Methods and Difficulties in Quantifying Archaeological Vessel Glass Assemblages

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Introduction

The ability to count artefacts accurately is key for many different types of archaeological studies. It is essential for establishing form chronologies; tracking changes in artefact types, trade, and industries; tracing artefact densities in a given area and establishing the relative date of sites (Orton 1980: 156). When examining the changes to the Roman glass industry brought about by the introduction of glassblowing, for instance, it is critical to compare the prevalence of various production types. In order to do this, one must be able to produce an accurate count of the vessels produced through casting, core-forming, free-blowing, and mould-blowing. The quantification of glass is a significant tool to understand an important aspect of the Roman economy and of the daily lives of Roman citizens and subjects. Glass is found at virtually every late-Republican and Imperial Roman site, and it was valued enough by the Romans for many ancient writers, from Pliny the Elder (*Nat. Hist.* 36.193), to Strabo (*Geog.* 16.2.25), to Martial (*Ep*. 1.41.3–5 and 10.3.3–4) and Juvenal (*Sat*. 5.47–48) to comment on it, to name just a few examples. Evidence suggests that Romans at all levels of society used glass, and quantification begins to allow scholars to understand the scale on which it was used. Stuart Fleming estimated that by the second century A.D., as many as eight million households within the Empire would have been using 60 or more glass items in an average day. He then uses this estimate to calculate demand and suggest a necessary production level of 100 million vessels annually to meet the Roman demand for glass vessels, allowing for an average breakage level of 12 items per household per year (Fleming 1999: 60). Although he did not state his methodology explicitly, assemblages from numerous sites must have been quantified to calculate his average, but without a defined standard method the accuracy of such claims cannot be tested.

Despite its usefulness in understanding the role of glass in Roman society, the quantification of glass is something that often has been avoided in scholarly writing. In fact, only two articles, by Fletcher and Heyworth (1987) and Cool and Baxter (1996), focus on this subject specifically. Other discussions of glass quantification generally form small portions of the methodology sections of other studies and assemblage catalogues, with very little detail or discussion of the choice of methods used. There are several reasons for this oversight including the difficulty of quantifying glass, and the uncertainty of how well an assemblage relates to the actual usage of glass on a site owing to the routine practice of collection and recycling. There are, however, good reasons to consider tackling the problems of glass quantification. It can be used for understanding the spread of forms, which may still be compared to other forms represented in assemblages, and proportions of similar forms missed in recycling may be proportionate. In certain cases, where a short period of occupation may have limited the impact of recycling, or the sudden destruction or abandonment may allow glass to be found in usage rather than discard or loss contexts, for instance, quantification can also lead to an understanding of how much glass was used on a site.

Quantifying archaeological assemblages can be a relatively simple procedure when dealing with certain types of artefacts that are found whole, but when dealing with objects such as ceramic or glass vessels, establishing an item count can be a difficult and contentious matter. This difficulty was expressed well by Clive Orton who said; '…a coin is a coin, and there's not much doubt about that. But what are we to do about objects that are found broken more often than not' (1980: 156). In other words, objects such as coins can be counted and, for the most part, each one can be recorded as a distinct member of its assemblage. Coins, of course, were sometimes cut or otherwise altered for various reasons in antiquity, including decreasing value to make change, demonetisation for offerings, destroying counterfeits, or for personal or political reasons (Buttrey 1972: 31), but they are found whole most of the time and thus function well enough to express Orton's idea. In the case of glass vessels, and other breakable artefacts, multiple fragments may represent single items, even when not found in the same immediate vicinity. Even if every fragment of all the vessels in an excavation were recovered – an exceedingly rare occurrence, as many vessels can be broken down into unrecognizable pieces and be missed in excavation, and some may have been collected for reuse for another purpose or for recycling (Orton 1980: 161) – there is simply not time to connect each fragment to the correct vessel and create distinct easily countable reconstructions. Due to the inability to count fragmentary artefacts simply, it becomes necessary to find other, more creative ways to quantify these assemblages.

The problem with trying to quantify glass assemblages accurately is that there is not a standard recognised practice that is entirely satisfactory. Most techniques tend to follow practices utilised in the study of ceramics, which should, in principle, work in the same way for both glass and ceramic vessel assemblages, because both types of artefacts come in relatively similar forms, and present the same major problem: Both glass and ceramics are found most often in broken states, with individual vessels being represented by either single fragments, or a handful of fragments. The four main approaches for quantifying these assemblages are fragment count, fragment weight, estimated vessel number, and estimated vessel equivalency (Orton 1980: 167). The problem then is that there are additional factors to consider when looking at glass compared to ceramics. There is a wider variety of colours, varying degrees of opacity, and a lack of standardisation for sizes and finishing techniques within forms. These factors can all complicate the quantification of fragmentary glass vessels, so any researcher studying glass must determine what exactly he or she is attempting to learn from the assemblage, and which quantification technique will best meet the necessary requirements and can address all relevant factors. Only once this decision has been made and an assemblage has been quantified can a researcher move on to the even bigger questions concerning how representative the assemblage is of an entire site, its context within a site, how the 'site' is defined, the use of the finds (Orton, Tyers, and Vince 1993: 166), and what the assemblage can illuminate of its historical time period.

To gain an understanding of the quantification methods that are used and the value of each for quantifying vessel assemblages it is necessary to look at how each method is used, how it works with glass, and whether or not it addresses the issues that complicate glass and set it apart from ceramics.

Fragment Count

The simplest method of counting a glass or ceramic assemblage is fragment count, but it has limited practicality, and any researchers using this method must consider its value to the aims of their studies carefully. Counting fragments simply reveals the number of individual pieces and ignores the original number of vessels that would have been used, making it ineffective for any study of usage patterns. Fragment count is unreliable even for determining the simple quantity of glass in an assemblage or for drawing comparisons of total quantities of glass between assemblages, because assemblages at sites with more opportunity for breakage appear larger than those at sites with less disturbance. This method may not even be consistent for subsequent studies of the same assemblage if there is any further breakage in storage or transport between periods of study. The fragility of archaeological glass makes this a very real risk and has been witnessed first-hand by the author when examining catalogued assemblages, some of which (e.g. portions of Xanten, Vetera I; Pompeii; and Herculaneum) were excavated before or between the First and Second World Wars and have been through bombings and museum moves.

A further problem resulting from the fragment count method is that if it is used to try and look at numbers of fragments of varying vessel types, then it will generally under-represent sturdier vessels. Sturdy vessels will normally break into fewer fragments than their more delicate counterparts and, therefore, will appear to have been present in smaller numbers. The vessel forms that break into more fragments will appear to be much better represented on the site even when they may actually be represented by the same number, or even fewer vessels than durable vessel that are not as badly broken (Orton 1980: 163; Fletcher and Heyworth 1987: 36).

Fragment count can be very useful, however, for certain types of studies, when combined with other quantification methods. If the number of vessels is determined through the use of another method, then fragment count can be extremely significant for studying fragmentation and deposition patterns. On its own, however, fragment count simply cannot provide information about vessel numbers for tracing patterns in item production and usage, which are key factors in many glass studies that require accurate vessel counts.

Fragment Weight and Adjusted Weight

Fragment weight can be a quick method of identifying the total quantity of glass in an assemblage, or of the glass from a specific form, while avoiding the problem of breakage, but again, like fragment count, it does not identify the number of vessels present. If a form were so standardised that it was possible to have an accurate average weight, then the total weight could be divided by the average to determine the vessel count, but this degree of standardisation is not the case with Roman glass vessels. The common square bottle (Isings form 50) (Fig. 1), for example, can measure anywhere from less than 10 centimetres to more than 40 centimetres in height, with a body width that could be greater than the height, or less than half the height, allowing for a huge variation in weights for the same vessel form (Isings 1957: 63–66). If, rather than using weight to count vessels, weight is used to compare the total quantities of different forms within an assemblage, it will be skewed toward the heavier forms like serving jugs which will appear to represent a higher portion of the total glass than the vessel numbers would, as opposed to forms like cups (Orton 1980: 161).

Figure 1: Isings Form 50 Bottles of varying sizes, and with two different rim-finishing techniques. (Photos: Jonathan Prior).

One proposed way of compensating for the weight of different fragments skewing vessel count in favour of heavier forms is 'adjusted weight.' This is attained by multiplying the total weight (g.) of all fragments of one form, by the standard wall thickness (cm.) for that form, and then dividing it by the actual wall thickness of those fragments (Fletcher and Heyworth 1987: 36–37). The adjusted weight method has been shown to produce similar proportions of total assemblages to those of estimated vessel numbers (Table 1), but the process can be time consuming in tallying weights and calculating the average thickness of all the fragments of a form, and in doing the research to come up with a 'standard thickness.' When dealing with ceramics, this method over-represents vessels made with a high-density fabric (Fletcher and Heyworth 1987: 36–37). Density is less of an issue with Roman glass, which was quite homogeneous. However, different metals added to colour or decolour different glasses could affect the weights of different samples in a similar way, and there is no guarantee that the 'standard thickness' selected is, in fact, standard. A 'standard thickness' could easily be influenced by the excavation and recording biases of any studies looked at to get examples of this form. Thin examples of a form may be broken beyond recognition at some sites and may be under-represented giving a standard thickness that is greater than the average for whole vessels in their original state. Different studies using this method may also calculate different standard thicknesses, skewing any comparison of results between studies.

Table 1: Count, Weight, Adjusted Weight, and Minimum Number Figures for three rim types from a sample study of Middle-Saxon glass from Southampton. (After Fletcher and Heyworth 1987, Table 3).

	Count (no)	**Weight (g)**	**Adjusted weight (g)**	**MNI (no)**
Cavity Rims	74 (38.9%)	135.6 (47.55%)	67.8 (38.4%)	42 (35.6%)
Folded Rims	30 (15.8%)	35.1 (12.55%)	20.1 (11.4%)	21 (17.8%)
Rounded Rims	86 (45.3%	110.7 (39.9%)	88.6 (50.3%)	55 (46.6%)
Total	190 (100%)	281.4 (100%)	176.5 (100%)	118 (100%)

Weight can be useful, in some instances, for comparing vessels of the same type (Cool and Baxter 1996: 95), and for comparing different assemblages, since it is unaffected by fragmentation (i.e. the same vessel will weigh the same regardless of how many pieces it is in), and can be useful for discussing fragmentation if it is divided by the fragment count to determine the average weight of sherds (Fletcher and Heyworth 1987: 36; Orton, Tyers and Vince 1993: 169).

Estimated Vessel Equivalency (EVE)

In ceramic studies, EVE is widely used to estimate vessel numbers, but this method is problematic for use on glass. It is frequently possible to identify the type of ceramic vessel by rim or base sherds alone, and the quantity is high enough that body sherds can often be ignored (Cool and Baxter 1996: 97). Researchers can then total up the percentage of the rim and base circumferences for all sherds of the same form, fabric and vessel size, and round these numbers to the next complete vessel. The resulting number is divided by two to eliminate double counting of the same vessel represented by both rims and bases resulting in an estimated percentage of vessels represented. By dividing that number by 100 an estimate of the minimum number of vessels present can be achieved (Orton 1980: 166).

Glass vessels cannot be identified as reliably as ceramics by rim and base sherds alone. Rim and base fragments of glass vessels do not survive as well as those of their pottery counterparts, partly because larger fragments such as the diagnostic fragment types necessary for EVE would be easily collected for recycling, and there are not high enough numbers of glass finds to ignore body sherds with impunity, so counting only one or two types of fragments may greatly underrepresent the quantity of vessels in an assemblage. Furthermore, many glass rim fragments that do survive are so badly broken that it is hard to determine the original curvature and circumference of the rim, which limits the use of the primary EVE technique. Another reason that glass body fragments cannot be ignored is that they may be required to determine the form of a vessel. The same rim finish techniques appear on many different vessel forms, and the same vessel form can have several different finishes. This means that rims are not always useful diagnostic fragments on their own for counting vessels of any one type. For example, the square bottle (Isings form 50) can be finished with a vertical cracked off and flattened rim (Fig. 1: top right), with a horizontal rim that is folded out and either up or down and in, or a triangular folded rim (Fig. 1: left and bottom right). The triangular folded rim, or any other of these techniques can also be seen on other vessel forms including cylindrical bottles, flasks, aryballoi, and jugs (Fig. 2; Fig. 3).

Glass also has great variation in colour and opacity that would have to be accounted for before using any form of EVE. When dividing ceramics for tallying rim circumferences, fragments can be sorted by form and fabric. If the EVE of a bowl form were being determined, then one would gather all the relevant fragments of that form, which can then be split by fabric to ensure that sherds of different colours are not counted as one bowl. Fabric types of Roman pottery are quite well categorised (Tomber and Dore 1998: 4–7) and the colours can frequently be precisely determined using the number coded Munsell Soil Color Charts (1992) as well as subjectively, to categorise them accurately. These distinctions can be made quite quickly because of the standardisation and the vast body of work on ceramics. Glass, on the other hand, is more complex. Fragments of the same vessel could appear different as thickness and lighting can impact the appearance of the colour, making it very difficult to identify the colour value in an accurate and reliable manner, even using a set notation system like that derived by Albert Munsell for consistency in colour description (1975). Aside from colour, one must consider the opacity of the glass, decoration, and finishing technique to distinguish which fragments definitely come from different vessels before tallying up the percentages of those that are more-or-less interchangeable.

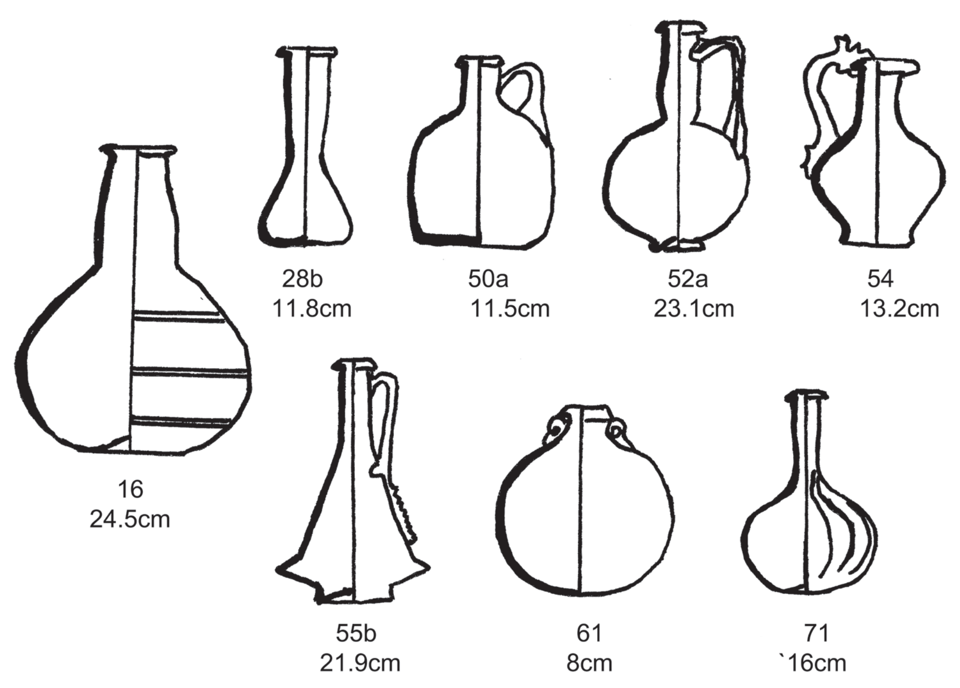

Figure 2: Vessel forms with triangular folded rims. (After Isings 1957: 34, 43, 63, 69, 71, 74, and 79).

Figure 3: Aryballos, bulbous bottle, and square bottle with the same rim type; all from Herculaneum. (Photos: Jonathan Prior).

Cool and Baxter: Adjusted EVE

H.E.M. Cool and M.J. Baxter produced a detailed study of the quantification of glass for the 1995 International Association for the History of Glass Conference in the Netherlands, in which they created their own adaptation of EVE for glass. Their method, which is based on techniques for quantifying bone using a zoning system, attempts to compensate for the relatively small number of glass finds and the inability to discount fragments other than rims or bases. Cool and Baxter decided that each zone of a particular vessel form, be it a rim, shoulder, body, base, or handle, could be given a number value representing an equal portion of a vessel totalling 100 per cent, if all zones are present. When looking at a fragmentary glass vessel, the tally of zones represented is then added to produce a percentage that represents each vessel. Cool and Baxter determined that most forms with no handles can be divided into five zones and vessels with handles like bottles and jugs easily divide into seven (Fig. 4). It is important to keep in mind that care must be taken to ensure that each zone present for an individual vessel is counted only once so as not to risk double counting. In a five-zone vessel, for example, in which each zone is worth 20 per cent, a rim fragment and a body fragment would give the vessel a value of 40. If there are two rim fragments and one body fragment only one rim is counted and the number is still 40. All vessel numbers of the same type of vessel are then added up and vessel equivalency is determined as in EVE.

This technique is an improvement on standard EVE for glass, but does come with its share of problems. A zoning method must be determined for each form before beginning a study, which can be time consuming at the start, but does not greatly increase cataloguing time after the zones are decided (Cool and Baxter 1996: 97). Another issue is that it can be very easy to count two fragments of the same zone of the same vessel as different vessels if they are not discovered and inventoried together. To ensure the best possible pairing of fragments, multiple variables including fragment size, form, production technique, rim and base finishing, decoration, and colour must be recorded very carefully. Additionally, all the fragments must be studied in the same lighting conditions, because the type and angle of light on a fragment can change the perception of its colour. A good example of how easy it is to make mistakes based on colours comes from the first century fort on the Kops Hof in Nijmegen, where two natural blue-green fragments of pillar-moulded bowls (find numbers 361/141 and 361/071) are recorded as fragments of the same bowl (Van Lith 2009: 19). When examined side by side in the same light, the fragments have different levels of clarity in cross-section, and one has a more greenish colouration showing that, although similar, they are not in fact from the same vessel. A more extreme example of how different lighting can change the visible colour of a glass would be the famous fourth-century 'Lycurgus Cup,' now in the British Museum, which can appear either green or red, due to nanoparticles in the glass (Fleming 1999: 92; Freestone *et. al*. 2007: 272). Other problems are that fragments of uncertain forms, or of rare forms may be misattributed to a vessel type, or may result in double counting. As a result, the decisions required to prevent double counting and to match vessel fragments, are the very same subjective methods that drive some scholars to prefer EVE above estimated vessel count.

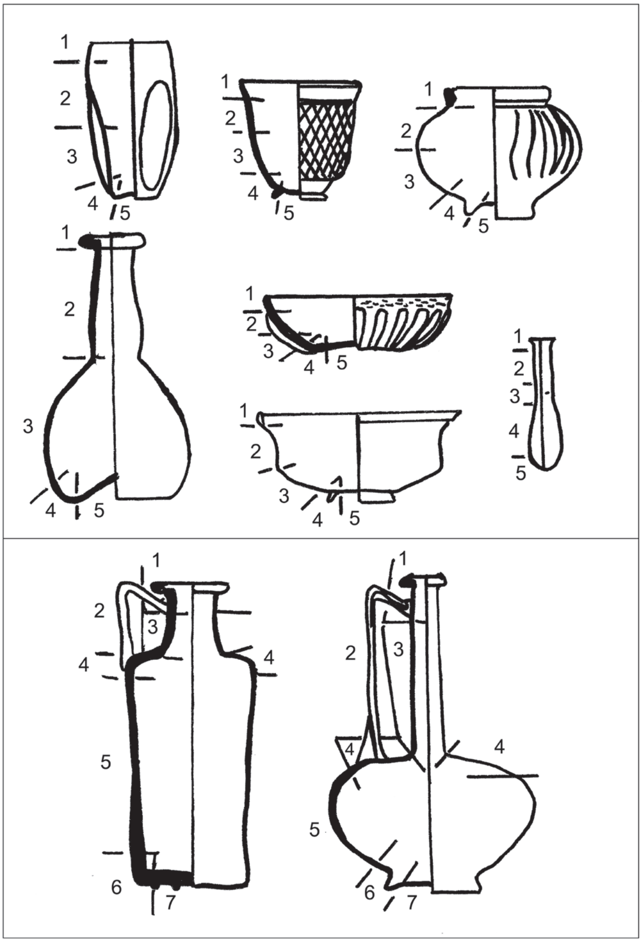

Figure 4: Cool and Baxter's vessel form profiles showing zones. (After Cool and Baxter 1996: Fig. 1).

Estimated Number Methods

The aforementioned problems with Cool and Baxter's method, which requires scholars to match fragments of the same vessel to one another, make it just as simple to tally up the number of vessels represented as to calculate the EVE, because individual vessels are already being identified. In fact, if all the fragments have been sorted by possible vessel connections to as avoid double counting, the Baxter and Cool method should result in identical vessel numbers to an estimated minimum number of individuals count.

There are two basic estimated number methods that can be used. Any fragments that cannot be readily connected to another vessel can be counted as independent vessels, which results in a count of the maximum number of individual vessels represented in the assemblage. Alternatively, unattached fragments can be counted as part of the nearest identified vessel of the same type resulting in a minimum number of individual vessels frequently referred to as MNI.

The maximum estimated number technique tends to over-estimate the number of vessels in an assemblage with numbers that can approach the level of fragment count. Due to the scattered and fragmentary nature of glass finds it is easy to find potentially connecting fragments in different contexts that are not immediately associated. The practice of recycling means that pieces that might have connected with excavated fragments may have not entered the archaeological record at all. This method does not take these facts into consideration, and will result in numerous individual fragments being counted as unique vessels when they may easily have originated as part of the same vessel. As a result, more fragile vessels that break into more pieces, which may be spread far apart and may be represented by fragments that do not connect, are over-represented. Looking at the Usk sample in Table 2, as an example, one would calculate a maximum number of individual vessels as 33, with 21 Isings 67c and 12 Isings 67b jars. These 33 potential vessels come from a collection of only 51 fragments (not shown in Table 2) and only six of these vessels are represented by more than one fragment. Item 183 was an anomaly in that 12 fragments were found together, but no other example of these two vessel types was found with more than three connecting fragments at Usk.

Estimated minimum number of individuals (MNI) is more likely to provide an estimate closer to the actual number of vessels represented by finds, because it takes into account the problem of fragmentation and strives to avoid double counting and over-representation of more fragile vessels. It will, undoubtedly, under-estimate the numbers to some extent, but its insistence on grouping any unattached fragments to potential matches does draw attention to fragment pairings that may end up being verified under closer study, leading to even more accurate numbers. The two techniques can be useful when combined, because one can use them to create a range of potential vessel numbers between which the actual number will fall. Although MNI calculation using spreadsheets is fairly simple to perform, and can be highly valuable in quantifying an assemblage by actual vessels, the resulting counts are still problematic. MNI methods rely on there being enough suitable criteria to distinguish between vessels, and there is a possibility of over-representing rare or minor types, since many fragments of different common vessels will be similar enough to require them to be counted as only one vessel in a site's MNI (Fletcher and Heyworth 1987: 37). When vessels are largely incomplete, there is a possibility that those that break into more pieces have a higher chance of being represented (Orton, Tyers and Vince 1993: 169), but with glass, those that are more breakable are often broken into chips so small that they are missed or cannot be identified to the level of a vessel form. This may mean that more durable vessels are more likely to be found, thus to some extent counter-balancing this potential discrepancy. Even so, it is preferable to look at minimum numbers of vessels represented rather than maximum to prevent more breakable vessels from being over counted.

Nevertheless, Fletcher and Heyworth argue convincingly that estimated vessel numbers are more meaningful than fragment count or weight because it relates directly to the number of vessels present (1987: 43), and combined with those techniques it provides information about fragmentation and deposition, but there are still concerns about its subjectivity and the ease of over-representing certain forms.

Admittedly, these techniques do rely on subjective analysis, and can be both time consuming and difficult if the assemblage is large and fragments cannot easily be compared to similar pieces of the same vessel type. For this reason, all the care that was necessary to make Cool and Baxter's technique feasible, such as working in consistent lighting conditions, must be taken when analysing an assemblage and recording variables. The use of a multivariable spreadsheet can be of great assistance in accurately pairing fragments that are carefully recorded. The present author makes heavy use of spreadsheets for an estimated MNI technique, which follows the same criteria laid out by Cool and Price in their catalogue of the glass from Roman Colchester (1995: 9). Every fragment or cluster of related fragments receives an entry in an Excel worksheet with cells for colour; fragment type; vessel type; production method; Isings form (where possible); provenance; notes on decoration; and where applicable, rim, base, and handle types. Using Excel's filter feature, the entire assemblage can be sorted by vessel type, form, colour, and production method, as Cool and Price outline (1995: 9), so that all of the fragments that could potentially come from the same vessel can be grouped together (Table 2). From this stage one can begin looking at size, fragment type, and find context to identify possible related fragments. Any fragments that can be matched through these filters are then recorded together as a minimum of one vessel, and any that do not match up can be counted as distinct vessels of their form. Once these determinations have been made, the numbers can be tallied up to calculate the MNI for the vessels of each form, or for the entire assemblage.

The example case in Table 2, with its limited available variables, allows for a MNI calculation of 22 jars (9 Isings form 67b and 13 Isings form 67c). These numbers are reached by eliminating possible connections. Table 2 has already been filtered to eliminate all fragments that are not jars, with the remaining fragments sorted by form. Within each form fragment entries are sorted by colour. By then looking at context and diagnostic features within each colour grouping it is possible to determine which fragments must be from distinct vessels and by counting all unique entries as one vessel a MNI estimate can be reached. For example, looking at items 184–187, all the entries are from dark blue Isings type 67c jars. Three of the entries are at least partly from unstratified contexts from the 1973 excavation. Two of these unstratified pieces connect to other fragments from identified contexts, but these stratified fragments have no markers that rule out the possibility of being from the same vessel either. These three entries, therefore, must be counted as one vessel. Fragment number 186 is also an unstratified dark blue Isings 67c Jar fragment, which cannot definitively be identified separately from the others in this number range, so based on the information present in this chart the total MNI from this whole cluster must be recorded as one. This table is, of course, a limited data set provided as an example, and with all variables considered, including wall thickness, measurements of the rim fragments and their curvature, and even comments on fragment condition, the MNI could be increased resulting in a number up to the calculated maximum of 33 vessels. This chart does not provide enough data to calculate EVE, but in the selection of items 184–187, EVE methods would calculate a vessel equivalency as one, because only one example of a rim and base is present to examine and items 185–187 would be discounted. Cool and Baxter's method would look at those items, but without conclusive data to distinguish them from the body fragment in 184, and to avoid double-counting, their method would not count 185-187 separately, and would therefore also estimate just a single vessel.

Table 2: Sample data sheet from the legionary fortress at Usk, Wales. Filtered for storage jars. Some variable columns omitted for space. (Access to material provided by the National Roman Legion Museum, Caerleon.)

Item	Context	Vessel Type	Isings Form	Fragment Type	Colour	Manufacture	Rim Shape	Base	Decoration
188	KRW(1) sixteenth century trench	Jar	67c	Body	Yellow-brown	Free-blown			Vertical Rib
191	69 Unstratified	Jar	67c	Body	Light green	Free-blown			Vertical Rib
192	69 RA(1) pre-Flavian fortress pit	Jar	67c	Body	Light green	Free-blown			Vertical Rib
189	69 EP(1) third century ditch	Jar	67c	Body	Yellow-green	Free-blown			Vertical Rib
190	FNL(2) first to second century extra mural road	Jar	67c	Body	Yellow-green	Free-blown			2Vertical Ribs
193	69 RA(1) pre-Flavian fortress pit	Jar	67c	Body	Yellow-green	Free-blown			Vertical Rib
184	73 unstratified; HCM(1) and (2) pre-Flavian/Flavian culvert by *Via Principalis*	Jar	67c	Body Rim and Base	Dark blue	Free-blown	Folded Collar	Open Ring	Vertical Ribs on body. Collar rim is tubular
185	73 unstratified; HON(1) pre-Flavian cistern	Jar	67c	Body	Dark blue	Free-blown			Vertical Ribs
186	68 unstratified	Jar	67c	Body	Dark blue	Free-blown			Vertical Rib
187	73 unstratified	Jar	67c	Body	Dark blue	Free-blown			Vertical Ribs
194	68 FM(1) pre-Flavian fortress pit	Jar	67c	Body	Pale blue-green	Free-blown			Vertical Rib
195	67 BI (13) South Ditch of *Via Principalis*	Jar	67c	Body	Pale blue-green	Free-blown			Vertical Rib

Item	Context	Vessel Type	Isings Form	Fragment Type	Colour	Manufacture	Rim Shape	Base	Decoration
196	65 XIV unstratified	Jar	67c	Body	Blue-green	Free-blown			Vertical Rib
197	69 AF(2) post-medieval stones	Jar	67c	Body	Pale blue-green	Free-blown			Vertical Rib
198	69 NZ(1) pre-Flavian trench of fortress granary B	Jar	67c	Body	Pale blue-green	Free-blown			Vertical Rib
199	69 HX(1) late first/second century pit with residual pre-Flavian material	Jar	67c	Body	Pale blue-green	Free-blown			Vertical Rib
200	69 RE (69 RA) pre-Flavian fortress pit containing material from first through third centuries	Jar	67c	Body	Pale blue-green	Free-blown			Vertical Rib
201	73 unstratified	Jar	67c	Body	Pale blue-green	Free-blown			Vertical Rib
202	LAL(1) pre-Flavian fortress well containing late first century pottery	Jar	67c	Body	Pale blue-green	Free-blown			Vertical Rib
203	LAL(2) Pre/early-Flavian fortress well	Jar	67c	Body	Pale blue-green	Free-blown			Vertical Rib
204	HKP unstratified	Jar	67c	Body	Pale blue-green	Free-blown			Vertical Rib
183	LNA(2)Pre-Flavian pit	Jar	67b	Body	Yellow-brown	Free-blown			
182	Pre-Flavian fortress ditch	Jar	67b	Body and Base	Dark blue	Free-blown		Open Ring	

Item	Context	Vessel Type	Isings Form	Fragment Type	Colour	Manufacture	Rim Shape	Base	Decoration
88	LAL (2) Pre/early-Flavian fortress well	Jar	67b	Rim	Dark blue	Free-blown	Folded Collar		Marvered opaque white blobs on interior surface of the rim.
205	65 X C (4) Antonine pit?	Jar	67b	Rim	Blue-green	Free-blown	Folded Collar		
206	71 unstratified	Jar	67b	Rim	Blue-green	Free-blown	Folded Collar		
207	73 unstratified	Jar	67b	Rim	Blue-green	Free-blown	Folded Collar		
208	69 unstratified	Jar	67b	Rim	Blue-green	Free-blown	Folded Collar		
209	LNA(2) pre-Flavian fortress Pit	Jar	67b	Rim	Blue-green	Free-blown	Folded Collar		
210	DOH(1) early second century ditch	Jar	67b	Rim	Blue-green	Free-blown	Folded Collar		
211	EOM(1) third century drain	Jar	67b	Rim	Blue-green	Free-blown	Folded Collar		
212	FAS(1) above north ditch of *intervallum* road. Flavian and later	Jar	67b	Rim	Blue-green	Free-blown	Folded Collar		
488	69 Unstratified	Jar	67b	Rim	Blue-green	Free-blown	Vertical		Folded over to form a ridge below the rim.

The advantage of using a spreadsheet in this way is that, once individual vessels have been identified, it is possible to back up through the levels of filtering to look at a wide variety of factors, enabling different research questions to be answered. A researcher can look at individual forms or a broader type-category, such as beakers, within the assemblage; calculate numbers of specific fragment types; or can examine the numbers of vessels of a specific production type, colour, or from a specific find context. One example of current research being undertaken on the Roman glass industry is focused on changes in glass usage brought about by the invention of glassblowing (Prior in preparation), so it is imperative to use a method of quantification that provides accurate vessel numbers (Table 3) and takes factors like production method into account when distinguishing between fragments so that accurate ratios can be calculated. The ability to filter by form, colour, and provenance using a multi-variable spreadsheet allows for an examination of the role of different production techniques in making utilitarian, or luxury items. All relevant factors can be closely examined, resulting in more accurate estimations of assemblage numbers than can be produced without such close comparison. In the case of the assemblage from the Vetera I fortress at Xanten, Germany, the published catalogue estimated that there were at least 350 vessels (Hanel 1995 v.1: 250), where close examination found many that could have come from the same vessel resulting in a refined MNI count of 314 (Prior in preparation). The spreadsheet was invaluable as it would have been impossible to spread out the whole assemblage and compare each piece of the same vessel type side-by-side to see if connexions could be made. The alternative is to rely on memory to find potential matches.

While such quantification methods can provide useful data and can illustrate patterns emerging across sites, Table 3 can illustrate some of the unavoidable issues that must be considered in discussions of such results. For example, when looking at the row for the common pillar-moulded bowl (Isings 1957: 17–21, Form 3) it is easy to become concerned about the reliability of cross-site comparison as it accounts for only three per cent of the vessels (nine examples) at Herculaneum while the other sites with poorer preservation have much higher numbers of the same form. It is important, therefore, to consider possible reasons for this discrepancy. One reason might be collection bias. The excavations at Herculaneum have been underway for well over a century and were originally focused on finding artistic display pieces rather than on scientific recording. This emphasis, combined with the sheer wealth of material has led to a collection and retention bias that favours complete or nearly complete vessels. In fact, in the study represented in Table 3 there were no examples of vessels from Herculaneum represented by one or a handful of fragments, as was the norm at all the other sites. If retention bias is the reason for the low levels of pillar-moulded bowls one must ask why this form would be represented proportionally less than others. If broken vessels were discarded one would expect that this would also lower the numbers of other forms, and if anything, one might expect that a sturdy, thick-walled vessel like the pillar-moulded bowl would be over-represented as a result of a bias of this type. In this case, collection biases probably result in an under-representation of the total number of vessels in use at Herculaneum at the time of its burial, but may not, in fact, cause the under-representation of specific production types. A possible explanation for the low number of pillar-moulded bowls in comparison to sites like Usk could be social context. Hanel (1995: 242) has proposed that throughout the first century A.D. pillar-moulded bowls maintained popularity among soldiers, perhaps for their durability, and if we look at the Nijmegen *Batavorum* site, the only other civilian settlement in Table 3, we can see that its pillar-moulded bowls also represent less than ten per cent of the glass vessels in the assemblage. The three legionary fortresses, including that on the Kops Hof at Nijmegen, which was recorded and conserved in the same way and by the

Table 3: MNI vessel distribution by production type from an urban context in the heart of the Roman Empire, three frontier legionary fortresses, and a frontier civilian settlement (Batavorum) (Prior in preparation. Access to materials provided by the Soprintendenza Speciale per I Beni Archeologici di Napoli e Pompei; The National Roman Legion Museum, Caerleon; LVR Rheinisches Landesmuseum, Bonn; and the Museum het Valkhof, Nijmegen and Gemeente Nijmegen).

Production technique	Herculaneum	Usk	Xanten: Vetera I	Nijmegen: Kops Hof	Nijmegen: Batavorum
Pillar-moulded	9	83	67	43	18
Other casting	18	5	22	13	7
Free-blown	234	572	142	104	169
Mould-blown	25	60	31	17	10
Mould-blown or free-blown	5	0	41	9	3
Cut	1	0	0	0	0
Core formed	0	0	1	1	0
?	7	0	9	1	1
Total	299	720	314	188	208

same municipal archaeologists as *Batavorum*, show pillar-moulded bowl percentages between 11 and 22 per cent of their total assemblages. Hanel's explanation requires further study to see if the pattern is present across a greater number of sites, but potential explanations, such as popularity among specific subsets of society, must be kept in mind when doing any sort of cross-site comparison of vessel forms.

Conclusion

Not one of the methods presented here is perfect and each has significant pros and cons, but, when used together or for set purposes they can provide us with valuable information about assemblages with which one can undertake further study of glass forms, trade, production, usage, and deposition. EVE and MNI are the best ways to quantify the vessels represented in an assemblage, because they seek to work around issues of fragmentation by avoiding double counting and creating minimum estimates, allowing for studies of seriation and usage alluded to in the introduction. When used together, it is possible to test the accuracy of vessel type proportions determined through EVE and MNI by checking how closely the numbers of different vessel types determined through each method align. If a maximum estimated number of vessels is then calculated researchers can then evaluate the potential for error in their calculations and provide a range in which the actual represented vessel count must fall. It can also be useful to use a combination of the methods discussed in this paper when branching away from discussions of usage and vessel numbers to talk about issues of deposition and fragmentation.

Other scholars will have their own methods of quantification, or different techniques for the methods discussed here, but the fact remains that the field is under-published, and serious discussion of the quantification of glass is needed if consistency is to be achieved, enabling better cross site comparison and a better understanding of trade, the Roman glass industry, and the day-to-day lives of the ancient Romans. Even with a variety of methods available to researchers, glass continues to be a difficult material to quantify. Until a standard method is developed, it is necessary for each scholar to determine which method is suited to his or her research goals, and must clearly outline the methodology used so that others can reliably consult the data for further studies.

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