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A POST-POSITIVISM VIEW OF FUNCTION BEHAVIOUR STRUCTURE

Wenjuan Wang, Alex Duffy, Mark Haffey
CAD Centre, Design Manufacture and Engineering Management, University of Strathclyde

ABSTRACT
Design artefact knowledge elements and their causal relationships have been presented in previous work. Aiming to explore the existence of these elements, as well as their relationships, from a post-positivism view, this paper presents a new model of Function-Behaviour-Structure (P-FBS) by examining the related literature, and supported by collecting and analysing data based on a sample of a student's design project. Three fundamental artefact knowledge elements, i.e., function, behaviour, and structure, and their causal relationships are re-presented in P-FBS. These elements are presented as being distributed across the three design artefact knowledge spaces, i.e., expected, working, and interpreted. However, our post-positivism perspective has highlighted a contradiction that rather than being inherent in all of these three design knowledge spaces, the function only exists in expected and interpreted design artefact knowledge space, and that the structure only exists in expected and working design artefact knowledge space. Consequently, causal relationships among function, behaviour, and structural are limited to where they exist.

Keywords: Post-positivism, Design knowledge, Function, Behaviour, Structure, Causal relationships

1 INTRODUCTION
Function (F), behaviour (B), and structure (S) are considered to be fundamental elements of design artefact knowledge [1-5], of which function is the intention or purpose of the artefact [6, 7], behaviour describes what the artefact does and how it achieves its functions [8], and structure describes distinctive variables that identify the artefact and their interactions [9]. Considerable research has been conducted focusing on various aspects of artefact knowledge. Some have focused on individual artefact knowledge elements [10-14], some have emphasised the causal relationships among them [15-18], while others considered a holistic view of artefact knowledge [2, 3, 19-21]. Of the aforementioned research, Gero et al. have extended the basic FBS model to different aspects, such as situated design [3, 22], situated agent in design [23], analogy-based design [7], and evolutionary design [6].
Gero presented his initial FBS model [1] in 1990. In this model, F, B, and S are presented with transformations within a design process model. Although it presents a general design artefact (as well as process) knowledge model, which includes function, expected behaviour, structural behaviour, design description, and basic transformations among them, it does not provide a complete description of design artefact knowledge elements and their causal relationships, since it was only an initial concept.
In another extended model, Gero and Kannengiesser[3] depicted a more detailed account of F, B, and S covering three different worlds, i.e. external, interpreted, and expected world. The framework, however, does not reveal the evolution of design requirements effected by designers' interpretation of current artefact behavioural and functional knowledge, which in turn, affects the development of an artefact's expected functional, behavioural, and structural knowledge development. Furthermore, it would seem that, from a post-positivism view (see Section 2 for its discussion), function and structure are not actually reflected in their three design worlds description.
Design can be considered as a cognitive and social activity. Consequently, it has been argued that the design research paradigm is shifting from positivism to post-positivism [24]. However, it would seem that the aforementioned work has not revealed the true nature of fundamental design artefact knowledge elements with respect to this paradigm. Dorst [25] has criticised Gero and his colleague's FBS model on the basis of: i) an inconsistent definition of F, B, and S in different papers; ii) location

of transition from intentional to structural description; and, iii) the empirical data validation. This paper explores the intrinsic nature of design artefact knowledge from the designers' point-of-view, and it is hypothesised that function and structure only exist in specific design worlds. Specifically, a function only exists in expected and interpreted design artefact knowledge spaces, and structure only exists in expected and working design artefact knowledge spaces. Consequently, causal relationships among function, behaviour, and structural are limited to where they exist.

Based on the post-positivism perspective, the aim of this paper is to overcome the shortcoming of existing work by determining a more representative model of FBS in design, incorporating a designer's perspective. In order to achieve this, the objectives of this paper include, first, exploring the existence of fundamental design artefact knowledge elements; second, exploring existing relationships among the identified elements in terms of logical design process (flow); and lastly, presenting P-FBS through displaying the existing causal relationships.

2 POST-POSITIVISM PHILOSOPHY

Since its recognition in the 1950s [26], post-positivism has provided an alternative to the traditional positivism approach for conducting disciplined inquiry. Positivism is a philosophy that regards objective reality as existing while being independent of human being's thought and behaviour [27]. People who hold this philosophy, i.e., positivists, believe that science should study only those aspects of the world which we can be positive about, and the purpose of science is to know the world so as to be able to predict and control it. However, one of the major criticisms of the positivist approach is that "it does not provide the means to examine human beings and their behaviours in an in-depth way" [28].

In contrast with positivists, post-positivist researchers believe that reality exists only in the mind of human being [27] and it is a creation of the individual [28]. As a result, there could be various constructions of reality depending on its different contexts. From a post-positivism view, all observation is fallible and has error, and all theory is revisable. Post-positivists view human beings as being unable to know true reality with certainty. Despite their tendency to objectivity, post-positivists believe that knowledge and facts are subjective [27]. Therefore, qualitative approaches are the main research methods adopted by post-positivists. For them, research is 'soft' and generally small samples are employed for more in-depth investigations.

Much of the nature of design research is similar to cognitive psychology or sociology due to the involvement of people, society and organisations [29]. Accordingly, there has been a growing appreciation that designing is a social process. For example, Bender et al. [30], Cross and Cross [31], and Horvath [32], among other design researchers, have identified that the research methods used in social sciences should also be taken into account in design research.

Due to the often social nature of design research, to take account of the human elements and their behaviour in design, of the two main streams of research philosophies, positivism and post-positivism, the latter is adopted in the research work reported here.

P-FBS was hypothesised after examining related literature. To validate the model, a sample of student's design project were collected and analysed to reveal the fundamental design artefact knowledge elements and their causal relationships within the model.

3 BASIC DESIGN ARTEFACT KNOWELDGE ELEMENTS

From a post-positivism view, as Gero and Kannengiesser have proposed, there does seem to exist three artefact knowledge spaces in design, namely expected, what we call here working, and interpreted artefact knowledge spaces. The expected design artefact knowledge space (ES) composes of designers' expectations towards a designed artefact, such as what components it will contain, how it will function and behave. The working design artefact knowledge space (WS) contains the design artefact knowledge that has been specified by designers and could be realised in a future implementation. Lastly, interpreted design artefact knowledge space (IS) exists in designers' mind which is built up from their interpretation of the artefact being designed. These three design spaces contain design artefact knowledge in different states.

Generally, design artefact knowledge can be considered to include functional, behavioural, and structural knowledge [1-3, 33]. As a result of designing, design solutions are represented with various combinations of functional and structural descriptions [34]. During designing, behavioural knowledge works as a transformer ("hinge") connecting function and structure [35]. Moreover, artefact knowledge may exist in the form of causal relationships among them and constraints, which in turn may affect these three fundamental knowledge types. Taken together, artefact knowledge can be considered to consist of five basic elements, namely: functional, behavioural, structural, constraint, and causal relationship knowledge.

3.1 Function

The function of an artefact is the intention, purpose [6, 7, 33] or as Hubka [36] called it, duty of the artefact. Put simply, the primary reason of designing an artefact is to meet some desired function(s) [37]. Similarly, Zeng and Cheng [38] argue that the ultimate goal of designing is to create a form that displays the prescribed functions in its environment. Clearly, then, it is a prominent concept in determining an artefact's features [39]. In the early design phase, most design decisions are made with concern of the artefact functions [40]. Much more specifically, function plays three roles during designing [41]. First, designers can use it as a modelling language to construct and develop design requirements. Second, it can link requirements and artefacts. Finally and third, it could be used to evaluate whether the artefacts meet their requirements in the late design phases, i.e. when structural parameters are elaborated.

From a post-positivism viewpoint, artefact function is a subjective and situated concept and its existence depends on individual human being's expectation and interpretation of the artefact. Based on our observation and analysis of student design projects[*], function does not exist in WS due to its subjective character. This is partly because, although a function could be recognised by designers in WS, it is still interpreted by a human being. Thus, depending on whether it is derived from designers' intentional expectation, or their interpretation of the artefact being designed, artefact function can be categorised into two types: expected function (F_e) and interpreted function (F_i). The former stems from design requirements (R) which are descriptions of constraints, specifications, or customers/designers' intention. In contrast, the latter is derived from the artefact working structural and behavioural knowledge. As Hybs and Gero [6] have argued, it is a representation of a designers' perception of structure. Others (e.g. [15, 41]) explain F_i as an explanation of observed artefact behaviour when it works in a desired environment. That is, F_i becomes a combination of interpreted behaviours and these behaviours are observed based on a set of possible behaviours of the artefact [15]. This classification of function as being F_e and F_i is similar with Chandrasekaran and Josephson's F_E and F_D [42]. However, their representation is based on whether the function description is environment-centric or device-centric. Though, artefact and its working environment are indivisible throughout designing. Based on the protocol analysis of the "Roadside furniture" project, Table 1 shows some examples of F_e and F_i.

Table 1. Examples of functions

Expected function (F_e)	"Because you are actually going to design something, and one of the benefits would be the **ability to be replaced**, **be recycled**, and **positioned really easily**, and then replace, recycled when they get damage very easily."
Interpreted function (F_i)	"There are two elements basically to my project. There is the mechanism of actually installing the barrier to the ground, and the actual barrier itself. The actual barrier itself could **encourage better green cross codes**, crossing road in a safer manner. And the installation mechanism ..."

3.2 Behaviour

Simulating how an artefact works [15], behaviour describes what the artefact does, and how it achieves its functions [8]. Moreover, it is physical laws that control how an artefact demonstrates its behaviour through a series of status changes [33, 41]. An artefact functions in specific environments [33] and therefore behaviour is the effect of an artefact's interaction with its environment [6].

[*] Seven design projects were studied for this work. They were conducted in the Design, Manufacturing and Engineering Management department in the University of Strathclyde from September 2005 to April 2006. The example used for this paper is the project "Roadside furniture". The following examples of functional, behavioural, structural knowledge elements, and causal relationships are all from the protocols of this design project. Part of this design, "Post Installation" has applied British pattern and the application filing number is 0613906.7

From a post-positivism viewpoint, in comparison with function, artefact behaviour could be either an objective or subjective concept. On the one hand, it is an objective one in that it can be derived entirely by objective qualitative physics [43]. On the other, it is a subjective one in that it can also be derived by subjective observation. Viewed in this regard, three types of behavioural knowledge can be employed in defining an artefact. The first is called expected behaviour (B_e), which is the attributes expected from the artefact's structure and can be derived from its F_e. The second is working behaviour (B_w), which is also called behaviour of structure [1]. This type of behaviour is the attributes derived directly from the artefact structure that the designers are currently working on. Moreover, it is B_w that an artefact can exhibit with the designed structure. The last one, interpreted behaviour (B_i), refers to the behaviour observed by designers and could be exhibited by an artefact within a specific working environment, which is an explanation or analysis of an artefact according to the designers' expectation. Accordingly, B_i can then be used to evaluate the design.

Furthermore, during the course of designing, behaviour can be used for problem formulation, synthesis, analysis, evaluation and reformulation [7], which are realised by applying different types of the aforementioned behaviour. For example, whether B_i is the same as B_e is one evaluation criterion of the designed artefact.

Table 2. Example of behaviours:

Expected behaviour (B_e)	"Then I've been looking at that kind of sacrificial material for the low part of wings of the legs, so that if car or vehicle whatever hit the actual barrier, it could be made of sacrificial material in that **it would break, sheer or whatever, the barrier from the legs**."
Working behaviour (B_w)	"Yeah, but with this one, the poles, **they can be in any orientation**, because they are cylinder."
Interpreted behaviour (B_i)	"This panel is really quite strong, and the legs are really quiet strong. These attachments are relatively weaker. So that if a car hit the panel, then it just **break** off and sheer the attachment, so the panel can be reused again."

Function and behaviour

Having described artefact functional and behavioural knowledge, it is necessary to mention their relationship, not least because this has been often debated [15, 21, 39, 41, 42]. These two concepts are different, yet, they are cognate concepts while linking with each other closely at the same time. To clarify the differences between these two concepts, Sasajima et al. [15] talk about the intentional and structural descriptions of an artefact. As mentioned earlier, function could be divided into F_e and F_i, and behaviour could be divided into B_e, $B_{w,}$ and B_i. Of all these types, F_e and B_e belong to the intentional description of artefact knowledge; B_w belongs to the structural description, and F_i and B_i belong to a human being's subjective explanation of an artefact's structural description. Thus, B_w does not depend on a human being's judgement as it can be derived by qualitative physics. That is to say, it could be derived from artefact structure and the environment whithin which it operates. B_i, represents the designers' view of the artefact behaviour based on their observation. However, in comparison with B_i, Braha and Reich [44] argue that F_i of an artefact is a combination of B_i selected from a particular situation. Moreover, the F_i is subjective and context dependent [8]. It depends not only on the structure and the environment in which the artefact works, but also on how designers and users view the artefact.

The relationship between behaviour and structure could also be observed from some other definitions of function. As Takeda et al. [41, p.187] have pointed out, function is "a description of behaviour abstracted through recognition of behaviour for utilisation". This implies that different interpretations of function could be derived from the same behaviour by different people. For example, a standard pair of pliers could be used to hold something with its two flat ends; pull a nail out of a wall; fasten a nut to a bolt; or, crack walnuts. From these examples, it could be concluded that function describes what an artefact is for and behaviour describes what an artefact does [39].

Despite the foregoing differences between function and behaviour, these two concepts are closely related. According to Iwasaki et al. [16], to fully understand how an artefact works, especially to evaluate it based on F_e and B_e, the interpreted function of an artefact depends on its interpreted behaviour. To put in another way, two issues seem to be relevant here. First, in order to reason how an artefact works in an unexpected environment or how to infer the behaviour of an unfamiliar artefact from its structure, the F_e knowledge alone is insufficient. Second, in order to predict how an artefact will behave under a given environment, artefact structure knowledge and general physical principles might be sufficient. However, without the F_e knowledge, it is impossible to determine the desirability of the B_e and B_i [33]. One reason is that although an artefact can exhibit a number of behaviours, but as Takeda et al. [41] have argued, not all of them are meaningful for designers.

3.3 Structure

Derived from the artefact's components and their physical relationships, structure describes distinctive attributes that identify the artefact, and their interactions [9]. The configuration and arrangement of these components and their interconnections and relationships with the structure of an artefact [1, 6, 38] are decided by numerous factors such as working principle, material, cost, and manufacturing.

With a post-positivism viewpoint, artefact structure is an objective concept. Based on our observation of the student design project, structural knowledge of the artefact being designed exists in two states, either in relation to the designers' expectation towards what the artefact structure will or should be, or in relation to the state that has been specified by designers for the current artefact. Therefore, artefact structure remains consistent regardless of a human being's interpretation and is limited to the two existing design spaces, i.e., ES and WS. Consequently, an artefact's structure can be classified into expected structure (S_e) in ES and working structure (S_w) in WS. While the former refers to designers' expectation of the components of the artefact and relationships among them, the latter refers to the structure of the artefact being designed and specified at a particular point in time. Table 3 lists examples of S_e and S_w.

Table 3. Examples of structures

Expected structure (S_e)	"Then I've been looking at that kind of **sacrificial material** for the **low part of wings of the legs**, so that if car or vehicle whatever hit the actual barrier, it could be made of sacrificial material in that would brake, sheer or whatever, the barrier from the legs."
Working structure (S_w)	"This **panel** is really quite strong, and the **legs** are really quiet strong. These **attachments** are relatively weaker. So that if a car hit the panel, then it just break off and sheer the attachment, so the panel can be reused again."

3.4 Constraints

Designing is a constrained activity [1]. Various design artefact constraints need to be specified and simultaneously satisfied by designers throughout a design process [45, 46]. For example, designers set function constraints from the beginning and continuously introduce other additional constraints whenever it is necessary. By definition, design constraints are restrictions on an accepted design solution [47], which includes design specifications, requirements, needs, performance criteria, and objectives [48]. For Chen and Lin [49], a constraint is a relation which links design variables. When setting values for the variants of an artefact, designers will limit their choices considering the design constraints. For example, constraints may define what form the artefact should have, or how much its cost should be. In addition, constraints on function may appear as expected behaviours and constraints on structure normally reduce the range of structural possibilities. As a result, constraints knowledge can guide designers in finding acceptable design solutions [46].

Constraints can represent conditions which are defined in relation to the function, behaviour, and structure, and that need to be adhered to by designers. Therefore, in the following discussion of a post-positivism view of FBS, constraints do not appear as an individual element in the model, but rather as the background conditions of the function, behaviour, and structure.

3.5 Causal relationships

Gero [1], Schulte and Weber [50] and Chen and Lin [49], among others, have observed the existence of relationships between function and structure. Others (e.g. [7, 8, 33, 35, 41]) take this argument further by stating that such a relation is established through an artefact's behaviour. Takeda et al. [41], for example, developed the FBS diagram which reveals the existence of a relationship between function and structure through behaviour. A closer look at Takeda et al.'s proposed model, however, indicates that the model does not show the causal relationships among function, behaviour, and structure, and hence, the model could not answer the question 'which type of knowledge may result in change(s) in another?' To put it another way, which type of knowledge is 'cause' and which type is the 'effect'.

It is evident that there exist cause-effect links among the aforementioned three fundamental elements of artefact knowledge, i.e. F, B, and S, which are causal relationships that can reflect the evolution of design artefact knowledge. Knowledge of causal relationships is considered by Gero [1] as relational knowledge. It provides, and makes explicit, the dependencies between the variables in the functional, behavioural, and structural knowledge and can be represented as a dependency network. In his FBS model, Gero [1] revealed parts of the causal relationships among function, expected behaviour, structural behaviour, structure, and design description (Figure 1). However, this only provided an initial description of causal relationships. Although in their situated FBS framework (Figure 2), Gero and Kannengiesser [3] depicted a more detailed model of FBS, the framework didn't reveal the relationship between requirements and designers' interpretation of current artefact behavioural and functional knowledge. In addition, function and structure are not actually reflected in their three design worlds description, which in turn appended some causal relationships that didn't exist in the design world.

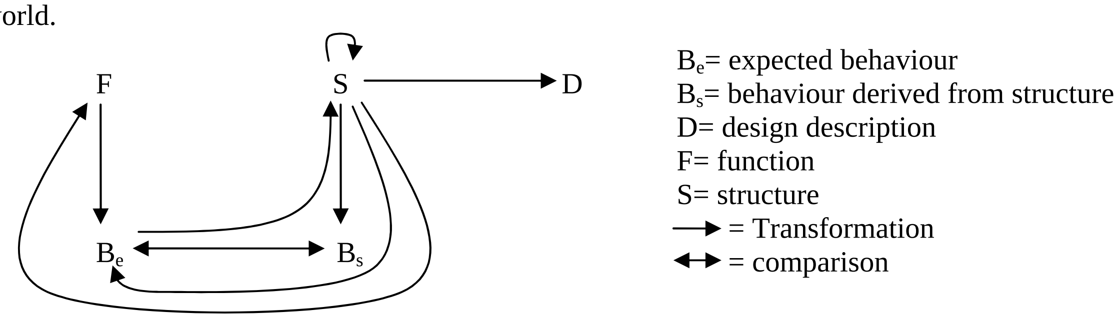

Figure 1. FBS framework [1, 3, p.375]

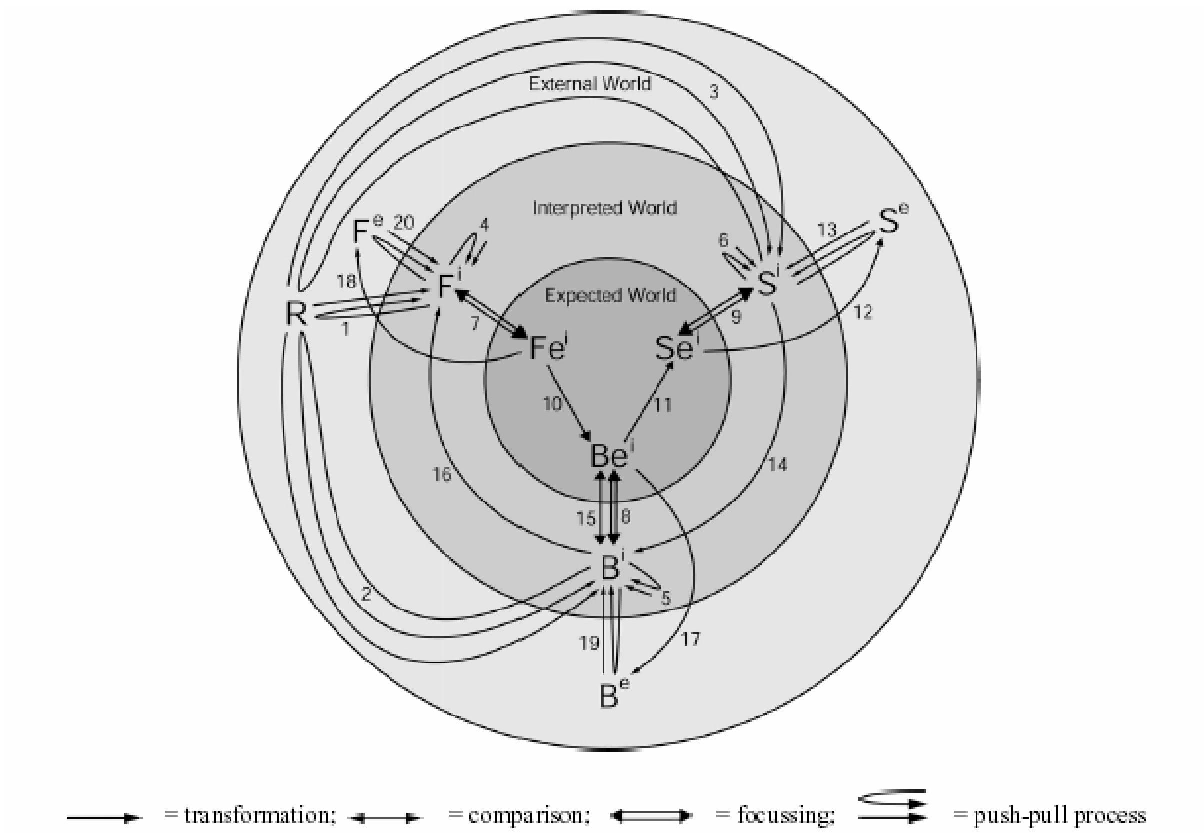

Figure 2. The situated FBS framework [3, p389]

Causal relationships become design constraints in some particular situations when the relationships must be realised. While the chunk of knowledge belongs to causal relationship knowledge, it also belongs to constraint knowledge in that design context.

4 A POST-POSITIVISM VIEW OF FBS (P-FBS)

From sections 3.1, 3.2, and 3.3, it can be deduced that function and structure do not exist in all of the three spaces (ES, WS, and IS). Specifically, *function* exists in the ES and IS; *behaviour* could be derived entirely by objective qualitative physics or subject observation so it exists in all three worlds; and *structure* only exists in ES and WS. As a result, there are seven fundamental artefact knowledge elements altogether: F_e, B_e, S_e, B_w, S_w, B_i, and F_i. In addition, F_e is normally deduced from requirements (R), which exists in the ES and derived from some motivating needs or the desires of customers or the designers themselves. Moreover, as a result of designing, a design description (D) is delivered in the WS. Specifically, of the design artefact knowledge spaces, the ES comprises of R, F_e, B_e, and S_e; the IS includes F_i, and B_i; and in the WS, B_w, S_w, and D (See Figure 3).

As a consequence, the existing causal relationships are limited to where the basic design artefact knowledge elements exist. In the ES, R can be derived from some motivating needs or desires of the customers or designers. F_e then could be deduced from R, and B_e from F_e. S_e can be derived from B_e by synthesis. Then S_e can be embodied to S_w in the WS, and B_w could be derived from S_w in this space. Based on the B_w, designers could observe B_i from it, and this could then be interpreted to F_i. Once B_i and F_i are derived, comparison between B_e and B_i, F_e and F_i can identify whether the design satisfies R. If the design is plausible, D can be documented as part of the final design. Overall, there exist three main causal streams in the design space, which are distributed in the ES, WS, and IS respectively.

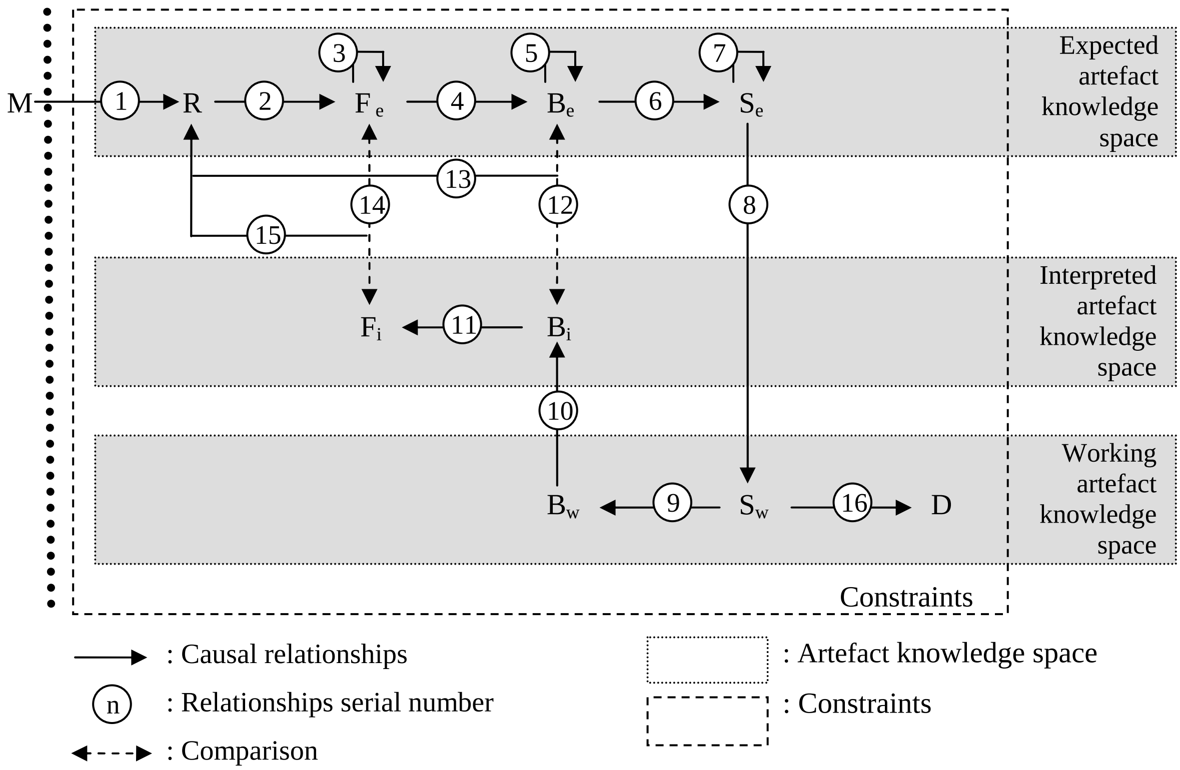

Figure 3. Post-positivism view of FBS (based on [1, 3, 14, 51])

Based on the FBS framework [1] and the situated FBS framework [3], Figure 3 presents a new model of FBS from a post-positivism point-of-view (P-FBS) with the fundamental artefact knowledge elements and causal relationships among them in terms of a logical design process (flow). As Figure 3 shows, the round dotted line divides M and other design artefact knowledge elements in the design world. The shaded areas represent the three design knowledge spaces. Causal relationships are represented with solid arrows. Furthermore, comparison/evaluation activities between F_e and F_i, and B_e and B_i, are represented with straight dashed double arrows. In addition, constraints, working in the background, are modelled as a dashed square which cover these basic artefact knowledge elements and causal relationships. Moreover, these causal relationships presented in Figure 3 are delineated in Table 4.

Table 4. Causal relationships between fundamental design artefact knowledge elements

Representation	Causal relationships	Explanation
1. M (Motivation) → R (Requirement)	Conversion	Design requirements are derived from some motivating needs or desires of customers or designers themselves. The requirements may be "incomplete, inconsistent, imprecise, ambiguous and/or impossible" [51] at the beginning of design because of designers' unclear understanding of design problem. Therefore, they need revision through later evaluation of the design.
2. R → F_e (Expected function)	Deduction	This relationship reveals the deduction of artefact F_e from design requirements. The F_e indicates designers' expectations towards design, i.e., what is the design for.
3. F_e → F_e	Function decomposition	A concept which is represented by a single term can generally be decomposed into more detailed concepts [21]. Function decomposition creates sub-functions or detailed functions by analysing the primary F_e, which is the basic function unit. By decomposition, the problem can also be simplified through designing the artefact to satisfy these sub-functions [33].
4. F_e → B_e (Expected behaviour)	Deduction	B_e of the artefact can be predicted, observed, described and verified from expected F_e [16]. In which case, designers presume that the F_e could be realised through execution of some particular B_e. Therefore, B_e is defined to be the set of values of parameters of the function.
5. B_e → B_e	Behaviour decomposition	Similar to F_e, B_e could also be decomposed to sub-behaviours. Therefore, a primary B_e could be realised through a set of sub-behaviours executed either concurrently or sequentially.
6. B_e → S_e (Expected structure)	Mapping/Synthesis	Based on knowledge of achievable behaviours produced by some specific structures, S_e is defined, which is expected to produce B_e so that the F_e could be realised through this mapping.
7. S_e → S_e	Structure decomposition	Sometimes, a structural element is required to be decomposed to realise a B_e. By doing this, the structural element is decomposed to some primary elements, which are the structural units that could not be further decomposed. This causal relationship is called structural decomposition.
8. S_e → S_w (Working structure)	Embodiment	Having S_e in mind, designers then embody them with S_w in the WS.
9. S_w → B_w (Working behaviour)	Deduction	Structure's attributes, relationships among elements, and certain external effects interacting with the structure at a particular time within a specific environment determine the structure's behaviour. B_w can be exhibited by a structure which is derived from analysing physical properties of a given structure.
10. B_w → B_i (Interpreted behaviour)	Observation	With regards to all B_w that could be exhibited by the artefact, designers obtain B_i within a specific working environment according to their own observation.
11. B_i → F_i (Interpreted	Interpretation	As part of a human being's ideology, F_i is the designers' interpretation of artefact according to their expectation

function)		towards design. It can be derived through designers' analysis of B_i. In other words, F_i can be satisfied by B_i.
13. $B_e \leftrightarrow B_i \rightarrow R$	Refinement	Since the initial requirements might be "incomplete, inconsistent, imprecise, ambiguous and/or impossible" [51], they need to be identified and refined by reformulation and modification. New requirements may be discovered by comparing B_e with B_i. Through this evaluation, in case of any inconsistency between them, the designers can deduce new design requirements.
15. $F_e \leftrightarrow F_i \rightarrow R$	Refinement	Meanwhile, in case of any inconsistency between F_e and F_i, new requirements might be discovered by a comparison between them.
16. $S_w \rightarrow D$ (Design description)	Documentation	When F_i and B_i are in the permitted limit of expected ones, i.e. the requirements are satisfied by the design, the design description could be then documented for this final design. Generally, design description, as a detailed depict of the artefact structure, contains structural and functional information, as well as its detailed manufacturing information.

In addition, the two comparison activities involved in this P-FBS model are listed in Table 5.

Table 5. Activities involved in P-FBS model

12. $B_e \leftrightarrow B_i$	Comparison/Evaluation	In order to discover whether the S_w of current design is plausible or not, B_i needs to be compared with B_e to find out whether B_i match B_e.
14. $F_e \leftrightarrow F_i$	Comparison/Evaluation	Similarly, in order to discover whether the S_w of current design is plausible or not, F_i needs to be compared with F_e to find out whether they match.

Due to limited length, this paper gives only two examples of aforementioned causal relationships, which were taken out from the protocol analysis of the "Roadside furniture" design project.

Table 6. Examples of causal relationships

Deduction $F_e \rightarrow B_e$ B_e (looks different) F_e (turns signals to any road users)	"Different roadside equipments near schools relating to children …… **They might be more physical. They might be more obvious, and that might turn signals to any road users**. Oh! This is a school! Because **it looks different**."
Deduction $S_w \rightarrow B_w$ B_w (they can be in any orientation) S_w (they are cylinder)	"A: Yeah, but with **this one**, **the poles, they can be in any orientation**, **because they are cylinder**. B: That's right. A: Which is less hassle I suppose, for the people installing them."

5 CONCLUSION

Within existing work on FBS models, it would seem that function and structure are not accurately reflected in design artefact knowledge spaces, i.e., Expected, Working, and Interpreted (ES, WS, and IS). Moreover, the effect of requirements evolution caused by the evaluation of current design artefact had been omitted. A more representative model of FBS is presented in this paper based upon a post-positivism point-of-view, incorporating a designer's perspective. By doing so, the existence of fundamental design artefact knowledge elements as well as existing relationships among them were explored, and supported by examples extracted from design protocol analysis. The new post-positivism view Function-Behaviour-Structure (P-FBS) model indicates that functional, behavioural and structural knowledge only exist in specific design artefact knowledge spaces. Function (F) only exists in ES and IS, structure (S) in ES and WS, and behaviour (B) in all three. Accordingly, causal relationships among the basic design artefact knowledge elements are limited to where the elements exist in this model. Moreover, requirements are evolved through evaluation of B_i and F_i, which in turn, affect the evolution of all the other fundamental artefact knowledge elements.

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Contact: W. Wang
University of Strathclyde
Design, Manufacturing and Engineer Management
CAD Centre
75 Montrose Street
Glasgow
UK
Tel +44 141 548 2374
Fax +44 141 552 7986
e-mail wenjuan.wang@strath.ac.uk