

## **Utilizing CAD/CAM Models for Ongoing Weight Estimation and Control**

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### **Abstract**

*Controlling the weight of a vessel over the design and engineering lifecycle is critical but is an ongoing challenge for shipbuilders. Excellent tools exist for both weight estimation and control and design and engineering; however the area where these two meet is often filled with Microsoft Excel spreadsheets or databases developed in house by individual shipyards. These approaches leave much to be desired. This paper will explore the implementation and benefits gained by integrating existing design and engineering tools with existing weight control applications.*

## **1 Introduction**

### **1.1 Weight Control**

Good weight control should start when the very first weight and center of gravity (CG) estimates in the tender phase of a project are carried out, and carry on all through basic design, detailed design, and construction until the vessel is completed. Through these phases, weight data is available in different formats and at a different level of accuracy and quality. At early stages of the tender and basic design, when detailed information of the vessel is not available, weights and center of gravity come from experience, whether it is from the designer's own experience, or from a more structured approach using systematic regression of weight data from historical vessels. As the project progresses, more detailed information becomes available. Information can come in the form of weights for equipment from the vendor, it can be modeled or calculated weights from a CAD system's model, or come from the actual recorded weighting of items at the shipyards. At any point in time during the design and construction of a vessel one should have available and be utilizing the most accurate and most up-to-date weight and center of gravity information to allow purposeful monitoring and control of the evolution of weight and CG.

### **1.2 3D CAD Tools**

Since their introduction in the 1990's, 3D CAD tools have become a potentially powerful source of information about the vessel. Over time, these tools have been developed to become more of a product model than a geometry model. When the vessel's geometry is modeled in the 3D tool, properties for densities can be assigned to the materials of the model and thus weights and center of gravity can be calculated from the 3D model. Naturally, the ship engineer will be very interested in exploiting this weight and center of gravity calculation derived from the model. At first glance it may seem like a very straightforward thing to do: assign material density and be done with it. However, it is unfortunately not as trivial as one may first think. This paper will discuss some of the issues involved with utilizing CAD models for weight calculation and weight control and offer some guidance on how to best deal with them.

### **1.3 Benefits**

The benefits of utilizing a 3D CAD model for weights are obviously numerous, if one is able to do it the right way. It can provide a rather accurate weight and center of gravity in a timely way and with a small amount of effort. Having this information readily available can provide earlier detection of negative trends in mass properties and provide more complete and accurate as-built weight databases.

## **2 Weight Data in 3D Models**

A valid question from the reader would be why the 3D CAD model is not the weight tool of reference, since it seems so well suited for calculating weight and CG. Why use anything else for weight control during the engineering design process? There are several reasons for this:

- First of all, a 3D CAD model is not available in the early stages of a ship design.
- A CAD model is rarely complete enough, and generally will include only most of the structure, major pipes and HVAC ducting, some if any at all of the electrical and at best only some of the equipment.
- Almost without exception the 3D model is only available after the design contract has been entered into, and weight control needs to be set in motion before this part of the design cycle occurs.
- Further, the 3D CAD model tool often offers no place to store as-built data when this weight information becomes available and therefore should be used as the most accurate recording of the weight at that time instead of 3D weight data that is calculated.

There is a period during the engineering process where the 3D CAD model plays a major role in containing the most accurate and up-to-date weight data within a vessel design, but this period is of limited duration. Finally, a 3D CAD tool has no or limited capabilities for required functions for data collection and revision involving weight estimation, monitoring, tracking, and the corresponding reporting.

## **2.1 Limitation with respect to Weight Data in 3D Models**

Even within the period of time where 3D CAD models do contain good and valuable information for weight control, there are limitations one needs to be aware of. Two important questions to ask are:

- What weight data is available in the 3D model?
- What is the quality of the data in the 3D model?

The answers to these questions are not necessarily as straightforward as they seem. For example, the weight data that is available is determined by what has been modeled and given a material density property. If there is no material density assigned to the modeled object, no weight can be calculated. It is important to remember that for good weight control, knowing what is not present is equally important as knowing what is present.

Equally knowing what has been modeled and has assigned density properties does not answer yet another question, which is the quality of the data available. In order to determine the quality of the data one needs to know the level of maturity of the modeled parts. In addition to knowing the maturity of the parts, there can be modeling errors that have little impact on the geometry of the model, but can give significant errors in the calculated weight. This is often a result of the CAD modeler not having weight calculation in mind during modeling.

The typical example could be explained by a cable tray that is modeled as a rectangular solid rather than as a U-shaped hollow figure. In most cases such errors do not create any geometrical problems, but for calculating the weight of the cable tray the error will be several hundred percent. Missing or incorrectly assigned density properties are another source of errors in the 3D CAD model. So, it is very important to know the quality of the data that will be received from the 3D CAD model, and to strive for the best data as possible. A lot can be accomplished through educating the 3D CAD modeler in the importance of weight control, but in addition, checks should be made to minimize the effect of errors in the model.

## **3 Harvesting Weight Data from 3D models**

When a good and reliable 3D CAD model is available, it makes sense to use this data in weight control. In other words, the data should be extracted from the 3D CAD model and imported into the weight control tool.

Assuming the 3D CAD model does offer weight data, this can be extracted in several ways for use by the weight tool. There are normally 4 ways of extracting data from a 3D CAD model in order to get it into weight control software:

- Normal export/import through an intermediate file using any of a number of techniques
- Direct access to the CAD file, for example using the facilities provided by the software's native language like (AutoCAD®'s LISP)
- Direct access to the database (if one exists) of the 3D CAD model from the weight control software
- for the more capable systems, access the 3D CAD model's database through the API and/or stored procedures of the 3D CAD model's environment

### **3.1 Export/Import through an Intermediate File**

The export/import through an intermediate file is the most common way of exchanging data between a CAD tool and a weight control tool, usually in the form of a text file or Excel® file. The advantage of this method is that most CAD systems are natively able or can be programmed to export weight information in formats like these. This method can work well, but the disadvantage is that it requires the weight control engineer to be very familiar with the contents of the file at hand, and to be able to very accurately manage modifications, deletions, additions, and replacement of items. The procedure is very “manual”, it is time consuming and error-prone, it must be enacted at the correct moment in time to capture the evolution of the CAD model, and may in some cases require formatting of the files to be imported.

### **3.2 Direct access to the CAD file**

This technique is not dissimilar from the export/import strategy, but it does carry the advantage of programmatic direct interrogation. Direct access to the CAD file is acquired in memory space as opposed to in an intermediate file which, by definition, structures the data being read. The step to formatting the data appropriately for the direct consumption of the weight tool is small, and required intrinsically for the process to complete.

### **3.3 Direct Access through a Database**

Direct access to the 3D model's database requires the 3D tools to store the information in a database that is accessible externally from other programs. Having this type of access is not always the case as some tools use proprietary, pseudo-databases or store the data in files that are not accessible by other software. The disadvantage of this method includes requiring good knowledge of the database table structure, the data to be accessed, and the custom programming for the extraction of the data which becomes obsolete when the database structure or nature of the data formatting changes. Moreover, the weight engineer must have the appropriate level of permissions to access the 3D model's database, which in some IT environments can be problematic. Finally, this strategy is also vulnerable to database changes resulting from design iterations and scenarios stored in the database, and design changes that will occur in the design cycle within the 3D tool; this may invalidate the method of data extraction. On the other hand, the advantage is that this constitutes a managed and faster way of importing, data both in regards to the actual import, but also in terms of the greatly reduced manual handling of the data to be imported.

### **3.4 Access through API or Stored Procedures**

For those cases where a database exists and access to it is made available, it tends to be one of the industry standard ones, such as Microsoft SQL Server®, Oracle®, etc. In this case, the best way of importing is through the use of an API (Application Programming Interface) or stored procedures made available from the 3D tool vendor. This will also require custom programming, but lacks several of the disadvantages of directly accessing the database. The significant advantage is that changes to the database structure, or the data formatting, and even to the nature of the data will not corrupt the interface. The API and stored procedures are always maintained (and generally used by) the software manufacturer as their own software programming will utilize the same API.

### **3.5 What to get from the 3D CAD Model**

Establishing the best possible method is a good start, but there are more issues to be considered prior to the harvest of the weight data. For example, what do we want to get from the 3D model?

- The complete model or only portions?
- What level of data detail is to be acquired into the weight database?
- Do we want additional data information beyond weight and CG?

The nature of the first point is practical, and has to do with the size of the 3D model. A 3D model can contain several hundred thousand weight items, and to import all of these every time a change to the model would warrant an update of the weight database can be a very inefficient way of working,

simply because of the time a large update will require. Therefore it makes more sense to restrict the import to only the model modifications and to only carry the data that is required to provide a given update. On the other hand, not updating often enough or artificially limiting the scope of the update can create different problems, as discussed in the next section on “Deleted Items”.

The second issue, the level of detail, is also relevant from a practical standpoint, as this will directly impact the duration of the updating procedure. Very large databases make for a slowdown in data handling and require more hardware power and network capacity.

In addition there is one more thing to consider: it is good practice, as far as possible, to import only those items that make sense to the weight control engineer. Effective weight control involves checking and reasoning based on the items present in the weight model database. It is much easier, for example, to ascertain the validity of the weight and CG of a ladder assembly as a single item rather than that of all its composing rungs, columns and rails individually.

Finally, weight control is more than just collecting items to be summarized for a total weight and center of gravity. It should also include:

- checking the validity of the data,
- measuring maturity
- reporting data for operations like lifting and launching
- making sure that the weight database can be utilized as an historical reference for future estimations.

It goes without saying that in order to accomplish collection of the items noted above, the associated weight data needs to be tagged with additional information that allows for grouping and summarizing according to the arbitrary criteria. A 3D CAD model will most often contain data valuable for this purpose, such as block, module, or unit information, and the modeled object’s discipline, for example.

## **4 Special challenges**

There are some special challenges to be kept in mind when importing data from a 3D CAD model, such as:

- Deleted items
- Temporary items
- Work breakdown structure.

### **4.1 Deleted Items**

It may be easy to overlook the fact that when a weight database is updated from a CAD model deleted items are just as important to account for as added and changed items. A list containing the latest and most up-to-date information on modeled parts of the vessel is likely to not include items that have been deleted, which should then be removed from the weight database as part of the update process . Generally there are two ways of handling this.

The first is to always import and update a complete “package”, a “package” being a structured list of items, for example; a block, a system, etc.; in essence, anything that is easy to group and to identify as a “package”. In this case, items are unambiguously either a part of the “package” or not. Updates should always address complete packages, and the packages should be replaced completely. This means that updating the “steel” of a particular block assembly means deleting this block assembly entirely from the weight model before importing its latest version. The following process ensures that a deleted item from the CAD model will also disappear from the weight database.

A second way to treat items deleted from the CAD model when updating the weight database is to retrieve the information of the deleted items from the CAD model and make sure these items are also deleted from the weight database. This technique obviously requires a much finer process in granularity and the ability to individually address any item.

Either approach would be acceptable in handling deleted items within a CAD model. Serious weight data collection, monitoring, and tracking problems would occur if the deleted items were not managed in the updating of data items from the CAD model.

#### **4.2 Temporary Items**

It seems to be quite common amongst 3D CAD modelers to draw “temporary” objects outside the “visible” drawing space. Unfortunately, often these objects are just left there as they don’t interfere with the drawing or the model. If these objects are left in the 3D CAD model, they become an unintentional part of the weight model and can be hard to find and remove, thereby constituting a dangerous error, and unknown in its existence with impossible to manage scenarios.

#### **4.3 Lack of Work Breakdown Structure**

A Work Breakdown Structure (WBS) should be used in every weight control exercise. There are several reasons why this is important. When an early weight and CG estimate is conducted, the vessel has to be divided into a set of weight groups in the form of a WBS. This is important because trying to estimate the whole vessel as a unique, all encompassing object seldom gives good results, as does the attempt to represent the vessel by a developed itemized list. The vessel must be broken down into groups that can be estimated individually, and then the summary of these groups makes up the whole vessel estimate. Further, during weight tracking and monitoring, weights are collected according to the weight model’s hierarchical organization as laid out by the weight groups. These weight groups support direct comparison against the values originally estimated for the same groups. Deviation of weight and CG is then checked at the weight group level. Incidentally, many navies require weight reports to be prepared during the construction of the vessel according to a specific WBS.

One common challenge lies within the fact that in most cases the items in the 3D CAD model are not tagged with WBS information, and most of the time this information cannot easily be derived from CAD model itself. Exporting thousands of items with weight and center of gravity information, but without any WBS information, to the weight tool does create a data management puzzle.

Depending on the type of WBS and meta-data attached to the items in the CAD model, it may be possible to define a logic that allows for some automatic or semi-automatic assignment of WBS information, but in many cases the only way of getting good WBS information is to have the CAD modeler directly assign this information during the design. This is easier said than done and requires the modeler to both have competence about the WBS and also knowledge about weight control to gather and tag the modeled items with the WBS information. Alternatively, the weight engineer can make the WBS assignment to each item when it is transferred into the weight control software. Then when the data is updated, each part “remembers” its WBS, while updating any other information. Alternatively, once the WBS has been assigned in the weight control software, that data could be exported back to the 3D CAD model, if a suitable interface is created. In either case, the idea is to only have to assign the WBS to a part one time in its life, whether that’s done by the CAD modeler or the weight engineer.

#### **4.4 3D Model versus As-built**

Great looking 3D CAD models of the vessel with a lot of detail often lead to the conclusion that the weight calculated from the model must be accurate. This can make people put their guards down in terms of executing the proper checking and verification of the results from the CAD model. But even without any mistakes from the 3D CAD modeler it is important that the weight engineer considers the as-built steel weight additions which are not necessarily a part of the model, such as mill tolerance and welding. These typically add up to about 2% of the steel weight. There are some CAD tools that can add these weights automatically, but it is important to know if they do or not. Even with the welding and mill tolerance accounted for, it is important that the weight engineer is aware of the fact that sometimes real construction does not always comply with the model. As an example, if the drawing specifies a plate of thickness 8 mm and only 10 mm plates are in stock, often a 10 mm plate will be used. This is not a problem with the strength of the vessel, but for the weight it represents an increase of more than 20% for the plate, and obviously has an effect on the CG of vessel. It is also important to

note that even the most detailed of 3D CAD models may not be completely detailed designed with all components that go into the construction of the ship. Some shipyards may subcontract out entire systems that are not contained within the 3D CAD model and therefore as-built configurations with weight and CG data must be considered in the overall weight control.

## **5 Getting 3D data from ShipConstructor to ShipWeight**

The following part of this paper describes the work done in the National Shipbuilding Research Program (NSRP) project “Leveraging Detail Design Data in Weight Engineering”. The purpose of the project is to focus on the efficient use of detail design data as an input to weight engineering. During this project, current and desired business process work flows and improved use cases were documented through an activity based process modeling technique in cooperation within two large shipyards, VT Halter Marine and Marinette Marine Corporation. An interface strategy, beginning with a data alignment and exchange map, was developed based on the process information identified by the shipyards. The map documented allowed for software developers to improve the transfer of data from a detail design system to a weight engineering program based on the captured “To-Be” business process state. The project approach was not to be specific to improving or developing any particular detail design or weight engineering software. However, since software must be used for the proof of concept for this type of data exchange and development, it was decided that the implementation strategy for this project would be to transfer data from *ShipConstructor* to *ShipWeight*. *The main reasons why these software programs were chosen was due to the fact that both companies participating in the NSRP project were already using these programs.* Incidentally, these two programs are the most commonly used detail design and weight engineering tools in the US shipbuilding industry, including the majority of all the shipyard participants in the NSRP R&D program.

### **5.1 ShipWeight at a Glance**

ShipWeight is a state of the art weight control tool that can handle early stage design weight and center of gravity estimations, as well as weight tracking and monitoring from basic design throughout detailed design and construction.

In early design, weight and center of gravity are estimated based upon regression of historical data with the purpose of finding good correlations (scaling factors) between the weight and CG of a vessel and known parameters of the design (parametric estimation). The vessel is divided into a hierarchy of weight groups, and each group is assigned an estimation formula containing ship parameters and a scaling coefficient used to calculate the weight and CG for that particular weight group. When the design progresses and more detailed and specific item weight data becomes available, this information is collected in the appropriate weight groups. As the item weight data matures and becomes more accurate and certain than the estimated value, this value is carried on as the preferred one for the remainder of the project.

As more and more weight groups become itemized and more accurate weight data is available, the weight control exercise migrates from estimation to tracking mode. ShipWeight provides the environment and tools needed to continually harvest the most accurate data available from whatever source, whether this is from a CAD model, a vendor, an estimate, or as-built data from weighing.

For it to express all its power, ShipWeight should always be current with the most up-to-date information from all weight groups. At each milestone of the project, for instance entering contract, or at regular intervals throughout the project, a version of the current weight data is saved and stored as a separate revision of the weight model database. The weight development of the project can then be monitored by comparing and analyzing development from one revision to another. Also, a comparison supported by the data checking tools is needed to establish the validity of the Weight and CG figures, in detail.

## 5.2 ShipConstructor at a Glance

ShipConstructor is an AutoCAD®-based shipbuilding CAD/CAM software suite that provides fully integrated, multi-disciplinary detailed design and modeling tools for production engineering of marine structures. ShipConstructor captures all information relevant to the 3D design, manufacturing, maintenance, repair and refit of complex marine projects inside a Marine Information Model (MIM). At the heart of the model is a single relational database residing on a Microsoft SQL Server that can be integrated with related business processes and applications. ShipConstructor's unique software architecture and AutoCAD foundation provide significant competitive advantages.

ShipConstructor's AutoCAD foundation leads to a decrease in required training time. ShipConstructor is built on top of AutoCAD, where this foundation provides a population of skilled workers already familiar with the basic tools and general look and feel of the software. Additionally, ShipConstructor is a suite of products targeted specifically at the shipbuilding and offshore industries. The basic philosophy behind the technology allows clients to directly interact with the 3D product model of a ship or offshore project in a manner that is natural for their business. Users with a solid foundation of AutoCAD skills and a decent understanding of the industry can quickly become proficient with the software.

ShipConstructor facilitates the ability to shorten the detailed design process by allowing the ability to utilize a single Marine Information Model to create the associated production output. This means that all of the various design disciplines can work within the same model concurrently, and provides a means to respond to changes from other disciplines in real time. Production drawings are dynamically linked to the model so that when the model changes they are automatically updated without any loss of custom detailing. Consequently the engineering team can start production drawings much earlier than in other basic CAD systems.

The native format of ShipConstructor is DWG which is one of the most common standards for data exchange. ShipConstructor can also consume and create virtually any format required for communication with associated service providers in the shipbuilding industry including Autodesk DWG, DXF, DWF, SAT, STEP, IGES, and 3DM. This level of interoperability makes it far easier to import information from suppliers, manufacturers and subcontractors into a ShipConstructor project.

ShipConstructor has created an open architecture and a best of breed approach in efforts to meet and exceed the requirements of the shipbuilding and offshore industries. Integration and interoperability are supported by an open, accessible relational Microsoft SQL database with numerous APIs (Application Programming Interfaces). This platform enables ShipConstructor to work with a variety of software packages.

## 6 Architectural Overview of the Weight Data Transfer

### 6.1 Fulcrum Application - Middleware

The solution selected to accomplish the weight data transfer from CAD to the weight tool has been to develop a middleware software component, called Fulcrum. The Fulcrum application acts as the facilitator of the data exchange by extracting the data from ShipConstructor and preparing it for consumption by ShipWeight.

### 6.2 Fulcrum Application – Functional Requirements

The following list defines the functional requirements for the Fulcrum middleware application.

1. Open and retrieve weight data from an existing *ShipConstructor* database.
2. Extract specified weight data from a *ShipConstructor* database. Allow filtering by project, block/module, discipline, Ship Work Breakdown Structure (SWBS) group, drawing, planar group, and revision number.
3. Serialize weight data to a neutral file format that can be imported into *ShipWeight*.

4. Identify additions, deletions, and revisions made within a *ShipConstructor* database and transfer update information to a neutral file format that can be imported into *ShipWeight*.

### 6.3 Principal Use Cases

All of the use cases involve an actor defined as an engineer or naval architect who is the application end-user. The following list defines the principal use cases for the application:

1. **Collect by Project:** Retrieve all weight data for a specific project from a *ShipConstructor* database. All hull blocks/modules and all engineering disciplines would be included.
2. **Collect by Project and Block:** Retrieve weight data for a specific block in a specific project from a *ShipConstructor* database. Allow filtering by a single discipline or multiple disciplines.
3. **Collect by Project and Discipline:** Retrieve weight data for a specific discipline in a specific project from a *ShipConstructor* database. Allow filtering by one or more drawing numbers, block, or planar group.
4. **Collect by Project and SWBS:** Retrieve weight data for a specific SWBS group in a specific project from a *ShipConstructor* database. Allow filtering by one or more drawing numbers or by block.
5. **Collect by Project and Drawing #:** Retrieve weight data for a specific drawing number in a specific project from a *ShipConstructor* database. Allow filtering by revision number.

### 6.4 Workflow Description

The principal workflows for the prototype application are shown in the figure below. Each starts with the user opening a project in an existing *ShipConstructor* database that has been fully or partially populated with parts. Opening the project allows the prototype application to retrieve the current parts list and to identify and cache lists of valid values for various part properties (e.g., the list of valid block numbers or SWBS groups). The next step is for the user to select the data that is to be extracted from the database. This is done by creating the data extraction filters that define the block(s), discipline(s), SWBS group(s), drawing(s), planar group(s), and drawing revision(s) for the data to be extracted. A collection of these filters can be saved as a named filter set for future use. If any named filter sets have been previously saved, the user can choose a saved filter set and apply it directly or modify it. After the data extraction filters have been defined, the filtered weight data can be extracted from the parts list and then exported to a neutral file format by the user. The neutral file, which will contain sufficient information to define not only the part/weight data but also the lineage of this data, can then be imported into *ShipWeight*. During the *ShipWeight* import, items that already exist in the *ShipWeight* database are updated as appropriate, and any items that were deleted from the *ShipConstructor* model but had been previously imported into *ShipWeight* are deleted. Because the neutral file contains information about the weight data lineage (such as the definition of the filters that were applied), it can be used in an alternative workflow in which the user just extracts added, deleted, or modified part information from the *ShipConstructor* database relative to a prior data extraction. The architecture of the prototype software intended to facilitate these workflows is described in the following section.

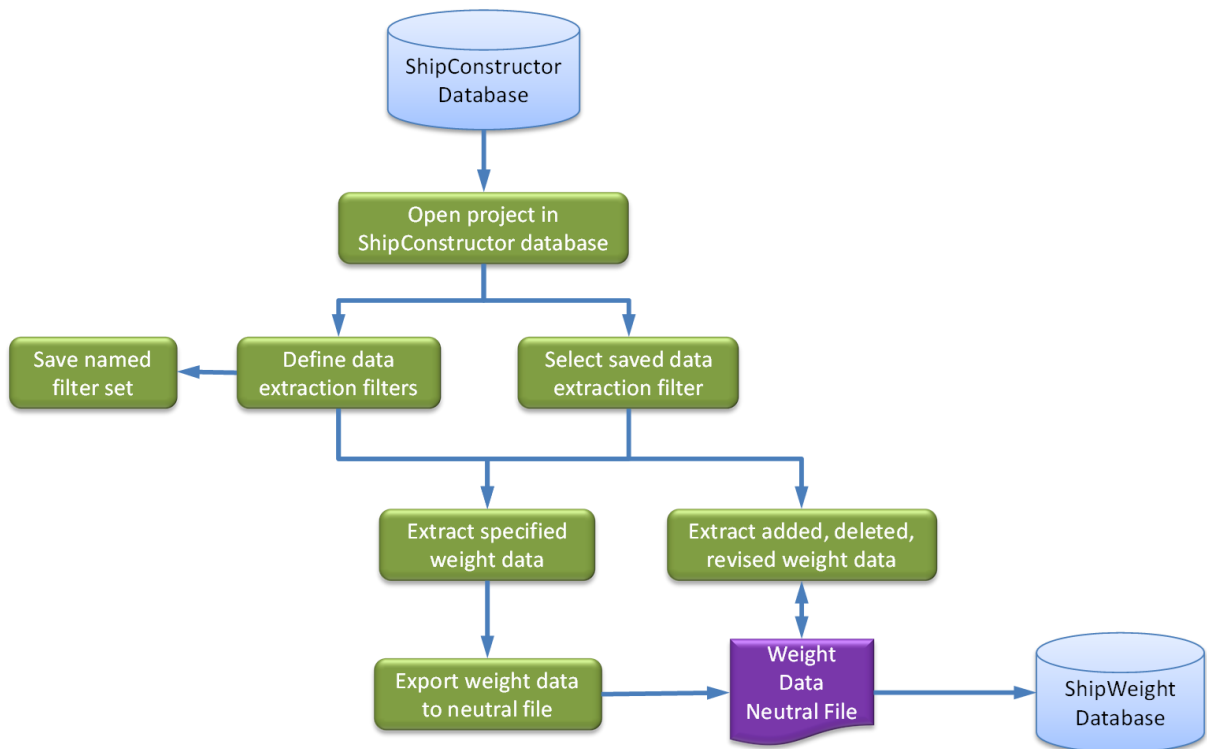


Figure 1 – Workflow for the Prototype Application

## 7 Key Issues

To be able to execute the data transfer as described above, the following functionality has been put in place:

For ShipConstructor, functionality needs to be in place to allow tagging of WBS information and other filter parameters to the items in the 3D model and also make stored procedure and/or API available to Fulcrum to access the data.

Part Name	Part Number	Part Type	Part Description	Mass (kg)	LCG (m)	TC
FuelOilTx		Equipment		200	56.1504222111729	1.97
FuelOilTx		Equipment		200	62.9357063174469	2.02
MAN Deisel		Equipment		1400	60.8297774612865	-0.2
FuelOilTx		Equipment		200	60.1618682027766	1.97
RO-12-A		Equipment		2300	61.7460585647632	6.19
OWS-34		Equipment		800	61.8860004412832	1.17
FirePump		Equipment		800	54.7895064263857	3.32
FirePump		Equipment		800	58.8807449405263	3.32
FirePump		Equipment		800	60.6174514355761	4.82
FirePump		Equipment		800	62.9486294062093	4.47
PlenumUnit3		Equipment		250	62.2634000002942	4.10
TestPump		Equipment		50	63.0837652782279	-0.0
800x400cross200x200-AI-001		Cross		6.1868577928422	60.0469384680142	6.52
800x400cross200x200-AI-002		Cross		6.1868577928422	62.788	3.75
300x500cross200x200-AI-001		Cross		5.07312	61.0000000000001	5.48
200x200-Rectangular-90degree-AI-001		Elbow		2.33012165989967	59.9857891842343	5.38
400x800-90 elbow-001		Elbow		8.65099312019348	60.0469384680142	6.60
200x200-Rectangular-90degree-AI-003		Elbow		2.33012165989967	60.0469384680142	7.67
800x400-Ovalr-90degree-AI-001		Elbow		13.5637845796909	59.9242689997661	7.19

Figure 2: Fulcrum showing data from ShipConstructor

Fulcrum must process the data retrieved from ShipConstructor and produce a neutral XML file containing the relevant information from ShipConstructor.

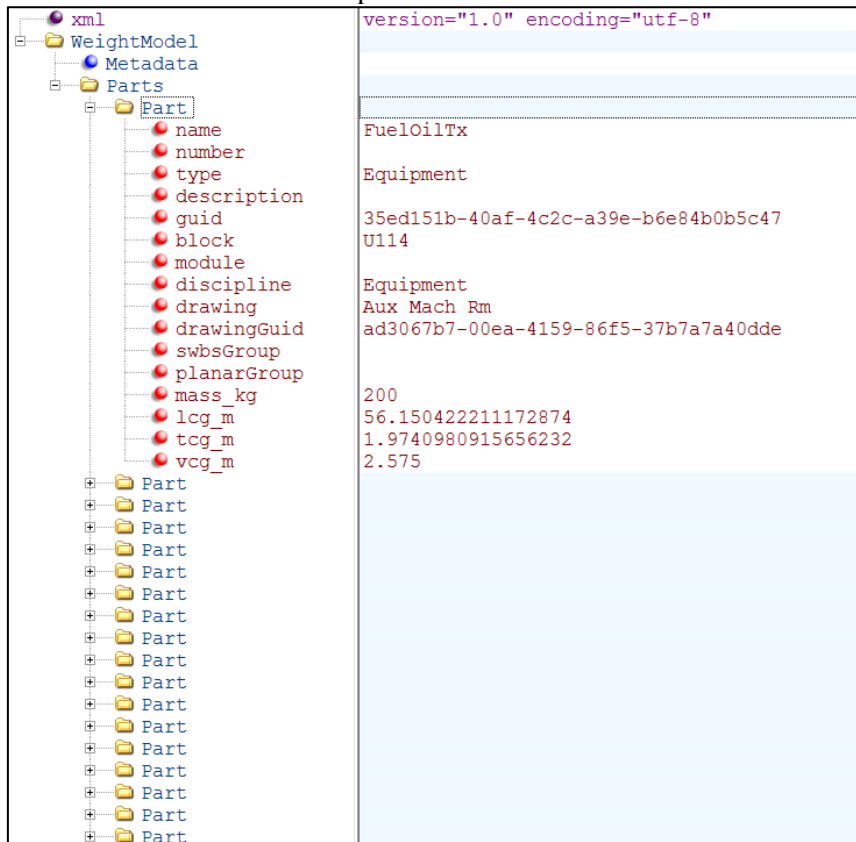


Figure 3: Sample XML Neutral File

For ShipWeight, the software must be able to interpret and consume the information in the neutral file produced by Fulcrum and execute additions, changes and deletions.

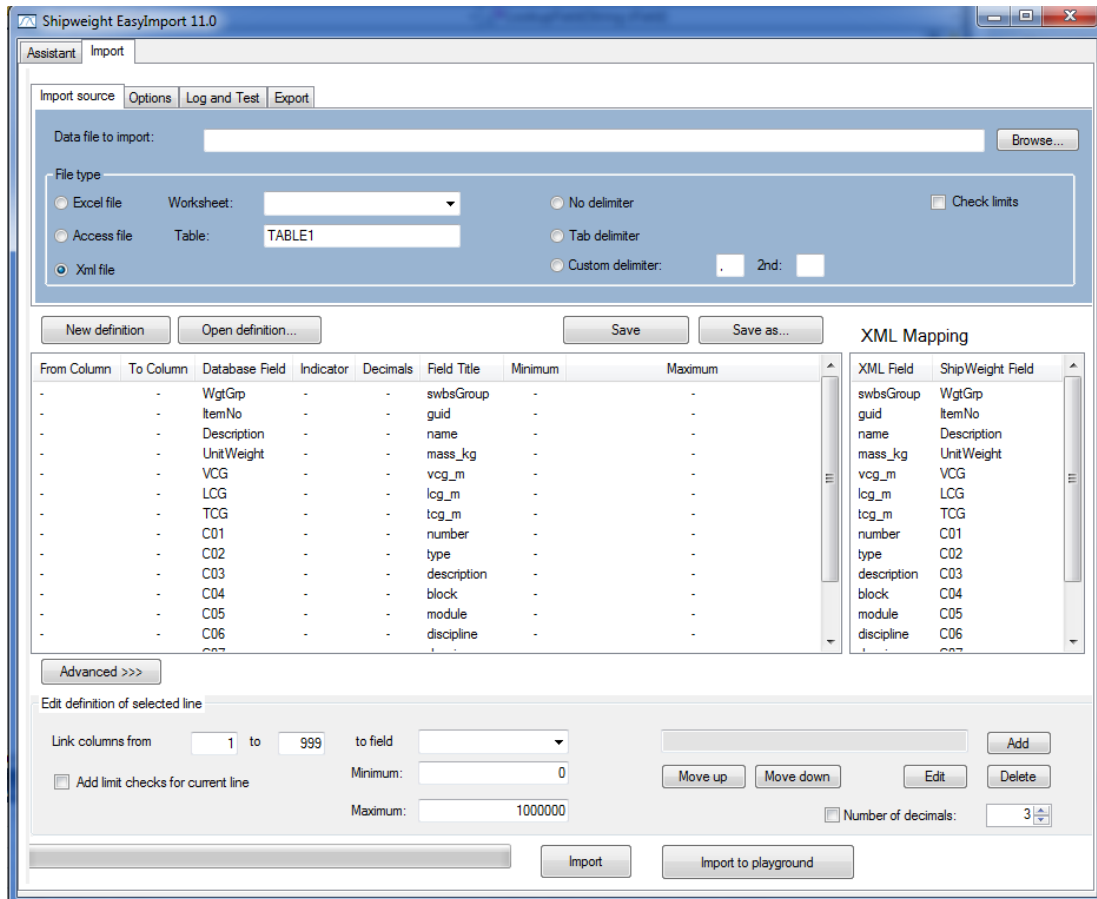


Figure 4: ShipWeight XML Import

## 8 Conclusion

While 3D CAD import may not be a trivial process, it offers significant benefits making it definitely worth harvesting weight data from CAD models to support the weight control process. One must consider the challenges and strive to find the best and most efficient way of doing it, which may involve not only software tools, but also a cultural and technical evolution of the corporate business process.

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