, however certain expressive conditions will require extra thought.

Conditions that increase supplier expressiveness will be harder to formulate on the bidding sheet, and may extend it significantly. Conditions such as XOR constraints or discount schemes will be harder to formulate on the bidding sheet.

5 COMPLEXITY OF HANDLING CONDITIONS

In the previous section, three methods of mathematical programming were introduced to solve different conditions on lots; linear-, integer and non-linear programming. Procurers may consider it essential to find the global optimum to a programming problem. For some of the proposed conditions this may be harder with an increasing number of bids and lots. The complexity and implied required computation time. That is why we make a clear distinction between LP- and IP problems that can be solved in P- and NP- time respectively.

5.1 INTEGER PROGRAMMING VS LINEAR PROGRAMMING

Linear programming uses continuous variables to form the solution region. However, when tendering, the number of winners for a lot must be exactly 1 (integer). While integer problems are seemingly easy to resolve at first sight, they may require a computation time magnitudes greater than the time required for finding the solution to a linear programming problem.

The ease of solving LP-problems comes from the fact that their solution is solely found at constraint intersections, where only intersections must be examined to determine minimum cost. Next to that, the optimal solution can be derived from a feasible region where all points in between two feasible points are feasible. Linear programs can be solved in polynomial time.

The difficulty with IP problems is that there is no location where the feasible points can be sought. Next to that, the availability of two feasible solutions does not mean that the points in between are feasible. IP feasible solution regions consist of a finite set of possible solutions, however finding feasible solution alternatives is difficult, shaping an NP-hard optimization problem.

Some integer programs can easily be relaxed into a linear program. In the case of integer programming, all $x_{ij} \in \{0, 1\}$ can be relaxed to a pair of linear constraints where $0<x_{ij}<1$, resulting in a linear program. A distinction can be made between the conditions requiring logical constraints; and integer variables, and continuously constrained values such as the base-case LP- tender allocation. The distinction between variables is found in table 8.

Linear programming	Integer programming	Nonlinear programming
▪ Maximum number of lots won per supplier ▪ XOR – Exclusivity on winners for multiple lots ▪ Monetary winning value ▪ Minimum required turnover	▪ Business volume discounts ▪ Min/ Max number of winning suppliers ▪ Constraining lot attributes ▪ Constraining supplier attributes ▪ Package bids ▪ Either/or conditions ▪ Lot attributes (e.g. regions) ▪ Supplier attributes (e.g. facilitating social integration)	▪ Discounts on number of lots win ▪ Progressive discounts

Table 8: Mathematical programming methods for conditions

5.2 NUMBER OF LOTS TENDERED FOR BY BIDDERS

When the tendering party allows the unconstrained use of package bids, computational cost increases exponentially with the number of lots that can be bid for. With the number of lots being n, the number of packages that can be bid for is 2^n-1. Multiplied with the number of suppliers N, the maximum number of bids offered is N(2^n-1). For large-scale problems, where N or n is large, finding an optimal allocation of bids may become a nuisance in processing the bids and determining the winners, requiring advanced optimization software to find efficient allocations.

Practice shows that the number of lots in public tenders is rarely problematic. For instance, public tender data from the Netherlands in 2014-2016 (TenderNed, sd) shows that, where tenders are divided into lots, the fraction of tenders exceeding 14 lots is less than 1% (Figure 4). Computational complexity increases with a greater number of lots. However, the number of lots is rarely a great number, increasing the aptitude of finding a global minimum cost for these conditions with simple IP/LP solvers.

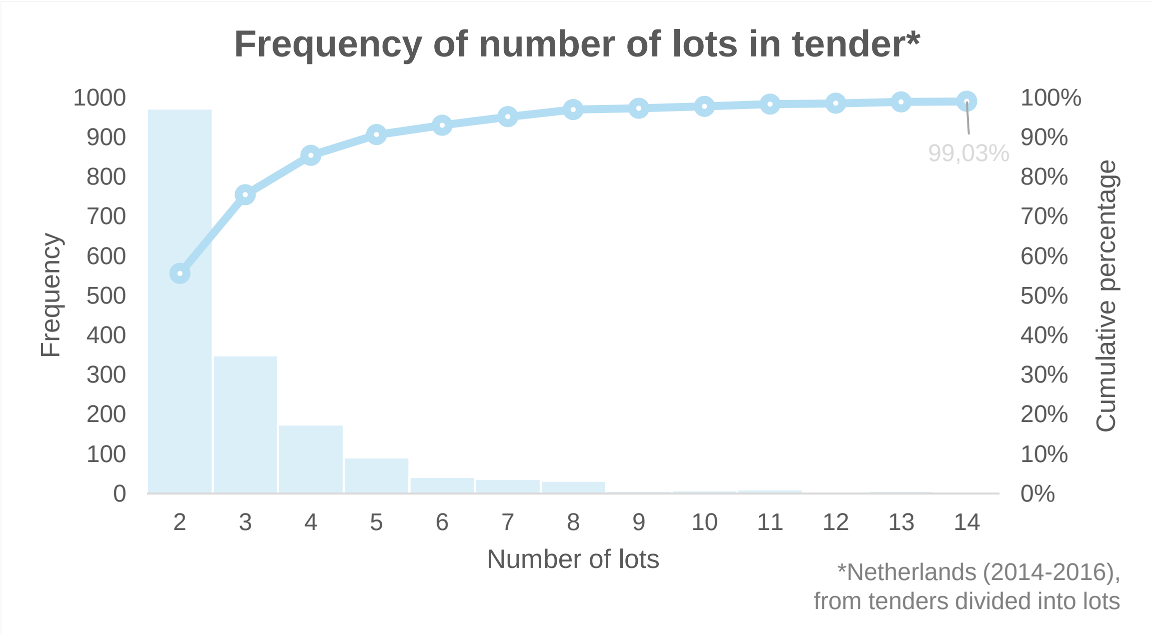


Figure 4: Number of lots in tenders in the Netherlands (2014-2016)

If the number of potential bids in package bids becomes problematic, the tenderer may decide to take additional measures that restrict the number of bids. Options include generic bounds, fixed packages or restricting packages to have non-empty intersections (Dimitri, Pacini, Pagnozzi, & Spagnolo, 2006).

5.3 FINDING A GLOBAL OPTIMUM

Contracting authorities may be reluctant to use optimisation software because they lose control of the allocation procedure by doing so. When 1. Formulating and 2. Optimising, they may find two main obstacles preventing them from implementing conditions themselves.

One may be that they make mistakes in the formulation procedure, and the second being that they are unsure of the result that the software finds; is the allocation proposed by the software the optimum?

For LP-problems, finding a global optimum in polynomial time can be done relatively easily for hundreds of conditions in a simple solver. For the IP conditions in Table 8, this formulation is more difficult, as the required computation time increasing quickly with the number of bidders and lots. However, as seen in figure 8, the number of lots is rarely abundant.

Quadratic programming problems such as finding an optimal allocation for progressive discounts are nonlinear, creating adverse effects on computation time. These problems are NP-hard (Sahni, 1974). For these non-linear problems, the optimal solution can occur in interior points and boundaries as well as extremes of a feasible region as well as at extreme points, therefore methods such as the simplex method that only search extreme points may not find an optimal allocation (Bradley, Hax, & Magnanti, 1977), causing the search for a global optimum allocation of bids to be more difficult.

However, all nonlinear conditions are discounts schemes based on the number of lots won. To truly reflect cost structure in these discounts conditions, lots must be homogenous, as for instance a progressive cost discount scheme offers similar discounts for any combination of lots. To more specifically reflect capacity and economies of scale, package bids may be a better alternative as they may be easier to optimise for small problems, and allow suppliers to fully express their interest in lots by bidding on any combination of lots.

6 METHODS FOR RESOLVING CONDITIONS ON TENDERS

These programming problems may use various algorithms to generate solutions for efficient allocations of lots in a tender. These algorithms differ in complexity and the required computation time. The options of resolving conditions can be categorised in two main software options: simple IP/LP software solutions such as Excel's add-on solver requiring a more hands-on approach and more commercial software solutions that allow for easy translation of conditions and require no knowledge of optimization techniques.

6.1 SOFTWARE FOR CONDITIONAL PURCHASING

There are numerous commercial software packages available for tenders, that offer easy-to-translate methods of implementing conditions. Next to that, there are more hands-on software solutions such as Excel's solver that require the use and formulation of mathematical programming by the user. These methods will be discussed in this section, allowing the procurer to assess trade-off premium of using commercial software packages over hands-on solutions

6.1.1 IMPLEMENTATION IN EXCEL SOLVER

Nowadays, bids are frequently submitted digitally, often through an Excel bidding sheet. Excel features a Solver add-in, this add-in can be used to solve mathematical programming problems and find the lowest cost combinations of bids subject to conditions. The formulation of these conditions can be done in a rather native method, where bids from bidding sheets can quickly be translated. Cells can be expressed as variables and constants, conditions can be set in the Solver add-in. The solver uses branch-and-bound methods to find an optimal allocation.

All conditions mentioned in this thesis can be formulated in the Excel solver. A tender subject to two simple conditions is displayed in figure X. The number of lots any supplier can win is not greater than 2, and lots 1 and 2 cannot be won by the same supplier.

These two conditions are implemented in figures 5, 6 and 7. In this sample sheet these above conditions are introduced on standalone lots. Consider four suppliers that submit bids on six lots. These bids by suppliers A, B, C, D on lots 1… 6 are formulated in cells B6:G9. The final assignment of these lots is displayed in yellow, where cells B13:G16 represent variables x_{ij} for the bids from supplier i and lot j. The formulas for these constraints are illustrated in figure 5, the LP-formulation is done in figure 7. These conditions are relatively easy to implement for procurers unfamiliar with mathematical programming. However, conditions such as business volume discounts are more difficult to implement and translate. As shown in Appendix A, a more extensive translation into Excel is required.

Objective function						
min =SUMPRODUCT(B6:G9;B13:G16)						

BIDS

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Supplier A	45	49	48	58	41	58
Supplier B	45	52	54	49	48	52
Supplier C	48	55	43	54	57	54
Supplier D	46	48	50	55	51	52

ASSIGNMENT

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Winners	Lot 1+2
Supplier A	b	b	b	b	b	b	=SUM(B13:G13)	=B13+C13
Supplier B	b	b	b	b	b	b	=SUM(B14:G14)	=B14+C14
Supplier C	b	b	b	b	b	b	2≥ =SUM(B15:G15)	1≥ =B15+C15
Supplier D	b	b	b	b	b	b	=SUM(B16:G16)	=B16+C16
	1= =SUM(B13:B16)	=SUM(C13:C16)	=SUM(D13:D16)	=SUM(E13:E16)	=SUM(F13:F16)	=SUM(G13:G16)		

Figure 5

Objective function						
min € 278,00						

BIDS

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Supplier A	€ 45,00	€ 49,00	€ 48,00	€ 58,00	€ 41,00	€ 58,00
Supplier B	€ 45,00	€ 52,00	€ 54,00	€ 49,00	€ 48,00	€ 52,00
Supplier C	€ 48,00	€ 55,00	€ 43,00	€ 54,00	€ 57,00	€ 54,00
Supplier D	€ 46,00	€ 48,00	€ 50,00	€ 55,00	€ 51,00	€ 52,00

ASSIGNMENT

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Winners	Lot 1+2
Supplier A	b 1	b 0	b 0	b 0	b 1	b 0	2	1
Supplier B	b 0	b 0	b 0	b 1	b 0	b 0	1	0
Supplier C	b 0	b 0	b 1	b 0	b 0	b 0	2≥ 1	1≥ 0
Supplier D	b 0	b 1	b 0	b 0	b 0	b 1	2	1
	1= 1	1	1	1	1	1		

Figure 6

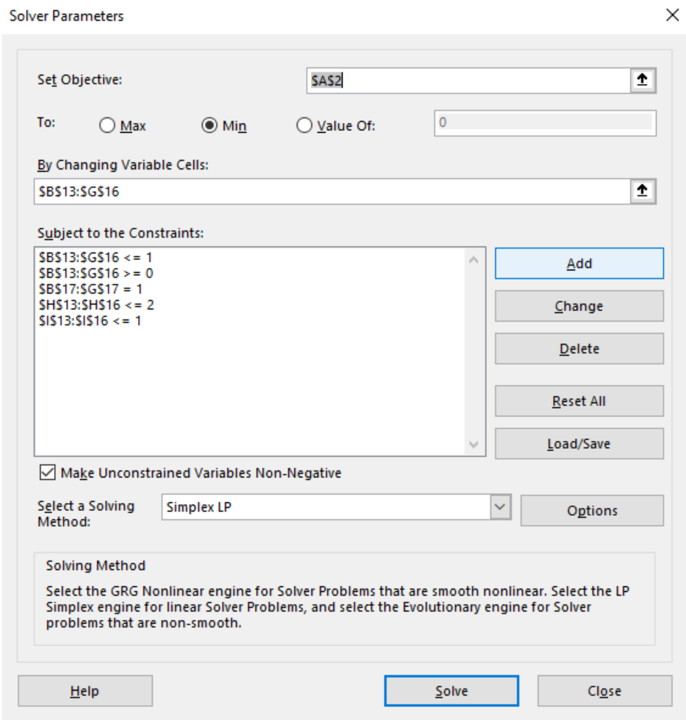


Figure 7

6.1.2 Custom commercial software

There are numerous companies that offer software for advanced sourcing and optimization, such as Trade Extensions and Keelvar. Their core focus has been the private sector, with tenders amounts typically ranging above €10 million. They may be fit for public procurement as well. Several interviews with these commercial parties have been conducted, to get a view of the applications of their software in the public sector. The main benefits and their respective tradeoffs will be described in this section, so that a judgement can be made on the necessity of using such software packages over standard solvers such as the Excel add-in.

Complexity

Simple linear, and especially integer programming solvers will be increasingly troubled with many bids or lots. However, as previously shown in figure 4, these numbers hardly ever exceed 10, let alone 100 lots or bids in practice.

Ease of translation and implementation

In section 1.4 the difference between in implementation stages of conditions in public- and private tenders was described. Private tenders allow procurers to evaluate, analyze and compare scenarios of implementing conditions on lots after bids were submitted. This allows them to conduct a trade-off analysis between the cost-effectiveness and the implied results of conditions.

For public tenders, this is not the case. This signifies that conditions must be added in the design phase by the procurer, not knowing the bids they will receive.

Cost

The cost for using private software solutions is much greater than using LP- or IP solvers that or often freely available, frequently they will require some training for employees that are not familiar with mathematical programming. Translation of conditions into commercial software packages is much less of a nuisance, and requires less knowledge of mathematical programming. However cost is generally far greater, because the software providers frequently provide their software with a team of consultants to implement the software, increasing cost.

	Simple IP/LP software	**Advanced optimization software**
Knowledge	Greater knowledge of conditions and formulation required	Less prerequisite knowledge required
Translation & optimization	Requires extensive translation of all conditions; fit for small number of lots or bidders; more risk for procurer	Easy translation
Complexity	Can handle small-medium scale problems well	Fit for extensive problems with hundreds+ of lots or bidders
Cost	Little to no investment required	Significant cost

7 LEGALITY OF CONDITIONS

The new 2014 EU directive on public procurement encourages the division of contracts into lots. Article 46 of directive 2014/24 states that contracting authorities must consider dividing contracts into lots. When they decide not to divide into lots, they must “provide an indication of the main reasons for their decision not to subdivide into lots”.

The complexity of the rules on procedures is one of the key problem drivers in public procurement (European Commision, 2011). Authorities frequently face uncertainty with regards to procedures resulting in fear of litigation, leading to sub-optimal and risk averse choices to be made in the design and participation of tenders. To reduce the risk-perception, the legality of conditions will be analysed in this section, allowing contracting authorities to make a more substantiated choice for using conditions on lots in support of the objective of “providing clarity and legal certainty with respect to scope and coverage”.

Few conditions are explicitly referred to in the most recent directives, causing ambiguity on the legality of conditions and risk-averse choices regarding conditions. Therefore, we will analyse the legal acceptability of implementing conditions that were introduced previously, from the buyer’s and the supplier’s perspective.

Awarding of contracts and relation to subject-matter of tender

Article 70 of the EU directive states that buyers may lay down special conditions relating to the performance of the contract, provided they are linked to the subject matter of the contract, indicating a broad range of strategic considerations for implementing them.

> (Article 70) Contracting authorities may lay down special conditions relating to the performance of a contract, provided that they are linked to the subject-matter of the contract within the meaning of Article 67(3) and indicated in the call for competition or in the procurement documents. Those conditions may include economic, innovation-related, environmental, social or employment-related considerations.

Article 67(3) and 70 seems to indicate that the relation of the subject matter of the contract is not directly restricted by the award criteria as contract performance conditions can extend to performance in another stage of their life cycle, or other strategic considerations.

> (Article 67(3)) Award criteria shall be considered to be linked to the subject-matter of the public contract where they relate to the works, supplies or services to be provided under that contract in any respect and at any stage of their life cycle, including factors involved in:
> (a) the specific process of production, provision or trading of those works, supplies or services; or
> (b) a specific process for another stage of their life cycle,
> even where such factors do not form part of their material substance.

One of the arguments supporting the relation conditions to the subject matter (Telgen, Uenk, Lohmann, & Manunza, 2015) is that the condition that maximises the number of lots awarded to any supplier performs economic value such as the limitation of supply risk, which relates to the execution of the contract and its economic consequences (article 70), in any stage of the life cycle as required by article 67(3) in the directive. Perhaps the strongest argument mentioned in the relation of conditions with the subject matter is the explicitly example of restricting the number of lots won by any supplier in the directive.

7.1 CONDITIONS WITH ECONOMIC CONSIDERATIONS

One of the explicitly mentioned conditions is that contracting authorities should be enabled to limit the number of lots for which an economic operator may tender (recital 79), and they should be allowed to limit the number of lots that may be awarded to any one tenderer.

> (Recital 79) Where contracts are divided into lots, contracting authorities should, for instance in order to preserve competition or to ensure reliability of supply, be allowed to limit the number of lots for which an economic operator may tender; they should also be allowed to limit the number of lots that may be awarded to any one tenderer.

But what about other conditions that serve similar economic considerations to limiting to the number of lots awarded to any supplier? The 2014 directive nor their recitals provide a conclusive and definitive answer to this question, but they suggest that others may be considered. The supporting argument for including the condition is "for instance in order to preserve competition or to ensure reliability of supply". This indicates that these economic considerations were generated as examples of methods that indirectly provide value for money for the tenderer – where value is added in reducing the risks of lock-in and reducing supply risk. The phrase "for instance" is suggesting there are more conditions that may be implemented to add economic value for money.

In chapter 3, we named other conditions that potentially contribute to the same objective of adding economic value, by constraining the solution space in the award procedure based on other conditions. The risk of endangered competition and reliability of supply primarily stems from economic considerations, where one, or a small number of suppliers, win all lots, resulting in a lock-in. Small-scale suppliers that do not win any lots may be prevented from future tenders by such allocations; causing an impairment in future competition. Next to that, reliability of supply is harmed as the risk of disruption of supply potentially increases with fewer suppliers, amounting to the same effects.

Analogous to limiting the number of lots that can be won by any suppliers, these economic considerations can be maintained by introducing a lower bound on the number of winning suppliers: through which small-scale (SME) supplier participation is promoted; preserving competition and ensuring reliability of supply. Following this argument, the implementation of a condition that restricts the number of winning suppliers would seemingly be legal as it impacts the economic procurement objective comparable to a restriction on the number of lots won, despite not being stated explicitly in the Directive.

Other conditions we found that constitute similar economic properties are the exclusiveness between lots (XOR), where the winners of multiple lots are restricted to be mutually exclusive, for instance to preserve competition, or limit supplier liability between lots. The nature of this conditions is the same as the previous two as it does not discriminate against specific suppliers and it adds economic value.

Another condition that is explicitly allowed is requiring suppliers to have a minimum turnover. This condition can be fit to lots, according to Article 58.3 where this condition may be viewed as to requiring a minimum turnover weighed with the grouped number of lots won. This condition may limit any supplier from winning lots above their desired volume.

> *(Article 58.3). With regard to economic and financial standing, contracting authorities may impose requirements ensuring that economic operators possess the necessary economic and financial capacity to perform the contract. For that purpose, contracting authorities may require, in particular, that economic operators have a certain minimum yearly turnover, including a certain minimum turnover in the area covered by the contract. In addition, contracting authorities may require that economic operators provide information on their annual accounts showing the ratios, for instance, between assets and liabilities. They may also require an appropriate level of professional risk indemnity insurance.*

Such methods and criteria shall be transparent, objective and non-discriminatory.

Where a contract is divided into lots this Article shall apply in relation to each individual lot. However, the contracting authority may set the minimum yearly turnover that economic operators are required to have by reference to groups of lots in the event that the successful tenderer is awarded several lots to be executed at the same time.

7.2 CONDITIONS SUPPORTING SOCIAL VALUE

Next to the aforementioned technical policy objectives of increasing competition and reducing supplier liability and collusion, there are socioeconomic goals that a procurer may wish to adhere to.

One of the cornerstones of the new directive is to increase SME participation in tenders, a goal that many contracting authorities seek to follow. Explicitly awarding based on the SME status, creating set-asides, is illegal. However, Article (78) states that “member states should remain free to further in their efforts to facilitate the involvement of SMEs in the public procurement market.” Other measures can be taken to facilitate SME participation, provided that they align with the requirements of non-discrimination, transparency and objectivity (Article 58.3). In chapter 3, we introduced some of these conditions.

7.3 BUNDLING OF CONTRACTS: PACKAGE BIDS

Article 46(2) states that the contract notice or invitation to confirm interest should indicate whether tenders may be submitted for one, for several or for all of the lots in which a given contract is divided. This indicates that simultaneous bid for several lots, a package bid, is allowed. Additionally, 46(3) states that contracting authorities award contracts combining several lots, creating package bids.

Article (46(2)). Contracting authorities shall indicate, in the contract notice or in the invitation to confirm interest, whether tenders may be submitted for one, for several or for all of the lots.

Contracting authorities may, even where tenders may be submitted for several or all lots, limit the number of lots that may be awarded to one tenderer, provided that the maximum number of lots per tenderer is stated in the contract notice or in the invitation to confirm interest. Contracting authorities shall indicate in the procurement documents the objective and non-discriminatory criteria or rules they intend to apply for determining which lots will be awarded where the application of the award criteria would result in one tenderer being awarded more lots than the maximum number.

Article (46(3)) Member States may provide that, where more than one lot may be awarded to the same tenderer, contracting authorities may award contracts combining several or all lots where they have specified in the contract notice or in the invitation to confirm interest that they reserve the possibility of doing so and indicate the lots or groups of lots that may be combined.

7.4 CONDITIONS EXPRESSED BY SUPPLIERS

The previous conditions can be introduced by contracting authorities, however: suppliers may be willing to express conditions on their bids so that they can better convey their interests and synergies in the tender. In section 2, we have illustrated the advantages that these supplier conditions provide, however: the EU Directives provide present little guidance on their legality.

Examples of these conditions include expressing dependences by introducing XOR conditions or stating a maximum number of lots they want to receive, or introducing business volume discounts. To comply with the mandatory non-discriminatory EU law, these conditions are presumably legal as long as they are explicitly mentioned in the invitation by the procurer, whereby each supplier receives equal treatment and opportunities to express synergies and cost savings.

When supplier conditions such as conditions are explicitly allowed in the tender notice, all suppliers can be treated equal and non-discriminatory, as the suppliers can only equally create economic effects for themselves and the contracting authorities

7.5 CONCLUSION

In the new directives, division into lots is strongly encouraged in a divide-or-explain vision. The directive does not explicitly state all conditions; however, they have an interesting take on one economic condition, from which the potential legality of other conditions may stem.

Conditions require transparent, objective and non-discriminatory in the tender notice. The creation of an upper bound on the number of lots won by any single supplier is explicitly allowed to preserve structural competition or ensure reliability of supply. This explicit mention seemingly stems from the EU aim of "delivering best value for money whilst achieving the best possible procurement outcomes for society", as it constitutes numerous benefits for contracting authorities. Many other conditions provide similar value to contracting authorities, their presumable legality is derived from similar reasoning, summarised in table 9.

Explicitly legal*	Presumably legal	Illegal
Maximize number of lots won by any supplier	Minimize number of winning suppliers	Maximize number of lots won for supplier attribute (e.g. SME/ incumbent status)
Reserve winning lots to operators whose main aim is social integration	XOR – Excluding the option of one supplier winning a specified combination of lots	
Package bids for combinations of lots	Maximize number of lots won by any supplier for a lot attribute (e.g. regions)	
Minimum turnover for supplier weighed by awarded lots	Supplier conditions such as discounts	

Table 9: Legality of conditions

8 CONCLUSION

Current use of conditions in public procurement is minimal, albeit the division into lots in tenders being strongly encouraged by the European Commission. In this thesis, some of the potential problem drivers of the limited use of these conditions are tackled, the results are displayed in table 10.

First off, the added value of implementing conditions in the award procedure is illustrated, through which they may contribute to economic and social procurement policy, such as preserving competition, increasing SME participation and limiting supplier liability. Next to that, inferior methods of pursuing these objectives are illustrated, to guide procurers towards acquiring better value for money by using the conditions.

Furthermore, the formulation of most conditions is conceivable, requiring basic knowledge of mathematical programming, whereas other conditions require some more advanced knowledge, as shown in table 10.

Similarly, optimisation is frequently doable for novice users of mathematical programming due to the availability of solvers in standard software packages such as MS-Excel, requiring only basic knowledge of the optimisation software. However, some conditions, such as implementing business volume discounts more extensive knowledge for a hands-on approach.

From a legal perspective, many conditions are presumably legal, following to the 2014 EU directives on public procurement. Displaying the difficulty, the path for increased future use of conditions is paved, removing potential obstacles for contracting authorities, so that they can take full advantage of the benefits that these conditions can carry out.

Condition	Perspective	Benefits	Formulation	Difficulty of implementation & translation	Legality
XOR – Maximum number of lots won in a set of lots	Buyer	Preserving competition, Limiting supplier liability	Easy	Easy	Presumably legal
Maximum number of lots won per supplier	Buyer	Preserving competition, Limiting supplier liability, Increasing SME participation	Easy	Easy	Legal
Minimum number of winning suppliers	Buyer	Increasing SME participation	Average	Average	Presumably legal
Maximum number of winning suppliers	Buyer	Mitigating performance risks	Average	Average	Presumably legal
Minimum required turnover per lot	Buyer	Mitigating performance risks	Easy	Easy	Legal
Maximum monetary winning volume	Buyer	Preserving competition, Limiting supplier liability, Increasing SME participation	Easy	Easy	Presumably legal
Either/or constraint	Buyer	Mitigating performance risks	Average	Average	Presumably legal
Constraining lot attribute (e.g. regions)	Buyer	Preserving competition, Limiting supplier liability	Average	Average	Presumably legal
Constraining supplier attribute (e.g. facilitating social integration)	Buyer	Increasing SME participation, Facilitating social integration	Average	Average	Presumably legal
Maximum number of winning lots	Supplier	Mitigating supplier's exposure risk, Matching supplier's capacity	Easy	Easy	Presumably legal
XOR – Maximum number of lots won from in a set of lots	Supplier	Matching supplier's capacity	Easy	Average	Presumably legal
Package bids	Supplier	Mitigating supplier's exposure risk, Applying economies of scale, Matching supplier's capacity	Average	Average	Legal
Either/or constraint	Supplier	Mitigating supplier's exposure risk, Matching supplier's capacity	Average	Average	Presumably legal
Business volume discounts	Supplier	Applying economies of scale	Hard	Average	Presumably legal
Discounts on number of lots won	Supplier	Applying economies of scale	Hard	Hard	Presumably legal
Progressive discounts	Supplier	Applying economies of scale	Hard	Hard	Presumably legal

Table 10

9 APPENDIX

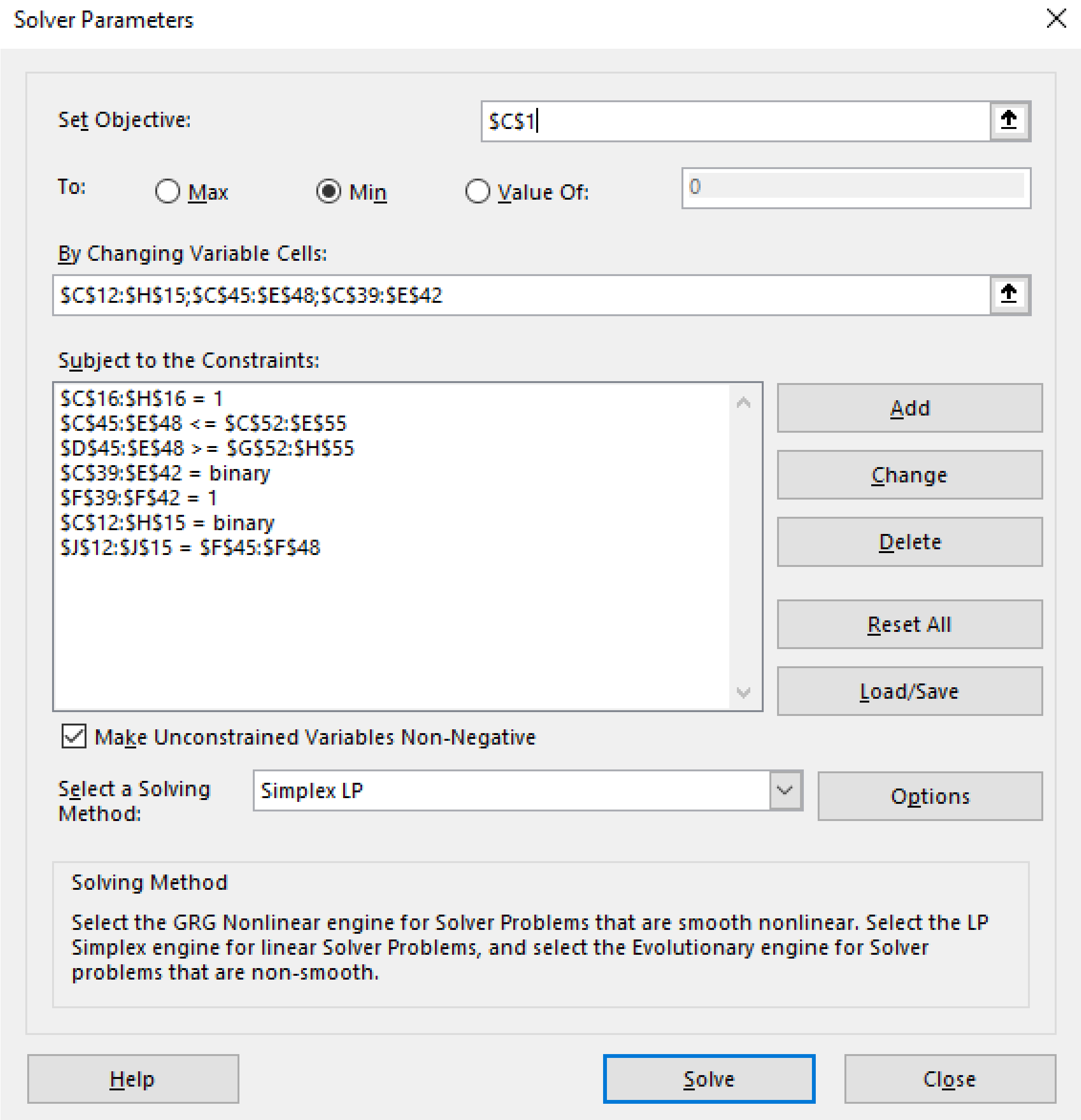
Appendix A

Objective Function	***988***							
BIDDERS	Lots							
BIDS	1	2	3	4	5	6		
A	€ 525,00	€ 238,00	€ 287,00	€ 591,00	€ 269,00	€ 755,00		
B	€ 130,00	€ 516,00	€ 805,00	€ 341,00	€ 209,00	€ 533,00		
C	€ 933,00	€ 439,00	€ 987,00	€ 734,00	€ 680,00	€ 457,00		
D	€ 188,00	€ 128,00	€ 963,00	€ 541,00	€ 796,00	€ 436,00		
BIDS	Lots							
ASSIGNMENT	1	2	3	4	5	6	NUMBER	VOLUME
A	0	0	1	0	0	0	1	287
B	0	0	0	0	1	0	1	209
C	0	0	0	0	0	0	0	0
D	1	1	0	1	0	1	4	1293
	1	1	1	1	1	1		1789
	Lots							
WINNING BID VALUES	1	2	3	4	5	6		
A	€ 0,00	€ 0,00	€ 243,95	€ 0,00	€ 0,00	€ 0,00		
B	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 156,75	€ 0,00		
C	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00		
D	€ 75,20	€ 51,20	€ 0,00	€ 216,40	€ 0,00	€ 174,40		
DISCOUNT BOUNDS	Uik	(Monetary volume)						
	d1	d2	d3					
A	€ 300,00	€ 600,00	€ 5.000,00					
B	€ 300,00	€ 600,00	€ 5.000,00					
C	€ 300,00	€ 900,00	€ 1.200,00					
D	€ 300,00	€ 600,00	€ 5.000,00					
DISCOUNT RATES	D1	d2	d3					
A	5%	10%	15%	0,15		0,95	0,9	0,85
B	5%	15%	25%	0,25		0,95	0,85	0,75
C	0%	20%	40%	0,4		1	0,8	0,6
D	0%	0%	60%	0,6		1	1	0,4
Sik ASSIGNMENT	d1	d2	d3					
A	1	0	0	1				
B	1	0	0	1				
C	1	0	0	1				
D	0	0	1	1				
Vik	d1	d2	d3					
A	287	0	0	287				
B	209	2,842E-14	0	209				
C	0	0	0	0				
D	0	1,724E-14	1293	1293				
				1789				
UikSik					UikSik+1			
A	300	0	0		0	0		
B	300	0	0		0	0		
C	300	0	0		0	0		
D	0	0	5000		0	600		

Appendix B

Objective Function	min 988							
BIDDERS	Lots							
BIDS	1	2	3	4	5	6		
A	€ 525,00	€ 238,00	€ 287,00	€ 591,00	€ 269,00	€ 755,00		
B	€ 130,00	€ 516,00	€ 805,00	€ 341,00	€ 209,00	€ 533,00		
C	€ 933,00	€ 439,00	€ 987,00	€ 734,00	€ 680,00	€ 457,00		
D	€ 188,00	€ 128,00	€ 963,00	€ 541,00	€ 796,00	€ 436,00		
BIDS	Lots							
ASSIGNMENT	1	2	3	4	5	6	NUMBER	VOLUME
A	b 0	b 0	b 1	b 0	b 0	b 0	1	287
B	b 0	b 0	b 0	b 0	b 1	b 0	1	209
C	b 0	b 0	b 0	b 0	b 0	b 0	0	= 0
D	b 1	b 1	b 0	b 1	b 0	b 1	4	1293
	1= 1	1	1	1	1	1		1789
	Lots							
WINNING BID VALUES	1	2	3	4	5	6		
A	€ 0,00	€ 0,00	€ 243,95	€ 0,00	€ 0,00	€ 0,00		
B	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 156,75	€ 0,00		
C	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00		
D	€ 75,20	€ 51,20	€ 0,00	€ 216,40	€ 0,00	€ 174,40		
DISCOUNT BOUNDS	Uik	(Monetary volume)						
	d1	d2	d3					
A	€ 300,00	€ 600,00	€ 5.000,00					
B	€ 300,00	€ 600,00	€ 5.000,00					
C	€ 300,00	€ 900,00	€ 1.200,00					
D	€ 300,00	€ 600,00	€ 5.000,00					
DISCOUNT RATES	D1	d2	d3					
A	5%	10%	15%	0,15		0,95	0,9	0,85
B	5%	15%	25%	0,25		0,95	0,85	0,75
C	0%	20%	40%	0,4		1	0,8	0,6
D	0%	0%	60%	0,6		1	1	0,4
Sik ASSIGNMENT	d1	d2	d3					
A	b 1	b 0	b 0	1				
B	b 1	b 0	b 0	1= 1				
C	b 1	b 0	b 0	1				
D	b 0	b 0	b 1	1				
Vik	d1	d2	d3					
A	287	0	0	287				
B	209	2,842E-14	0	209				
C	0	0	0	0				
D	0	1,724E-14	1293	1293				
				1789				
UikSik				UikSik+1				
A	300	0	0	0	0			
B	300	0	0	0	0			
C	≤ 300	0	0	≥ 0	0			
D	0	0	5000	0	600			

Appendix C


Solver Parameters
Set Objective:
$C$1
To:
Max
Min
Value Of:
0
By Changing Variable Cells:
$C$12:$H$15;$C$45:$E$48;$C$39:$E$42
Subject to the Constraints:
$C$16:$H$16 = 1
$C$45:$E$48 <= $C$52:$E$55
$D$45:$E$48 >= $G$52:$H$55
$C$39:$E$42 = binary
$F$39:$F$42 = 1
$C$12:$H$15 = binary
$J$12:$J$15 = $F$45:$F$48
Add
Change
Delete
Reset All
Load/Save
Make Unconstrained Variables Non-Negative
Select a Solving Method:
Simplex LP
Options
Solving Method
Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.
Help
Solve
Close

Appendix D – Objectives of the European Directives from: European Commission Impact assessment (2011)

Objectives of the European Directives – European Commission Impact assessment (2011)
General objectives • Promote EU-wide and cross-border competition for contracts • Deliver best value for money whilst achieving the best possible procurement outcomes for society • Aid the fight against corruption *Specific objectives* • Improve the cost-efficiency of EU public procurement rules and procedures • Take full advantage of all opportunities to deliver the best possible outcomes for society • Create European rather than national markets for procurement. *Operational objectives* *1. Scope and coverage* • Ensure that the rules capture the appropriate actors and subject-matter of procurement • Provide clarity and legal certainty with respect to said scope and coverage. *2. Procurement processes/procedures* • Streamline and simplify procurement procedures to (1) reduce operational costs (2) ensure proportionality and (3) provide for more legal certainty • Improve the flexibility of procedures to better respond to purchasing needs of authorities *3. Strategic public procurement* • Help public procurers to use public procurement to support other policy objectives (e.g. environmental, social, initiatives related to the innovative economy) in a legally compliant and fair manner *4. Market access* • Simplify the rules and introduce instruments to increase the transparency of EU public procurement rules and open-up the markets to greater cross-border competition • Ensure that the rules facilitate participation by MSMEs *5. Administrative organisation* • Ensure consistent application, controls and monitoring of public procurement policy and outcomes across MS • Reduce errors and problems with compliance with EU public procurement rules

Table 11: Source: European Commission – Impact Assessment (2011)

Appendix E - Issues with standard package bids

Risks of package bids: dead-lock tenders and predatory bidders

Package bids are an interesting opportunity from an economic perspective; allowing them may allow bidders to mitigate the exposure problem and to express economies at scale may enhance efficient and lower prices. However, default package bids may have some adverse effects on competition and public procurement objectives such as SME participation (Lunander & Lundberg, 2012).

One of these major risks is the potential occurrence of the dead-lock problem, where package bids result in an unsolvable allocation. Consider the case where there are just two smaller bidders (supplier 1 and 2) who have the capacity to bid for just two out of three lots for a reasonable price, their bids do not however fully overlap, and they did not express standalone bids because their costs for separate lots is greater. Bidder 1 decides to bid for package (A, B) whereas bidder 2 bids for package (B, C). The exclusivity between these bids causes a dead-lock, where no allocation can be made so that all lots are won.

	Lot A	Lot B	Lot C	Package (A, B)	Package (B, C)
Bidder 1	x	x	x	10	x
Bidder 2	x	x	x	x	10

Table 12: No winning bidder as no optimal allocation can be constructed

Suppose predatory supplier 3 decides to bid for the tender. Supplier 3 has a larger capacity. Perhaps knowing that bidders 1 and 2 are unable to supply an amount of lots greater than 1, they submit a high cost bid. This bid causes them to win the tender, despite offering inflated prices.

	Lot A	Lot B	Lot C	Package (A, B)	Package (B, C)	Package (A, B, C)
Bidder 1	5	x	x	x	x	x
Bidder 2	x	5	x	x	x	x
Bidder 3	x	x	x	x	x	**20**

Table 13: Bidder 3 wins at a seriously inflated price: €20

Introducing obligatory standalone bids to counter the dead-lock problem and predatory bidders

Obliging standalone bids for lots that are in package bids may resolve the dead-lock problem or the problem of a seriously inflated awarded tender value. Considering the example in table 14, bidders 1 and 2 may be unwilling to submit bids on single lots, so they submit high prices, barely lower than their packages. These do however allow one of the bidders to win with their package bid, and the other with a high single bid. This allocation mitigates the dead-lock problem. Moreover, the total number of bids is increased; decreasing the risk of a predatory bidder winning lots at an inflated price.

Limiting the power of large suppliers' packages and avoiding lock-in, introducing maximum package discounts

Despite the introduction of standalone bids, there may be another reason for which procurers refrain from implementing package bids: supplier lock-in. When substantial economies of scale exist, large suppliers may be inclined to submit a single package bid for all lots; locking-in the procurer to one final supplier, creating an unfavourable scenario for the contracting authority. They may neglect their obligation to submit standalone bids by bidding unrealistically high on the single lots. This effect is illustrated in table 14.

	Lot A	Lot B	Lot C	Package (A, B)	Package (B, C)	Package (A, B, C)
Bidder 1	8	8	x	10	x	x
Bidder 2	x	7	9	x	10	x
Bidder 3	10	10	10	x	x	**17**

Table 14: Bidder 3 wins all lots at a price of €17

When allowing unconditional combinatorial bidding, there is an increased risk of lock-in compared to bidding on single lots if economies of scale are present, where one party wins all lots, increasing supplier liability and limiting future competition and potentially increasing costs in subsequent tenders of similar goods, works or services due to competitors going out of business. Unconstrained package bidding may favour larger suppliers, allowing them to potentially shut out smaller parties by exploiting their capacity and bidding unrealistically high on single lots, causing them to win all lots by inflating prices for single lots.

A potential solution is to limit the maximum discount on package bids compared to single lots (Lunander & Lundberg, 2013). This method forces the bidder to submit low single bids next to low package bids, increasing the competitiveness of single bids of other suppliers as well. The drawback however, is that it may limit the supplier to express true synergies as their discounts are constrained. When the procure deciding the height of the discount rate, they should do it with respect to the expected obtainable economies of scale. Suppose a maximum discount rate of 20% is introduced, where the sum of standalone bids must be lower than 1.20x the package bid. In this case the standalone bids from bidder 3 are lowered, allowing the standalone and package bids from the small-scale suppliers to be more competitive. Bidder 1 now wins 2 lots and bidder 3 wins only one, preserving competition and limiting supplier liability.

	Lot A	Lot B	Lot C	Package (A, B)	Package (B, C)	Package (A, B, C)
Bidder 1	8	8	x	**10**	x	x
Bidder 2	x	7	9	x	10	x
Bidder 3	7	6	**6**	x	x	17

Table 15: Bidder 1 wins package (A,B), bidder 3 wins lot 3 at a price of €16

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