Exploiting Weight Data to Support Engineering and Corporate Decision-Making Processes

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Abstract

Weight control, from early weight estimation through life cycle weight tracking, is often conducted in dangerously inefficient ways or, worse, not conducted at all. Despite a general agreement on the utter importance of weight and centre of gravity calculations, during all phases of ship design, construction and operation, only seldom does weight data receive the attention and appreciation it requires on a corporate-wide scale. This paper will explore the nature of weight data, the tools available for weight control at the various stages through the life cycle of a water-bound vessel, and identity various players who influence the weight of a vessel. Examples of weight data sharing techniques and scope will also be reviewed. Finally, the means of implementing an effective weight policy will be described, and the benefits evoked.

1. Introduction

Weight control, from early weight estimation through in-service weight tracking, is often conducted in dangerously inefficient ways or, worse, not conducted at all. Despite a general agreement on the utter importance of weight and centre of gravity calculations, during all phases of ship design and construction, weight data never seems to receive the attention and appreciation it requires. There are many reasons behind this somewhat conscious disregard, spanning from the cultural to the technical.

Cultural reasons include lack of or limited knowledge of the weight subject itself, lack of statutory requirements (with the notable exception of some Navies), overconfidence in weight related considerations, incorrect appreciation of ships' similarities (or lack thereof), etc. Technical reasons include a limited market offer of dedicated, appropriate engineering tools, limited facilities for interfacing with CAD, limitations in many CAD tools, absence of managed feed-back from production management, difficulties in combining weight data into corporate management processes, etc.

The contradiction between the paramount importance of Weight and CG for a ship and the all too common disregard for these quantities is striking, as if the consequences of underplaying the importance of weight data were not damaging at best, catastrophic at worst. While at least some of the cultural reasons behind a correct and responsible approach to weight and CG calculations can be wiped by the use of appropriate technical tools, the fact remains that today only few technical tools lend themselves to an effective and reliable implementation of a constructive weight policy, able to support both the engineering and corporate decision making processes.

In this paper, for simplicity, we will refer to both weight and centre of gravity as weight, and we will review how the targeted use of state-of-the art IT technology can already today offset virtually all technical obstacles to the encompassing implementation of a corporate-supporting weight policy, as well as the cultural ones.

2. Weight, the skeleton in the closet

Weight is arguably the most common factor behind unachieved design and contractual goals, and generally the most difficult one to work with when it comes to identifying the genesis of error. The weight quantity exists in various forms during the life time of a ship:

- Macroscopic estimation at the very early stages based on a general mission statement and ship type selection.

- Estimation coupled with the development of feasibility study and conceptual design.
- Estimation evolved in parallel with pre- and contract reviews.
- Integration of CAD data during design.
- Integration of as-built data during production.
- Integration of in-service weight data to improve realism and quality of historical data

3. Weight groups and weight items

It is important to distinguish between weight groups and weight items, a distinction which is often overlooked, and to their complementarities.

Weight groups represent a range of unspecified but certainly present weight items. Weight items are be collected within weight groups, at the various levels in the weight model hierarchy. The weight value of a weight group can be estimated using macroscopic ship parameters such as type, mission profile, etc. For example, within a specific ship type, the weight of the engine room can be accurately estimated from ship size, service profile, etc. On the contrary, despite mostly containing the same equipment and machinery by nature, the engine room of a tanker will be identifiably different from the engine room of a tug or of an Offshore Supply Vessel and therefore one can hardly estimate the weight of the tanker's engine room from the know weight of an OSV's engine room.

More immediately identifiable to the layman, weight items are just that, individual components of the ship. While there are tools and ways to add up almost all the components of a ship, a complete list of all the items making a ship is simply not available until the ship's construction is truly completed, therefore an item list becomes a reliable approach to weight control only at later stages of the vessel's genesis.

The importance and usefulness of weight groups is therefore evident, from the very first stages of the ship design process. It also follows that weight groups and weight items are complementary, and that both are required to carry out a constructive weight control strategy.

Furthermore, it is important to factor in the too often disregarded yet very real role of non-engineers in the weight determination process. For example, consider the specification of heavy equipment, often dictated by price rather than absolute technical specifications or performance measurement, or by availability, and which may not be defined until a later stage in the design process.

Then, perhaps surprisingly to some, it becomes clear that weight is influenced by many different players within the corporate panorama, and that communication between them can only be beneficial to the success of a corporate weight strategy.

4. Weight data organization

In the more rational approaches, weight groups and weight items are organized in hierarchical data structures generally referred to as Weight Breakdown Systems (WBSs). Various WBSs have been developed ever since ship design became a formalized discipline, but they can be exploited most efficiently only since the invention of relational databases. On the other hand, the eternal, ubiquitous spread-sheets do not lend themselves well to the use of WBSs, because the macroscopic aspects of discriminating weight calculations made possible by the use of WBSs are very difficult to implement therein.

In WBSs, weight groups are organized in hierarchical fashion: for example, let us refer to the NATO WBS, used by many Navies and, until recently, more generally across the ships industry.

A brief history of Ship WBS

- since the 30th century BC: imaginative intuition, gut feeling, luck
- since the 19th century : weighted, proportional extrapolation, simple statistical analysis
- sometime in the 20th century - Ship Work Breakdown Structure (SWBS)
- 1970s onwards - pre-spreadsheet, in-house development of computerized weight tracking
- mid-1980s - advent of the spreadsheet
- 1988 - Expanded Ship Work Breakdown Structure (ESWBS) - the functional configuration definition of the ship is improved and expanded to serve logistics support, to become a integrating, common reference point from design through operation, allowing life cycle data to become an intrinsic contributor to the ship design process
- early 1990s - Commercial Ship WBS developed by BAS Engineering, Norway - departure from the US Navy-originated and NATO adopted SWBS, and from the ESWBS, to accommodate the different product model nature of and predictive algorithms required by commercial ships of different types.

Fig.1: Brief history of the ship WBS

Easy to guess, weight items are collected within weight groups. But, perhaps less easy to guess, not all weight groups are made to collect weight items. The reason for this is that higher level weight groups lend themselves well to predictive regression analysis, and at this rather macroscopic level individual weight items are not relevant. Of course, advanced software tools do allow the adding of the odd weight item even at the higher levels of a WBS.

Over time, several industry-standard WBSs have been developed from the one or two primitive WBSs of old, and they are loosely referred to in most weight estimation and weight tracking work. However, while it is always tempting to develop one's "special" WBS in the quest of perfecting the weight prediction exercise into a most accurate result, one must be careful to maintain sufficient homogeneity in the general WBS structures being used to allow the identification of similarities not only between ships of the same general type, but also, very importantly, between ships of different types.

In fact, ignored by many, it is this very ability to identify similarities within and across ship types that constitutes the basis of the most powerful and accurate weight estimations, and which can contribute the most to the overall corporate ship design and ship building process from the earlier stages. To keep to the corporate environment addressed by this paper, let us just remind ourselves of the relationship between weight and quantity (ex. steel plates) and between weight, production planning and financial planning (when will how much steel be required to support the planned production schedule?).

5. Weight Calculation Tools

Various tools of disparate nature are used for weight calculations. Concisely, tools lending themselves to weight data management can be grouped in major categories:

- Design tools
- Production tools
- Corporate tools

Across the categories listed above, the tools most used in weight data management range from the application of simple macro-multipliers, to the ubiquitous but intrinsically limited MS-Excel, to dedicated software applications custom developed by individual companies for in-house use and, finally, to encompassing commercial products like ShipWeight, by BAS Engineering, Norway.

Unfortunately, to date, general CAD and corporate software tools are not commonly considered to be a default integral part of a coordinated, corporate-wide weight policy. To make matters worse, many such tools lack even the simplest connectivity features, making data exchange virtually impossible.

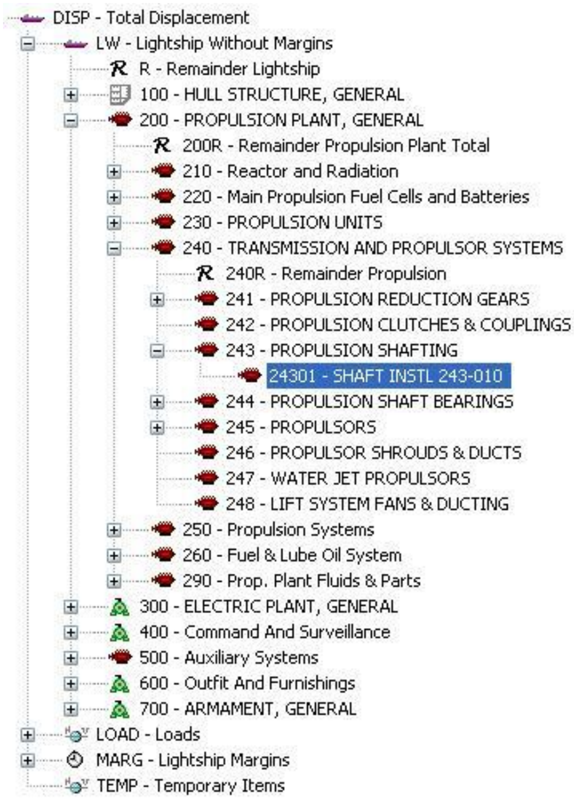


Fig. 2: Later version of the US Navy SWBS was used as the base of most modern SWBSs

5.1 Design tools

Referring to Section 2, design tools will be used until and throughout the integration of CAD data during design work. Design tools can be further grouped by the design phase during which they are used. For example, we could identify:

- Conceptual design tools
- Preliminary design tools
- Contractual design tools
- Detailed Design tools

There are of course tools which span the realm of the above, and they will be addressed separately.

The aim at the conceptual stage of design is to identify the overall weight of the ship, and to validate the estimated weight by analysing second and perhaps third level weight groups for congruency and consistency as a function of the mathematical methods employed. Conceptual design tools span the range from simplistic macro-multipliers to top-WBS level prediction methods. For example, if a relational database is available, one can regress a weighted and qualified interpolation through a historical database data set, using appropriate coefficients and drawing from a heterogeneous library.

Preliminary design tools are used to validate and converge the conceptual weight estimation. If a hierarchical WBS is used, third level weight groups are scrutinized very closely, and the first, heaviest weight items are included in the weight calculation, collected under the appropriate, lower level, respective weight groups. With simpler tools, the weight calculation remains ineffective at this stage, because too few of the weight items can be identified and located accurately in the ship to make for a realistic weight model. In both cases, some 3D CAD tools can assist to quite an extent, *Danese (2009,2010), Aasen (2010), Aasen et al. (2010,2011,2012,2013)*, e.g. ShipConstructor, which offers extensive interactive and associative weight calculation facilities.

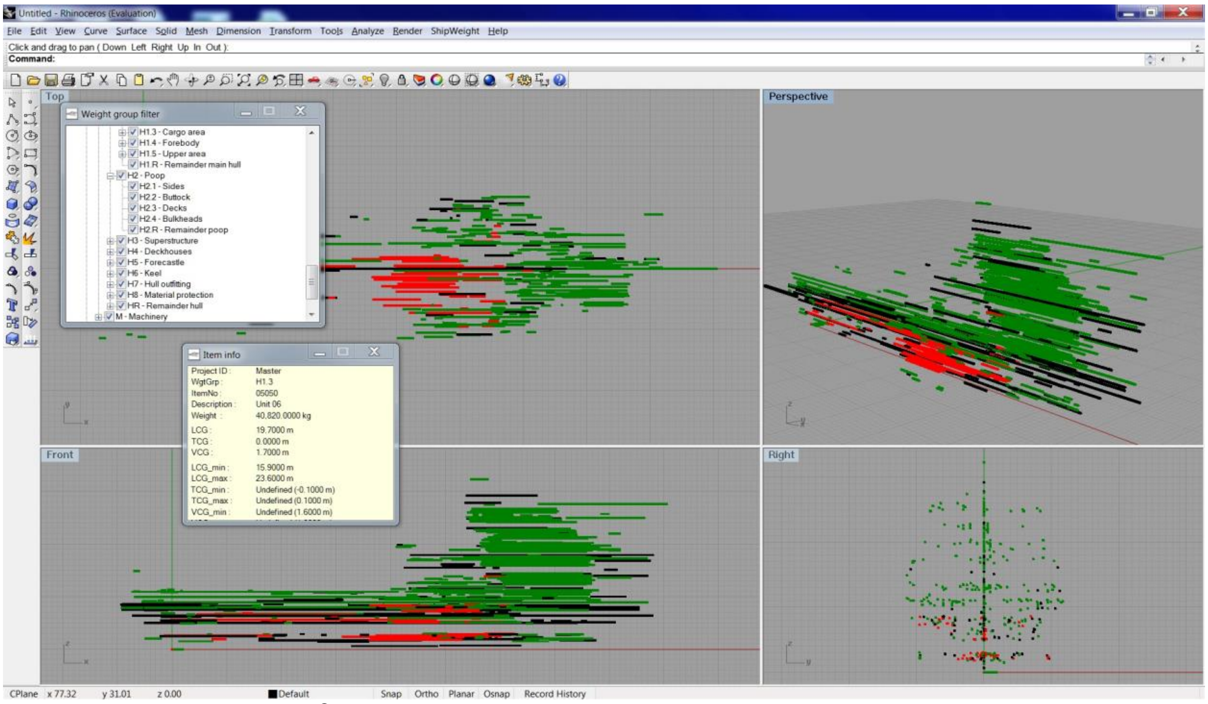


Fig. 3: Use Rhinoceros3D ® to check locations and spatial extents of ShipWeight weight groups and weight items

Contractual design tools reach into the CAD, 3D CAD for the modern, rational designer, realm. The role of 3D CAD becomes very important at this stage, particularly if the environment lends itself to analysis thanks to a relational database structure.

Corporate tools also begin to play a significant role at this stage, in that the establishment of a contract requires the identification and specification of most major components, equipment and machinery, where cost check may be influenced not just by type or nature of an item, but also by its quantity - all directly related to weight. Conversely, if cost were to be too different from the budget developed to this point, adjustments may also influence weight, even to significant extents. For example, drawing from real life, the author has witnessed occasions on which fluctuations in the raw material market forced the switching of the basic building material from aluminium to steel, or allowed the opposite. In both cases, an inaccurate weight estimation would have had severe consequences on the overall project and, in the former case, could have even spawned the bankruptcy of the yard.

Design tools begin to play a vital role once the design has advanced enough towards Classification that the weight estimation is replaced by weight tracking. At this point, fully managed 3D CAD models, interfacing to and interacting with corporate processes become essential. In addition to the purchasing office and its selection of major, heavy equipment and machinery, the production planning and human resource offices are now wholly involved. Weight will determine how big an assembly can be built, where in the shipyard it will be built, which crane and transport machinery will be needed to move it, how much pre-outfitting can take place at which moment during the production process, how many people will be needed where, at which exact moment in time and for how long.

In the case of shipyards building more than one vessel simultaneously, the importance of the above increases by orders of magnitude.

At this point, itemization of the weight model has begun in earnest, and multi-disciplinary, integrated CAD tools shine in supporting the maintenance of the weight model and the overall weight calculation.

5.2 Production tools

Perhaps also because design seems to be a never ending process, production inevitably starts before design is finished or, often times, even approved by Class. Moreover, to varying extents, some modern 3D CAD tools allow bridging the gap between design and production, and can be used seamlessly through both phases of the ship's genesis. These are, of course, 3D, realistic, CAD tools hinged on relational databases. More specifically, tools allowing multiple product hierarchies, one of which will mimic the weight software WBS, are perfectly suited to be an integrated part of the weight tracking and control process.

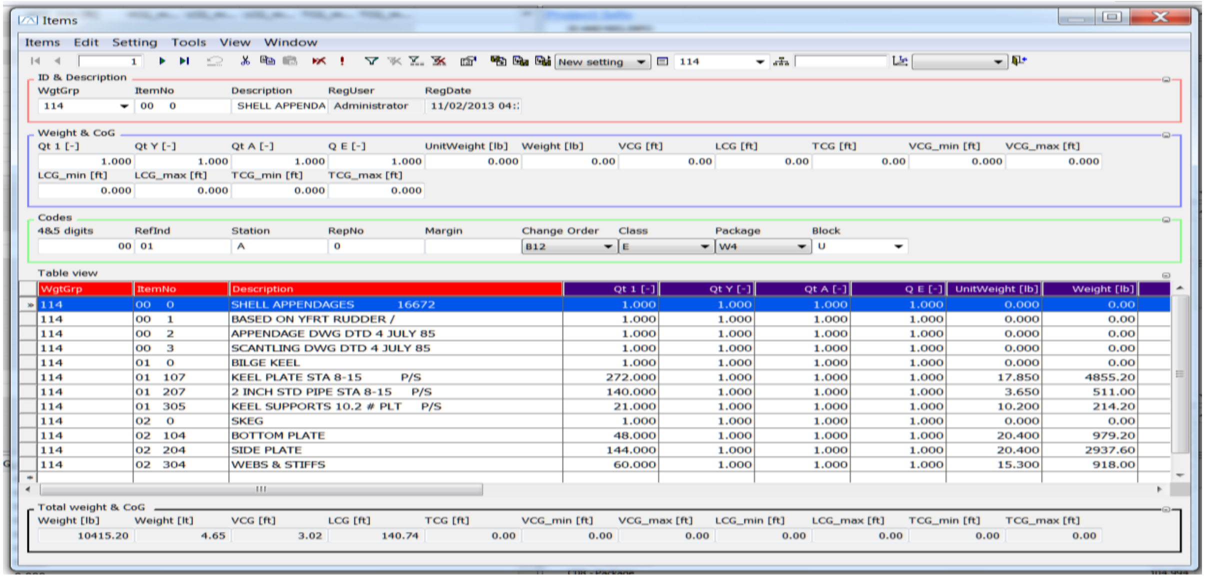


Fig. 4: Weight item inside a weight group

While production engineering should not engender remarkable changes to the model and its weight, it is the crucial moment when the design comes together and flaws may be exposed. Because in some vessels even small changes to the weight and/or its distribution can have noticeable, undesired effects, keeping a running check of weight is very important.

When production engineering begins, weight itemization fully replaces weight estimation. Continuing the verification process started during the later design work, it is now possible to accurately judge the accuracy of the estimation by measuring the remainders of each weight group, the remainder being the difference between the estimated weight and the itemized, discretized weight model. It goes without saying that the more complete the ship model is, the more accurately and realistically the remainder can be established, and the more reliable the extrapolation of this evaluation to the ship's scale will be. This is one of the crucial, bare truth moments in the course of the weight control process and, although it is already rather late in the game, only too often major issues appear during production engineering, their influence potentially reaching far beyond simple remedies.

5.3 Corporate tools

In today’s 3D CAD and product model world of ship design, it is easy to be lead toward thinking that such modelling tools are sufficient to accomplish all of the ship design tasks. But, weight control, for one, cannot be achieved by the use of CAD tools only, as it is influenced by other sizeable components of the ship's genesis process, such as corporate-wide planning, purchasing, factors influencing the supply of raw materials, equipment, availability of human resources, etc., all factors that are hard to address with 3D CAD and traditional product models. Therefore, the information available in corporate planning and management software needs to be harvested and processed in parallel with the continually on-going weight calculation. For example, any one of a score of non-engineering reasons could affect the planned outfitting of a ship's section, with repercussions not only on the shipyard's schedule but also on the handling of that section because of a now-challenging weight distribution, CG location, absence of a given item, etc. In other words, corporate reality may very much affect not only the final weight quantities, but also the in-progress weight quantities, at any given stage of design and building, or with respect to any given portion of the vessel.

The industry then faces a double challenge, cultural and technical. The cultural aspect of the challenge is related to the lack of awareness of the importance of non-engineering data in the ship design and production process too often found in corporate management. The technical facet consists of finding the way to convey the data and its meaning to those will be the most immediately confronted with weight deviations and who will be expected to elaborate solutions to the problem.

6. - The ShipWeight environment

ShipWeight is a state of the art weight control tool developed by BAS, Norway, and devised to be used from the earliest stages of design, through production and, uncommonly, throughout the life cycle of the ship. The unique scope of application of ShipWeight is achieved by implementing powerful, modern computer technology in a way that remains totally transparent to the user, on very standard hardware.

The ShipWeight environment can be resumed macroscopically as being composed of:

- a powerful, very flexible and fully customizable weight prediction engine, also allowing partial referencing, relative referencing of both complete and incomplete historical data models, in full or only of portions thereof. The core engine supports and is used for all types of vessel: ships, workboats, yachts, submarines, small craft, Navy vessels, as well as non-marine vessels, such as airplanes, land-bound carrier vehicles, etc.
- a fully customizable WBS structure, which also supports multiple WBSs
- a database centred data storage scheme, unlimited in terms of database size, number of simultaneously addressable databases, number of reference ships, number of weight items, etc.
- a very flexible data import engine, configurable to import virtually any custom data format
- the ability to directly connect to non-ShipWeight databases, files and programs to exchange data both mono- and bi-directionally
- an complete output engine allowing fully customized reports (tables, graphs, etc.)
- an easy to use, graphical, integrated query building system
- an open architecture, simple and fully documented database structure and query library

During the conceptual and preliminary phases of design, a macroscopic approach is privileged, and implemented by using advanced statistical data regression techniques that feed on historical data. The statistical regression tools offered by ShipWeight work by combining correlation coefficients (which can be conceptually compared to weighed scale factors) and parametric methods based on known vessel parameters, to estimate weight and CG of the vessel, or of portions thereof according to the WBS' hierarchical subdivision (the weight groups). Again, it is important to recall that the weight groups may or may not represent a geographical portion of the vessel, or the collection of items of similar nature regardless of their location, or a combination of the two.

Each weight group, in fact down to the very lower level ones, is assigned a method, which is an estimation formula based on appropriate ship parameters. The method is used to compute the weight group's quantity for each of the vessels selected from the historical database for the purpose of estimating the weight group in question. A curve representing the correlation coefficient is then fitted through the data according to a user selected or specified interpolation scheme. Finally, the correlation coefficient for the ship's weight group being evaluated is derived from the curve using one of the several selections and definition options made available by the program. The end result is the assignment of the estimated weight quantity to the weight group.

Once the early design process reaches the contractual stages, some major items will also generally have been included in the ShipWeight model, such as large, heavy or expensive equipment. On the other hand, while their quantity may be relatively well know at this point, at least macroscopically, items like steel will be represented by a lump number, and included in the weight model as such.

Not too far in time from contract signature, general arrangement, structural and distributed systems layouts, major machinery arrangements, etc., will have been advanced enough for a relatively rich, but probably not complete, realistic 3D CAD model to have been developed, and for most, if not all, the items to be sourced to have been defined.

This is another point in the ship design process where high-performance, integrated CAD tools become important in the weight calculation exercise, and yet remain of limited use corporate-wide if the data they generate cannot be integrated with the other IT tools in use and processes underway, the weight control tool and process in particular. In the case of ShipWeight, there are various ways to acquire data from CAD into the weight model, such as direct, managed interfaces (ex. with ShipConstructor) or unmanaged full data replacement interfaces (ex. reading Excel files, neutral dump files from CAD programs, etc.).

Because this is when CAD data should in most cases start constituting a converging, more reliable weight quantity than the macroscopic weight group's weight estimation, the ability to manage the data being acquired is paramount, especially when it comes to tracking the evolution of weight over time *Aasen et al. (2013)*. Once the weight item list becomes complete and accurate enough, quantitatively and quantitatively, the weight figure generated is considered to have superseded the estimated quantity in terms of accuracy and reliability, and becomes the value of record. Perhaps even more so than in previous stages, it then becomes vital to keep the weight-related communications between engineering and corporate players open. Thus, as more and more of the weight groups' values of record come from weight items, the transition from weight estimation to weight tracking occurs. And, as the vessel construction progresses, on-board items can be so tagged in ShipWeight, thereby confirming individual items in a given weight group. Of course, the grouping of on-board items during construction may not match the WBS grouping structure, and ShipWeight offers a powerful facility to reconcile the discrepancy: custom codes.

Custom codes effectively exploit the relational nature of the underlying ShipWeight database. For example, custom codes are used to add properties, attributes and qualifiers to items, without limit on the number of custom codes that can be assigned to a given item. One use of custom codes is to increase the variants in compiling custom reports, in which items can be grouped according to any property, attribute, parameter, ship location, date of handling, and / or other custom code assigned to one or more items. As a simple example, a custom report may group the items present in ShipWeight weight model - regardless of which weight group they are assigned to - in a way that mimics the CAD model's product hierarchy, or the production planning sequence, etc.. This will serve many purposes, one being the ability to compare the item's lists and correct any discrepancies between virtual (CAD, purchasing list, etc.) and real (what went on board the ship). Another use of custom codes is to tag imported items with the name of the weight group the item is destined to, as is done by the interface with ShipConstructor, requiring no further manual action upon import.

Thanks to its powerful and flexible import mechanisms, ShipWeight therefore provides an easy to use environment allowing the exploitation of up-to-date data, regardless of the data's source (CAD, vendor, purchasing, etc.) and format. In fact, much of this process can be semi-automated, or even fully automated, with a surprisingly small programming effort. When exploited, this ability is of great value to the ship genesis process, corporate-wide.

Two other corporate process supporting feature of ShipWeight are:

- revision control
- revision management

Both draw on the focused database aspects of the application, designed to allow moment-in-time freezing and archiving, as well as the historical tracking of data and meta-data, down to the individual item. Therefore, at each project's milestone (entering contract, during design and production, at launch, at delivery, at scheduled maintenance, etc.), a version of the current weight data model is saved. Moreover, because the history of each component of the weight model has been tracked and stored (ShipWeight will record who did what, when and, if the doer provides the information in form of comment, why), as is each action of each user, the revision history of the database and the weight development of the project can be monitored by comparing and analysing changes from one date to another, or from one formal revision to another, during a given period, etc. This ability is very precious in error checking processes.

The scope of application allowed by the use of a very developed database structure extends to areas otherwise very difficult to address, such as:

- weight distribution curves
- radii of gyration
- sanity checks on CG, etc.
- application and management of uncertainty factors
- export of weight curves to stability calculation programs (GHS, NAPA, etc.)

Also very important in a corporate-wide application, ShipWeight offers a possibly unique concurrent multi-user environment, managed by logins and permission controls. Therefore, the project administrator will assign read and/or write privileges (or none) to each user as a function of their role in the ship genesis process, for example:

- the data manager will have full rights, including to the data-validation input environment (the "sandbox" evaluation functionalities)
- weight engineers will have access to their respective input fields
- CAD managers will have access to the data import commands leading to the sandbox, where the data will have to be validated by the weight engineer holding that right before being admitted into the central weight model database
- the purchasing department will have access to some item input fields, to certain export facilities (needed to bring data to their own corporate programs), and to reporting
- the planning department will be able to use all reporting functions, including the creation of new report formats
- company management need not necessarily have access to use of the ShipWeight software itself, but it must have access to all reporting facilities which, in fact, can be fully automated and run without accessing ShipWeight at all

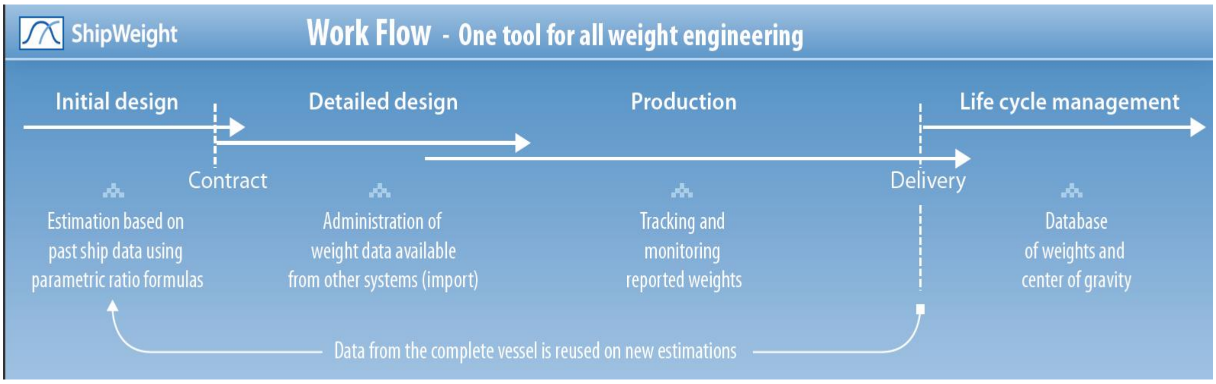
The above further strengthens the notion of data availability, and its importance in the corporate environment. ShipWeight includes a number of formatted reports including tables and graphs of many sorts but, more importantly, its data can be sourced by any program capable of querying an SQL database, such as SAP Crystal Reports. As one may immediately imagine, the power of direct data extraction from the ShipWeight database by third-part applications is compounded by their ability to also, simultaneously, source data from other sources, for example a CAD database (ex. ShipConstructor), or a purchasing application (ex. SAP, IFS, Trimergo, etc.), etc.

This is where and how ShipWeight data, but not only, crosses the boundaries of the engineering office and becomes directly useful and usable by non-engineering corporate players. For example, as demonstrated by the author on many occasions, top-management could have an icon on their PC's desktop which launches a simple Crystal Reports application comparing:

- estimated steel weight, from ShipWeight
- projected steel requirement as a function of the production calendar, from the planning department
- projected steel purchasing calendar as a function of the expected raw material futures market, from the purchasing department
- steel weight modelled to date by the design department (CAD model), cross referenced to the production calendar
- etc.

Access to data as described above is vital to all informed decision making processes within the corporate environment, and the ability to access, share and exploit data corporate-wide is available today, using off-the-shelf technology as implemented by programs like ShipWeight, ShipConstructor, IFS, and others.

Conversely, non-engineering considerations, requirements, changes to plan and decisions can be conveyed back to others in the corporate network, who may be located elsewhere on the planet, using the same data.



.Fig. 6: ShipWeight Work Flow

7. Implementation of a corporate-wide weight data and management strategy

A good weight control tool is necessary, but not sufficient, to achieve good weight control. The tool must be implemented in the organization alongside the other engineering and corporate tools, but a mutual adaptive evolution of philosophy of use, strategy and goals must also take place. As can easily be deduced from the present discussion so far, the obstacles on the path of achieving a successful corporate-wide weight data strategy are, today, far more cultural than technological: while the author's view may seem futuristic, the underlying problem to be solved was formally reported in detail at least 30 years ago, *Keeley (1988)*, and the technology required to achieve the goal has been readily available off-the-shelf at a lesser cost than a fashionable video game console for some years already.

Some of the principal factors underpinning the implementation of a corporate-wide weight data and management strategy are:

- acknowledge the importance of weight control
- standardize data formats or formally document data equivalencies
- organize the process

7.1 Acknowledge the importance of weight control

The accurate estimation of the ship's weight and centre of gravity may constitute the single most important parameter in the achievement of the design brief and contractual specifications. Deadweight, speed, strength and sea-keeping are only some of the crucial ship parameters that depend directly on weight and centre of gravity. Moreover, not insignificantly, weight is also closely connected to the cost of the vessel. In order to compete within the narrow margins and short turnaround time imposed by today's very competitive market, the highest confidence in preliminary weight estimation and effective weight control during construction of the vessel are a do-or-die requirement, not an optional ornament to the ship genesis process.

While this is readily acknowledged by most, an effective weight strategy must be embraced and put into practice by all connected to and affected by the weight control process. An effective weight control process will involve many people, with jobs and responsibilities spanning the overall corporate horizon, from design, to planning, to purchasing, to production, etc. Moreover, the effective weight strategy will work best, if not only, if all involved are fulfilling their role. If some do not, the damage will be many-fold: it will be difficult to achieve effective weight control, it will be more difficult to realise that the data is bad, and last but not least, it will be even more difficult to unearth the nature of the shortcoming.

Acknowledgement of the true scope of the importance of weight control is, still too often, a major cultural obstacle to overcome but, as mentioned in this paper, the use of off-the-shelf, state-of-the-art technology can provide significant help in bridging the cultural gap.

7.2 Standardize and agree on formats

The establishment of standards and standard equivalencies is the base of data organization. Standards must cater to very different needs (estimation, CAD, purchasing, project specification, etc.) but, to make matters easier, the WBS structure combining weight groups and weight items already provides a friendly basis to start from. Moreover, while there is scope to allow for somewhat differing WBSs (e.g. at the weight group level) being used on very different projects, commercial programs like ShipWeight do, thanks to the use of customs codes, allow for not only the cross-referencing of weight items between differently structured WBSs, but also between various corporate programs. For example, a given weight item will have, as custom codes, attributes like planned date of assembly, manufacturer's item reference number, location of storage and assembly, etc. Many industry standard data formats, such as SAWE, SWBS, SFI, ShipWeight, etc., lend themselves to weight control work and are used by various programs commonly found in the corporate environment.

It is obvious that good weight control implies a lot of data flow, and standardization and equivalency mapping are crucial to the process. Then, deciding on data format will satisfy more than one requirement:

- find the common denominator between CAD, text, databases, spread-sheets, vendors' software, etc.
- from each format extract the data required by ShipWeight
- make the data available to ShipWeight in a way that requires no further manual processing

The same holds for output, and especially the definition of terms. For example, consider how confusing it is to use the ubiquitous word "block", which means different things depending on the context of its use, and sometimes even carries linguistic connotations.

In the case of the Weight, CG and their derivatives, everyone must be sure to have a clear understanding of the nature of what these values refer to. How damaging could it be if the purchasing office bought the wrong amount of steel, or the wrong number of pumps, or …?

Last but not least, standardization must also encompass checking procedures, search procedures (for items, key words, etc.) and, not to be forgotten, limits and tolerances.

Relational database cored software like ShipWeight offers tabular and graphical tools for searching, grouping, checking, sanity checks, validation of imported candidate data, etc., but these must be matched across the full spectrum of corporate tools to ensure process consistency.

7.3 Get organized

Most will agree that data availability is key to its use, and to the improvement of all processes where that data is applicable. In this paper it is suggested that even data of disparate nature should be available to players in different disciplines, such a manufacturer's ordering reference number to the weight engineer or CAD modelling draftsman. On the other hand, the debate on where the data should be collected or how it should be made available is a never-ending one.

One source of doubt fuelling the debate on which data should be made available, when and how, is the very handling of data itself in the attempt to make it available. Traditionally, handling has been purely manual, a procedure with results in multiple duplications, is very cumbersome and time consuming and is extremely error prone despite the best intentions and efforts, errors which may in truth be more dangerous than the potential benefits of data sharing itself.

Today, the manual process can be easily replaced by off-the-shelf technology, and virtually guarantee the reliable organization and corporate-wide availability of up-to-date data. The key here is not immediate, multiple duplications as it is on-call sourcing. Thanks to flexible interfacing and open data structure architecture, programs like ShipWeight offer both options:

- a more traditional data replication by which data is copied to various pre-determined locations upon its validation (ex. upon saving a file), a procedure which requires the availability of the destination files and involves the thorough control and checking thereof, a non-trivial set of requirements . This can be referred to as data "pushing".
- a more modern source-as-needed approach, which better guarantees that the data is indeed up-to-date. This will require that the data sources are available, which is easy to check and report on. This can be referred to as data "pulling".
- a combination of the two, since some data will lend itself better to pushing and other to pulling

Still considering the use of custom codes to document an item's vendor purchasing reference number example, the weight figure of a given, identified item could be pushed from the purchasing office from the product's electronic specification sheet. Then, if the weight figure were to fail the sanity check carried out by ShipWeight, the weight engineer can report back to purchasing, uniquely identify the item in question and request a check and update of the weight figure, possibly from the manufacturer. In a similar fashion, prior to creating a weight report to match the production schedule; ShipWeight would pull planning data from the planning dataset, search its database by the relevant custom codes, and tabulate the weights and CGs corresponding to the various phases. For the sake of argument, it is a short step to imagine that ShipWeight will identify the item in the planning database by its vendor purchasing reference number, and that the purchasing and planning offices will share data likewise, by pushing and pulling as appropriate.

It is also tempting to then opt for a single database containing all data and being polled by several software applications, or even a single software application capable of handling all tasks. This, however relatively easy it is from an IT standpoint, remains for the moment both cultural science fiction and unviable business proposition.

On the other hand, the procedures and relatively simple techniques reviewed in this paper lend themselves very well to the simultaneous and combined use of various, disparate software programs and, in fact, is already today immediately applicable in more cases than not, the only requirement being the structured organization of data, its flow and of the procedures governing it.

8. Benefits

In the end, implementing a weight control strategy to support the corporate-wide ship genesis process does require an effort, which can vary greatly depending on many factors. To support the immediate applicability of the subject proposed in this paper, the author's direct experience strongly supports the fact that an introspective and pragmatic corporate process analysis will indicate the sequence of steps and actions appropriate to ensure that the new processes being developed remains in tune with fundamental requirements and evolving corporate characteristics through the development period, and thereafter.

Even after just the first steps of implementation have been accomplished, benefits appear. Well organized historical data, the key to accurate weight estimation in future projects, is one of the first. Time savings, the greater confidence on the side of those making use of the estimation and the ensuing reductions in engineering safety factors and planning and financial provisions follow at once, and while these are difficult to quantify in general, orders of magnitude of savings are not an uncommon measure thereof. The use of company standard report formats and contents save even more time and troubling soul-searching.

One, most desirable direct product of the above is that the now possible close monitoring of weight will ensure that deviations between contract weight and current weight estimation, at any time, are immediately evident to all who share in the responsibility of weight, who will be affected by the discrepancy, and who should play a role in remedying the condition - corporate wide.

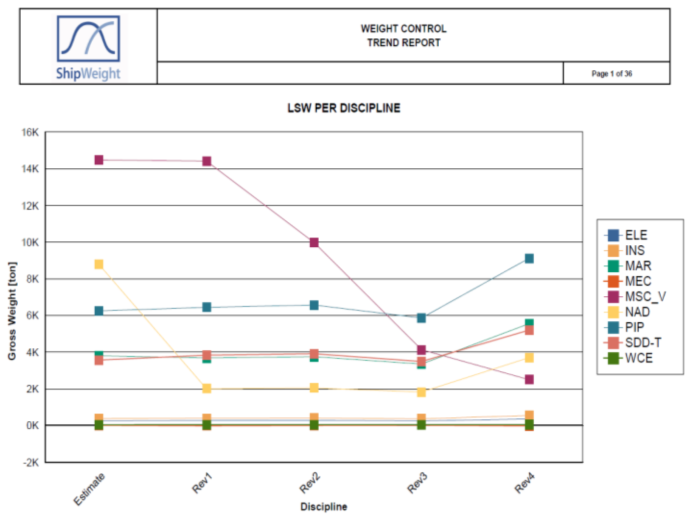


Fig. 7: Weight tracking through successive project milestones

9. Conclusion

Weight control is a fundamental factor in the successful achievement of a contract fulfilling ship design and ship building project. The data involved in weight control comes from various, disparate sources within the corporate environment, and is generated, collected and processed by several programs of different nature. While there are cultural obstacles to be reckoned with, modern off-the-shelf technology can play a significant role in offsetting them. Moreover, the same technology makes the data sharing required for successful weigh control readily achievable.

The implementation process leading to the corporate-wide exploitation of weight data is not effortless, but relatively easy and simple to achieve, requiring mostly an earnest and pragmatic corporate-wide process analysis, and a collective, cultural buy-in by all players concerned. And, while data generation and sometimes data input remains the concern of the individual, standard automation techniques can mostly, if not completely, replace manual data sharing procedures.

Very soon upon implementation, the exploitation of weight control produces long sought benefits, not least the ability to continuously compare the estimated weight figure to the evolving, project-specific one, thereby identifying any errors and allowing a remedy effort to take place.

In conclusion, especially when using the readily available appropriate software tools, implementing weight control and exploiting weight data in support of corporate-wide decision making processes is an achievable goal that will produce consequent benefits.

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