Harmonization of Product Interface Steel Construction and Industry Foundation Classes

Christoph HÖRENBAUM Dipl.-Ing.

Helmut SAAL Prof. Dr.-Ing.

Lehrstuhl für Stahl- und Leichtmetallbau, Universität Karlsruhe (TH)
76128 Karlsruhe, Germany
hoerenbaum@versuchs-anstalt.uni-karlsruhe.de

C. Hörenbaum: born 22.10.1968
1989 – 1995: Academic Education, Universität Karlsruhe
1996: Diploma Thesis, University of Toronto, Canada
Since 1996: Scientific Employee, Universität Karlsruhe

H. Saal: born 10.02.1943
1962 – 1968: TH Darmstadt
1971: Dr.-Ing., TH Darmstadt
1981: Habilitation, TH Darmstadt
1982 – 1988: Consultant Engineer
1988 – 1993: Ordinarius, Universität Stuttgart
Since 1993: Ordinarius, Universität Karlsruhe

Summary

This paper compares two product models for the building industry (*Product Interface Steel Construction* and *Industry Foundation Classes*) with respect to a possible harmonization. Different concepts for harmonization are evaluated. For one of them an integrated model is proposed.

1. Introduction

In the last years several product models with different and partly overlapping scopes have been developed for the building industry. They are intended to enable different software to communicate via a single standardized data format. For some of these models the great benefit for constructional and civil engineering has already been experienced through their application by commercial software, in which they have been implemented. In spite of using STEP [1] technology or even being completely STEP conform the different models are not generally compatible, though. Regarding project wide co-operation, the situation is therefore still not satisfactory. Thus, one of the main tasks in information and communication technology in the near future will be the harmonization of different product models.

Two successful, though very different product models of the building industry are the *Industry Foundation Classes* [2] (IFC) by the International Alliance for Interoperability (IAI), which aim at enabling global interoperability of all software for architecture, engineering, construction and facility management (AEC/FM), and the German model *Product Interface Steel Construction* [3] (PSS – Produktschnittstelle Stahlbau) by the German Steel Construction Association (DStV – Deutscher Stahlbau-Verband), which was developed for detailed data representation within the field of designing, dimensioning and manufacturing steel constructions. The PSS model is implemented in the most important software packages for CAD and structural analysis for structural steelwork on the German market and is already applied in every day use. By harmonizing these two models, an ideal synthesis of their different scopes and individual advantages could be achieved. Both IAI and DStV have officially decided to support the harmonization. The task is performed simultaneously for the structural analysis part and the constructional model part of PSS. This paper reports on the latter only.

2. Product Interface Steel Construction

The Product Interface Steel Construction (PSS) was developed at the University of Karlsruhe, see [4], and is recommended for application by the DStV since 1996. It facilitates product data exchange in the field of constructional steelwork, i.e. between software for CAD, structural analysis, parts lists, process organization, numerical control of processing machinery, bidding procedure, order placement and cost calculation. The actual version [3] comprises structural analysis data, data for representing beam- and plate-like principal members, add-on parts and assemblies, detailed constructional data for member processing and surface preparations as well as welded, bolted and glued connections. In order to allow partly implementation, the entire model is divided into so-called *Implementation Areas*, see Figure 2.1. Most parts of the documentation are available in German language only. In order to insure that software implementations conform to the standard of the Product Interface Steel Construction, the University of Karlsruhe is at present developing a method for conformance testing for the DStV. This test package will be available for both software developers and end users on the Internet site of the DStV (*http://www.deutscher stahlbau.de*). One of the main achievements by the DStV was the constant involvement of both software developers and end users of the steel construction industry. The result of this are implementations in the most important software packages and applications in every day use. As an example of application Figure 2.2 shows a CAD model of the structural steelwork of the brown coal fired, 170 m high power plant at Niederaußem, Germany (planned start of operation is in summer 2002). It was modelled in 3D with a special software for plant construction. The dimensioning of the extremely complex structure was carried out by a third party structural analysis software. The data exchange was managed via the Product Interface Steel Construction, as shown in the example for the boiler room wall. The example also demonstrates the coupling of CAD and structural analysis software, which is an important application scenario of PSS in structural engineering.

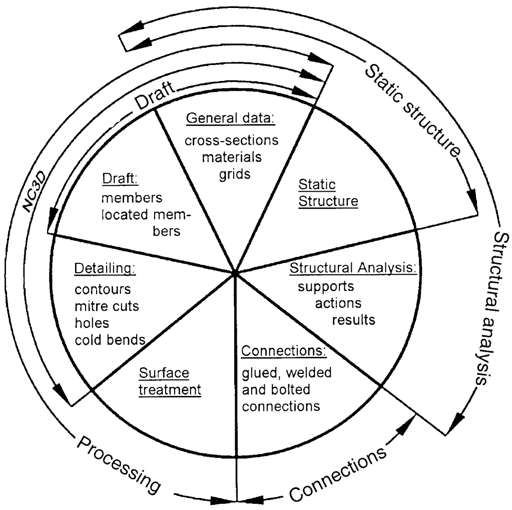

Fig. 2.1: Model architecture of PSS

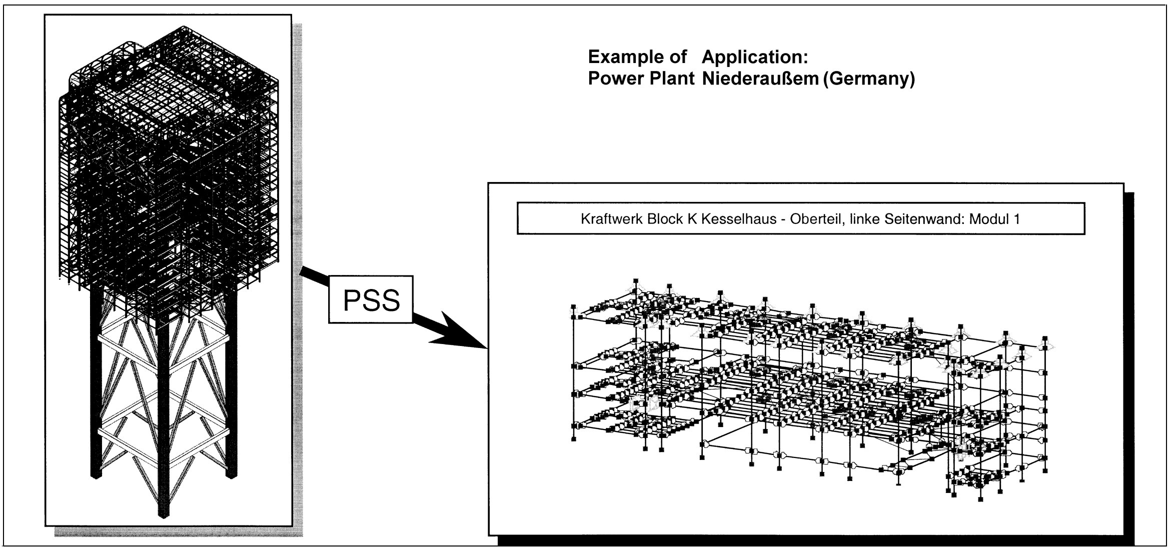

Fig. 2.2: Example of practical application of Product Interface Steel Construction

3. Industry Foundation Classes

The Industry Foundation Classes (IFC) are being developed and maintained by the International Alliance for Interoperability, an international, industry-based organization. The IFC are intended to facilitate product data exchange between possibly all software involved in the life cycle of a building. The data model of the IFC has a strictly hierarchical, modular architecture consisting of *Resource, Core* and *Interoperability Layer* as well as several *domains* for specific fields of application. Data interchange can be performed either within a single domain between software for this specific field of application or among several domains between software for different fields of application. For a maximum of flexibility, extendibility and modularity, which are according to [5] the most important requirements for a product model of the building industry, the Core Layer provides both means for representing basic objects as well as general concepts such as properties and relationships. Furthermore, the actual version of the IFC [2] makes use of the so-called *platform approach*. This means that the Core Layer is kept stable for several years in order to provide a certain reliability for software implementers, whereas the domains, which are “plugged into” the Core Model, can be developed flexibly. Therefore, the data structures applied in the Core Layer must be general enough to cope with the wide range of possible software applications of all AEC/FM disciplines expected to join the IFC in the long run. With respect to implementation and maintenance the modelling paradigms of object-orientation and property inheritance are applied in the IFC model. Thus, model and software components can be reused. The actual scope of the IFC, which is reflected by the existing domains, comprises the fields of architecture, construction management, facility management, interior and electrical equipment as well as heating, ventilation and air conditioning. However, the level of detailing of the IFC is comparably low.

4. Possibilities and Benefit of Harmonization

4.1 Two Models

Comparing the scopes of the two above described product models at first sight, it becomes obvious that they are not competing against each other. On the contrary, a harmonization would be an ideal synthesis with mutual benefit: On the one hand the PSS would supplement the IFC in the fields of constructional steelwork and structural analysis on a high level of detail. On the other hand the wide scope of the IFC could serve as a platform for integrating the efforts already made by the German steel construction and software industries into a more general context. This is true in the sense of integrating both the steel construction sector into the whole of the building process as well as a national movement into an international one. However, the two models have been developed with different intentions and under different circumstances. The differences arising from this are as follows:

1. The models use different resources for geometry and materials representation.
2. The PSS data structures reflect the way of thinking of the constructional engineer. A profile for example has both geometric and mechanical properties. In the IFC the general rule of self-contained resources applies. Therefore, a profile is a strictly geometric object.
3. In PSS matters are often defined implicitly or by textual description, whereas in the IFC virtually everything is defined explicitly in a formal way.
4. PSS relationships are represented by references between objects. The IFC generally use the concept of the objectified relationship, in which the relationship is an object of its own.
5. The IFC make use of entity inheritance, whereas PSS does not.

These differences do not question the benefit of harmonization, but increase the effort necessary.

PSS [3], Implementation Area “Draft”	IFC [2]
1. Materials representation: a) parametrically b) by standardized names only	a) not possible b) possible
2. Profile representation: a) parametrically b) by standardized names only c) explicit geometric representation d) composite profiles	a) possible for some profile shapes b) not possible c) possible d) possible
3. Grids representation: a) “free” grids b) parametrical representation of rectangular grids	a) possible b) not possible
4. Representation of block definitions and locations: All beam- and plate-like members are defined as so-called blocks and can be located several times.	possible
5. Representation of beam members: a) straight beams b) curved beams	a) possible b) possible
6. Representation of plate members:	not possible
7. Representation of custom parts without geometry	possible
8. Grouping of members: a) assemblies b) principal parts with add-on parts	a) possible b) possible

Table 4.1: Detailed comparison of scope concerning steel raw construction

In order to weigh up the benefit against the difficulties, a comparison of the scopes of the two models was carried out in detail for the constructional steelwork part of PSS. Because of the above described fact that PSS would supplement the IFC in scope (and not vice-versa), this was done proceeding from the engineering items of the PSS model, see Table 4.1. With respect to clarity, only the most important Implementation Area “Draft”, i.e. the steel raw construction, is shown. As a summary of the comparison, it can be said that it is possible to express the general concepts of the PSS model by means of the IFC Core Model. However, most of the PSS items have no direct equivalent in the IFC. Concerning the other, more detailed parts of PSS (member processing and connections), there are no equivalents in the IFC.

4.2 Two Alternatives for Harmonization and Decision

When talking about harmonizing two product models, there are generally two alternatives. Harmonization by *mapping* implies a software tool that transforms data from one exchange format into the corresponding objects of the other format and vice-versa. None of the models would have to be changed, neither would existing implementations. The tool could be used by every software package that has implemented one of the product models. The scope of this solution is the intersection of the two models. Data which is out of scope is lost during the mapping process. Considering the above comparison of the two models, the common scope for a mapping solution would allow only the exchange of data for the raw construction without plates, member processing, connections and some of the most important profiles. The mapping solution is therefore not worth considering. The alternative is the *true integration*: one or both models are adapted in order to obtain a single, homogeneous product model. This means that existing implementations would have to be adapted, too. The scope of this solution is the union of the two models.

In November 2000 the DStV has made the official decision in favour of the true integration of the Product Interface Steel Construction into the Industry Foundation Classes, being aware of the fact that this means adaptational work at the PSS model and its existing implementations. The expected benefits from this outweighed the difficulties arising from the differences between the two models as shown in chapter 4.1. The decision was also supported by the software vendors among the members of the DStV. In return, the German-Speaking Chapter of the IAI announced an extension project for structural analysis and constructional steelwork of the IFC. As stated before, this paper deals with the latter only.

5. Proposal for an Integrated Model

5.1 Strategy for Integration

As stated in chapter 4.1, the IFC provide means for representing a wide variety of technical items, whereas the PSS model provides means for a very detailed representation of items in a very specific field of application. Therefore, the PSS model has to be adapted in order to fit into the plug-in architecture of the more general IFC model. The adapted PSS model will be referred to as the *extension model*. The entire model, i.e. the extended IFC model, will be referred to as the *integrated model*. These models are shown in Figure 5.1. The extension model cannot be seen as an independent model in the IFC. Naturally, the most tangible items will be found in the new *Steel Construction Domain*. However, there they will not be visible for other domains. Considering the importance of every item in the overall model, extensions will therefore have to be made on all functional layers, see Figure 5.1.

The DStV has made the following prerequisites for his decision: None of the abilities of the PSS model must be lost in the integrated model. In order to minimize programming work at existing implementations, the data structures of the old model shall be kept up in the extension model as far as possible. In other words, the extension model is being developed by expressing the PSS items by means of the IFC Core Model. Requirement by the IAI was that existing data structures of the IFC must be supported by the extension model in order to deeply integrate it in the IFC Core Model. This applies to data structures on all functional layers of the IFC.

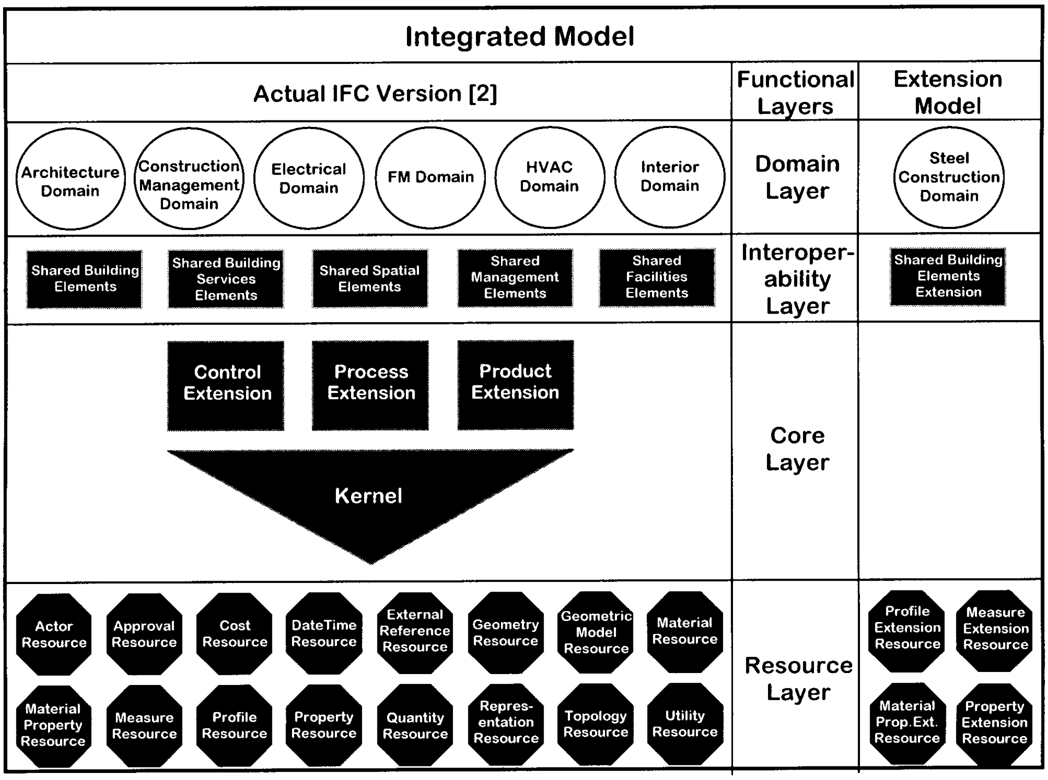

Fig. 5.1: Integrated IFC model with extensions for constructional steelwork

5.2 Proposed Extension Model for Steel Raw Construction

The task of extending the IFC model is demonstrated by the following example of beam representation. Figure 5.2 shows the simplified PSS model definition for a straight beam in EXPRESS-G, a graphical definition language by ISO 10303. The rectangles represent so-called entities, which are classes for objects with common properties. Thin lines represent references between the entities, whereas bold lines represent entity inheritances. According to Table 4.1, a steel beam is represented by a block definition (entity MEMBER) with geometric properties (cross section, length of member) and an assigned material. The location of this block is represented by an entity MEMBER_LOCATION, which is defined by a co-ordinate system consisting of three VERTEX entities and a reference to the MEMBER to be located. By means of this representation a single beam can be located several times. This corresponds to the way of thinking of the steel constructional engineer. Figure 5.3 shows the equivalent representation as proposed for the integrated IFC model. The three columns to the right contain those entities that already exist in the actual IFC version. The column on the left contains the necessary extension entities. First of all, it can be seen that the original data structure with block definition and location can be expressed by means of the IFC model (entities *IfcMappedItem* and *IfcTypeProduct*). Secondly, the number of new entities is small compared to that of the already existing entities involved: Only the two entities *IfcSteelBeam* and *IfcSteelBeamType*, which are specializations of existing entities (so-called *subtypes*), are to be found in the new Steel Construction Domain. This shows how deeply integrated the extension model is in the Core Model. The function of the new entities is on the one hand to define new properties for weight and surface area and on the other hand to specify and explain to the implementer the use of the appropriate means of the IFC Core Model. Regarding the complexity of the IFC Core Model – Figure 5.3 is strongly simplified – the latter is probably the more important aspect.

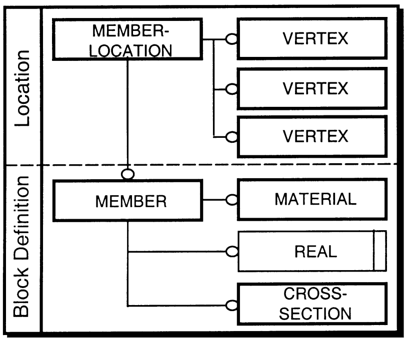

Fig. 5.2: Beam representation in PSS

Concerning the other items for steel raw constructions as shown by Table 4.1, the procedure is analogous. Similar extensions can be defined for curved beams and steel columns – the differentiation between beams and columns is a necessity of the IFC model – as well as for plates. The basic means for representing parts without geometry, assemblies and add-on parts are also already provided by the IFC Core Model (*IfcProxy, IfcGroup, IfcRelAggregates* and *IfcRelNests*). However, special attention will have to be paid to the problem of coupling the constructional model to the structural analysis model, because of the above-mentioned prerequisite by the IFC that profiles are not allowed to have mechanical properties, as they have in PSS. These properties will therefore have to be attached to the *IfcTypeProduct* entity.

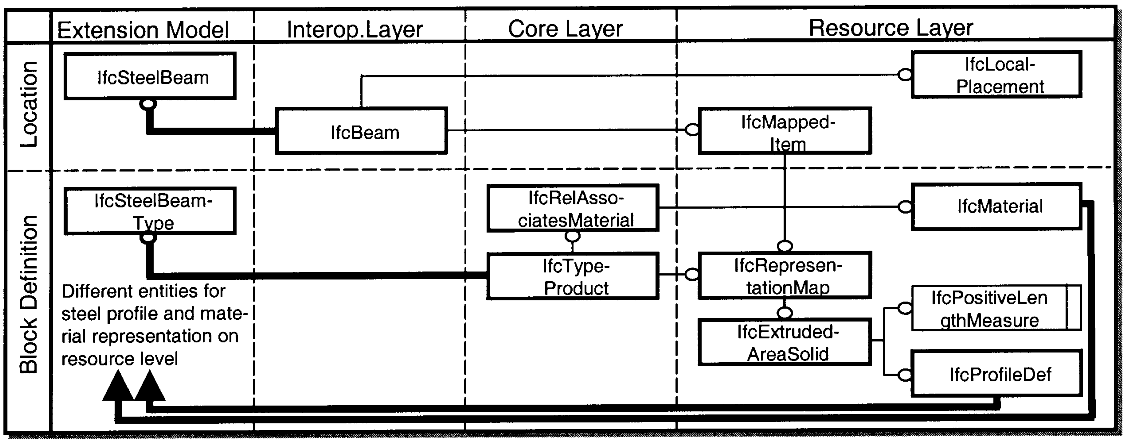

Fig. 5.3: Beam representation in integrated IFC model

6. Discussion, Conclusions and Acknowledgements

For harmonizing the Product Interface Steel Construction and the Industry Foundation Classes a true integration is both possible and strongly advisable, whereas a mapping solution is not. The integrated model would combine the advantages of both product models: international acceptance, extendibility for truly all future AEC/FM software domains and a high enough level of detail for practical application. Therefore, both DStV and IAI have decided in favour of this solution. A proposal for an appropriate model extension of the IFC has been made. It fulfils the requirements of both the DStV and IAI, i.e. that no abilities of PSS are lost, that its data structures are kept up as far as possible and that it is truly integrated in the IFC model. At present this proposal is discussed in a joint working group of both organizations. However, the proposal is a first draft. Its scope is the steel raw construction only. Funding still has to be raised for an extension model that is ready for submission to the IAI and that covers the entire scope of the actual version of PSS including member processing and connections.

At this place the authors would like to acknowledge the support concerning the IFC by Prof. Rasso Steinmann and Dr. Thomas Liebich of the IAI. The permission for publishing Figure 2.2 was kindly granted by the consortium ALSTOM and BSO Babcock Steinmüller, Oberhausen (Germany).

7. References

[1] ISO 10303: “Industrial Automation Systems and Integration – Product Data Representation and Exchange”, *ISO/IEC*, 1994

[2] IAI: “Industry Foundation Classes – Release 2x”, *International Alliance for Interoperability (IAI)*, 2000

[3] DStV: “Standard Description for Product Interface Steel Construction, Release April 2000 – Part 1: Recommendations for Users”, *Deutscher Stahlbau-Verband (DStV)*, Düsseldorf, Germany, 2000

[4] Saal H., Haller H.-W.: Feature based product model for steel structures; *Proceedings of the 1st European Conference on Product and Process Modelling in the Building Industry ECPPM’94;* Dresden, 1994

[5] Hannus M., Karstila K.: “Requirements on Standardised Building Product Data Models”, *Proceedings of the 1st European Conference on Product and Process Modelling in the Building Industry ECPPM’94,* Dresden, Germany, 1994