CEN WORKSHOP AGREEMENT

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Building information modelling - Integration of architectural design intentions for creating social values

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European foreword

This CEN Workshop Agreement (CWA 18321:2025) has been developed in accordance with the CEN-CENELEC Guide 29 "CEN/CENELEC Workshop Agreements – A rapid way to standardization" and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by the Workshop CEN/WS SDI, the secretariat of which is held by DIN, consisting of representatives of interested parties on 2025-12-05, the constitution of which was supported by CEN following the public call for participation made on 2025-03-24. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

The final text of this CEN Workshop Agreement was provided to CEN for publication on 2025-12-05.

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Introduction

Architectural design intentions for creating particular social values (hereinafter referred to as “social design intentions – SDI”) are a fundamental part of the architectural design process, as they directly impact the wellbeing and quality of life for individuals and communities. Building designers develop design intentions in an iterative process, in response to a given building program, client brief, site and location, and other contextual factors. Social values include comfort, privacy, accessibility, a sense of belonging, forming of social connections, and so on. Despite their critical role in the performance of a building, SDIs are not currently captured or documented in an explicit way in the digital representations of buildings, referred to as Building Information Modelling (BIM) processes and associated standards. There is a growing need to capture, formalise, and integrate design intentions into the BIM process and digital models so that these concepts are considered during design decision-making processes.

1 Scope

This document defines social design intentions for digitalisation and automated BIM-based (Building Information Modelling) analysis. This is distinct and complementary to frameworks that assess specific social values (e.g. privacy, accessibility, spaciousness, etc.), where this document defines social intentions at a more general level. It is also distinct from, but aligned with, processes of documenting, predicting and evaluating a building's performance and adherence to design intentions, which may be done as Post Occupancy Evaluation (POE) or applying space syntax principles.

This document describes a generic data model for representing social design intentions, a process for capturing social design intentions (from elicitation to implementation), the integration of social design intentions into BIM models, and the relationship between social requirements, social intentions, and social values. These concepts apply to both existing buildings and newly constructed buildings.

The target groups of this document are primarily the following stakeholders:

— Architects and Building Designers in their leading of the design process;

— Architectural researchers and Consultants (e.g. anthropologists or sociologists based in architectural studios) in their support of evidence-based design and evaluating social impacts;

— BIM specialists and software developers for developing software that enables interoperability with BIM and supports the integration of social design intentions;

— Public agencies in their preparation of design briefs, managing public design competitions and tenders;

— Social commissioners when they assess social aspects of a building before design handover and after construction.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp/

— IEC Electropedia: available at https://www.electropedia.org/

3.1
social requirement
impact on building occupants that has to be realised for a specific aspect of a building, in a focused location, to be considered to perform satisfactorily and effectively

3.2
social design intention
SDI
architectural design decision intended to create an impact for building occupants, i.e. with the intention to create a social value

3.3
social value
impact on building occupants and/or a community of occupants in a specific context, created by the building design

Note 1 to entry: The term "social" refers to human- and socially oriented aspects. It involves a focus on the well-being and health of people and/or communities.

Note 2 to entry: A social requirement defines what shall be achieved. SDIs express how the design aims to achieve social requirements. Social value refers to the actual outcome experienced in reality by the occupants as a result of the design. Social intention refers to the intended outcome.

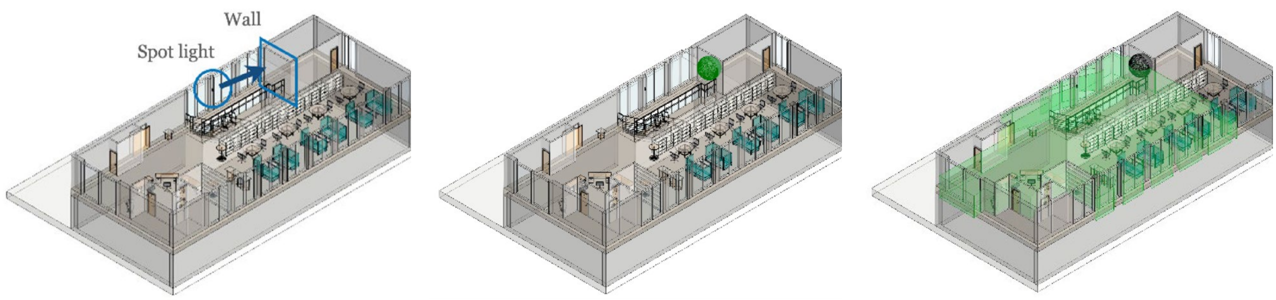
3.4
SDI justification
evidence used to support the claim that an SDI will, or does, create the social value

3.5
ProBIM model
Building Information Model (BIM) that explicitly includes SDIs as instances of objects defined in the corresponding BIM standard

3.6
spatial artifact
location in a building in which either occupants have particular sensory experiences, emotive experiences and are afforded or inhibited from particular behaviours or other social and physical phenomena occur

EXAMPLE Hearing, seeing and touching are sensory experiences. Interest, awe and belonging are emotive experiences. Sitting, moving, using and glancing are behaviours. Sound, light, shadow, crowds, aroma and hazards are social and physical phenomena.

Note 1 to entry: Spatial artifacts are represented in BIM models as special empty space objects, similar to spatial zones. The difference is that spatial artifacts are always caused by the potential interaction between people and objects in the environment, or dynamic physical phenomena such as light and sound. Therefore, they can only be introduced into a building design indirectly, e.g. by placing and arranging particular objects, whereas spatial zones can be introduced into a design directly, e.g. by asserting that a given region is a work area. Examples of spatial artifacts are illustrated in Figure 1.



a) A spotlight is directed at a wall

b) the spotlight creates a light beam, modelled as a spatial artifact (green region on the wall)

c) the light beam is visible to occupants from certain locations in the room, modelled as a spatial artifact (green region)

Figure 1 — Example of a social design intention that involves two spatial artifacts in a building (a light beam and a visibility space of the light beam), caused by a spotlight directed at a wall

Note 2 to entry: Further information can be found here – [1] and [2].

3.7
occupant
hypothetical person in the building

Note 1 to entry: When referring to occupants in the design, a list of profile attributes can be included if they are relevant to the social design intention, e.g. "wheelchair user", "student", "child".

4 Abbreviations

Table 1 — Abbreviations

Abbreviation	Long title
BIM	Building Information Modelling
IFC	Industry Foundation Classes
POE	Post-occupancy Evaluation
SDI	Social Design Intention
UML	Unified Modelling Language
VR	Virtual Reality

5 Overview of workflow from social design intention (SDI) elicitation to digitalization

This clause presents an overview of the major activities and tools used to identify and digitalise SDIs, and how they relate to each other.

As illustrated in Figure 2, the overall approach is to:

— Identify SDIs in a design together with architects;

— Bring each SDI into a form that can be represented digitally using the Product-Goal Causality data model. This activity is typically undertaken using an SDI specification software tool;

EXAMPLE A plugin for a BIM authoring software application is ProSpect for Autodesk Revit [3][1].

— Gather evidence that the SDIs will lead to, or have led to, social values in the actual building by undertaking verification activities and other analyses, including the use of computational tools (referred to as ProBIM Utilities in the diagram);

— Add the SDIs into the BIM model, referred to as a ProBIM model.

SDIs are represented digitally using the Product-Goal Causality data model (described in Clause 6).

[1] This information is given for the convenience of users of this document and does not constitute an endorsement by CEN of this product.

The SDI Elicitation and Modelling process (described in Clause 7) provides a systematic way of identifying SDIs (elicitation) and representing them in a digital form (organisation, formalisation, implementation).

Means of verification (described in Clause 8) are employed to justify the claim that social design intentions will lead to social values in actuality, including activities such as simulation, post-occupancy analysis, compliance with standards, and ensuring that the logical structure of the SDI is sound and well-formed.

In Clause 9 a case study is presented showing, in detail, how the SDI elicitation and modelling process can be applied, and how the resulting SDIs can be exported into Industry Foundation Classes (IFC) BIM models, as a detailed example of how a ProBIM model can be created.

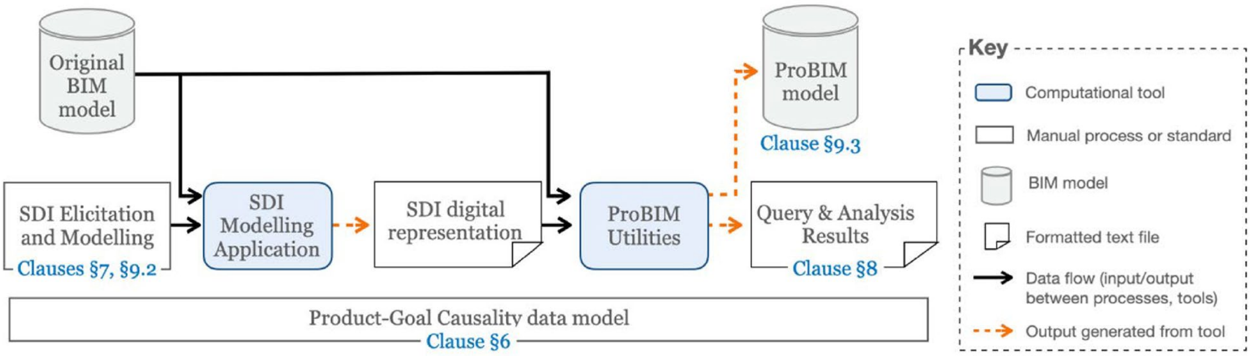


Figure 2 — Overall workflow of processes, data models and computational tools for identifying and digitalising SDIs

6 Data model of social design intentions (SDI)

6.1 Product Goal Causality Model

6.1.1 General

Many aspects of SDIs are "invisible" since there is no standard way of drawing intended social values such as interest, awe, or the sense of belonging, into a BIM model.

The Product-Goal Causality Model addresses this problem. The Product-Goal Causality Model is a data model for digitally representing SDIs, and for enabling their inclusion in BIM models. As a data model, it is an abstract model that defines important SDI concepts, and the relationships between those concepts. It is a causality model because it is based on the rationale that intended social values (the "goals") are caused by the products, and their properties and spatial arrangements in the building.

Subclause 6.2 defines social requirements and how they can be satisfied by SDIs.

Subclause 6.3 defines the Product-Goal Causality data model for digitally representing SDIs. The Product-Goal Causality Model consists of three levels of concepts: Product level, Domain level, Goal level (see Figure 3).

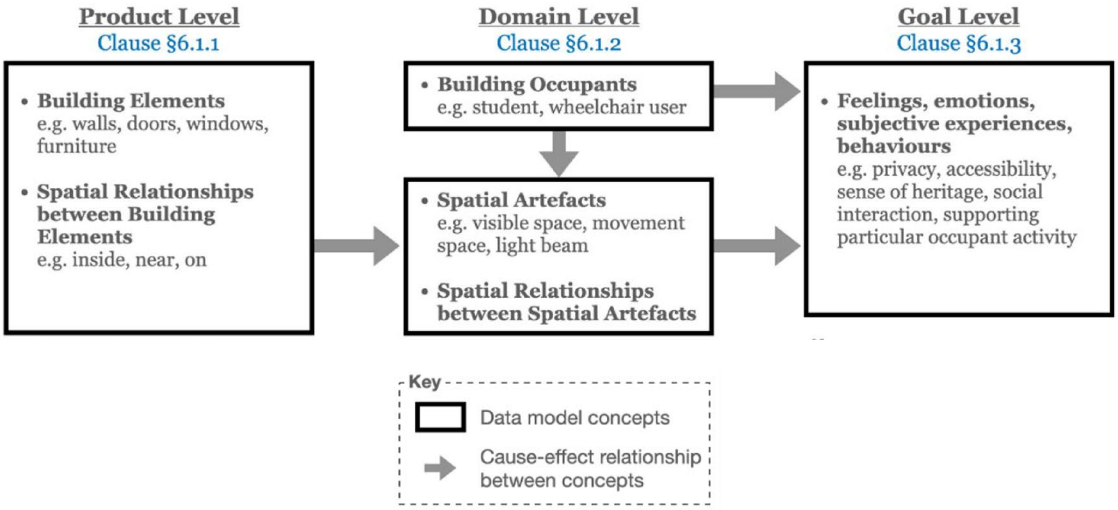


Figure 3 — Concepts and their cause-effect relationships in the Product-Goal Causality Model for digitally representing SDIs, organised according to level

6.1.2 Product level

The product level consists of building elements (e.g., wall, floor, door, etc.) that a designer deliberately includes or excludes in the building, and a qualitative description of their relevant spatial relationships (e.g. between, behind, on) and spatial properties (e.g. round, large). All building elements shall exist as object instances in the BIM model.

Building elements are *persistent* in contrast to being *transient*. This means that product level elements are intended to be included in the building and remain in place for the foreseeable future, e.g. the installation of doors, walls, beams. This also includes more temporary building elements such as furniture and artwork, where the exact pieces and location may change over longer periods of time, although day-to-day, for the foreseeable future, the furnishings and other similar building elements are intended to remain where they have been placed in the design.

Similarly, product level spatial relations and properties are persistent, and are not intended to routinely change. For example, artwork hanging on a particular wall is a persistent property, whereas the state of a light being turned on or turned off, or a door being open or closed, are transient properties.

EXAMPLE In the following quotes, building elements are indicated by boldface and spatial relations and properties are indicated by italics and an underline.

"**A spotlight** is *directed at* **the wall** so that the light beam striking the wall is visible to students as they enter the library, creating a sense of curiosity and interest, encouraging students to explore further down the corridor."

"A *large* **window** is installed *between* **the corridor** and **the office** so that people can see whether the meeting room is occupied or not, to avoid unnecessary disruptions."

6.1.3 Domain level

The domain level consists of transient objects that come and go through the normal functioning of the building, and a qualitative description of their relevant spatial relationships (e.g. disjoint, overlapping, adjacent).

By their nature, domain level objects cannot be directly added to the building by a design team, and instead are part of the context and environment of the building (e.g. occupants, rain, daylight, birds), or are the effect of occupants being able to experience and interact with product level building elements or other domain level objects (e.g. the region of space in which an occupant can hear birdsong).

The two main kinds of domain level objects are:

— occupants; and

— spatial artefacts.

EXAMPLE In the following quotes, domain level spatial artifacts are indicated by boldface and occupants are indicated by italics and an underline.

“A spotlight is directed at the wall so that the **light beam** striking the wall is **visible** to *students* as they **enter** the library, creating a sense of curiosity and interest, encouraging students to explore further down the corridor.”

“A large window is installed between the corridor and the office so that *people* can **see** whether the meeting room is **occupied or not** to avoid unnecessary disruptions.”

6.1.4 Goal level

The goal level consists of regions of space in which occupants experience the design team’s social intention. SDIs can draw on established social value frameworks such as universal design [4] (e.g. awareness, accessibility, body fit, comfort, wellness) and can also directly refer to an elicited emotion (e.g. curiosity, sense of heritage, creating a stimulating environment) or occupant behaviour (e.g. creating a quiet reading area in which students can study, promoting more social interaction between occupants, etc.). Because they are meaningful regions of empty space, goal level objects are a special kind of spatial artifact.

EXAMPLE In the following quotes, goal level SDIs are indicated by boldface.

“A spotlight is directed at the wall so that the light beam striking the wall is visible to students as they enter the library, creating a sense of **curiosity** and **interest**, **encouraging students to explore** further down the corridor.”

“A large window is installed between the corridor and the office so that people can see whether the meeting room is occupied or not **to avoid unnecessary disruptions**.”

6.2 Social requirements

During the design process, it is often informative to indicate locations on a floorplan at which certain social values are necessary or important.

When a person for example *enters* the library, the light beam on the wall needs to be visible to evoke a sense of curiosity, or that signage needs to be visible ensuring that occupants have a sense of orientation.

Such locations (i.e. the library entrance), together with the necessary social value, shall be referred to as *social requirements* in the Product-Goal causality model.

A social requirement is *satisfied* by an SDI if the social requirement location (represented as a spatial region) is contained within the SDI’s goal-level region that has the corresponding social intention (e.g. sense of orientation). Every social requirement in a design needs to be satisfied by at least one SDI.

6.3 Product-goal causality model classes and relations

The Product-Goal Causality Model consists of six classes that are specialisations of three common BIM classes:

— general *Object* class,

— *Building Product* class (abstract representation of objects that have a geometric or spatial context), and

— general *Relation* class.

Figure 4 presents a Unified Modelling Language (UML) class diagram of the Product-Goal Causality Model classes. Numbers that decorate the association relationship arrows denote instance multiplicity, i.e. a spatial relation holds between one or more building products, and words that decorate the association relation denote the type of association, i.e. each spatial artifact is *caused by* zero or more building products.

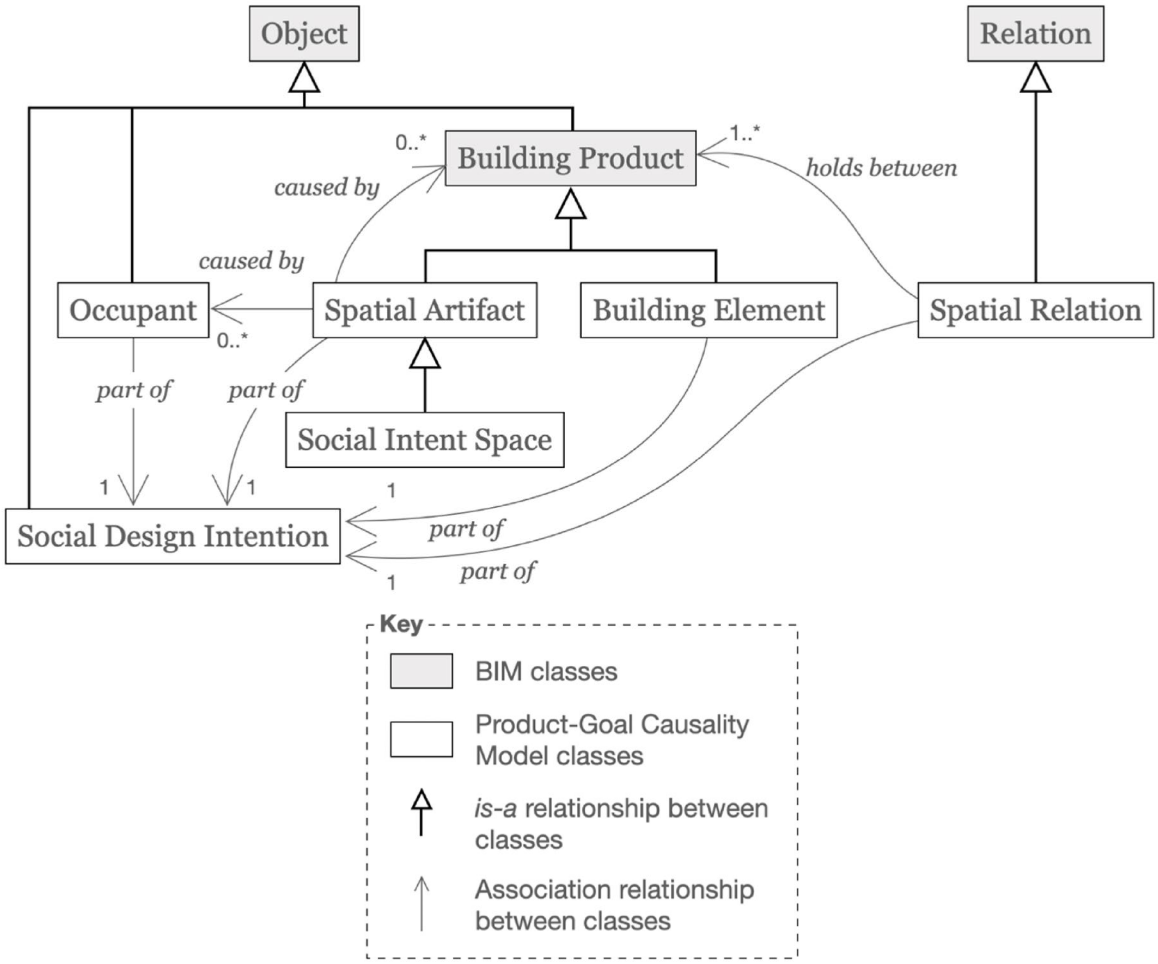


Figure 4 — UML class diagram of the Product-Goal Causality Model as a specialisation of common BIM classes

An SDI shall be digitally represented as instances of the Product-Goal Causality Model classes.

Within the context of an SDI, each SDI object and spatial relation has its own *type* identity and geometric representation tailored to the SDI. For example, a building product can be an instance of *Furnishing* according to the BIM model standard used to digitally represent the building, and can take on the type identity of *Artwork* as a *Building Element* within the context of an SDI. Moreover, the building product can be assigned a geometric representation of a detailed 3D mesh in the BIM model, while the corresponding *Building Element* in the SDI may be assigned a 2D centre point in a floorplan view as its geometric representation. This flexibility in tailoring the *type* identity and geometric representation of objects in an SDI is critical to the effective modelling of SDIs in a way that captures the design team's intentions.

Once the SDI object instances are added to the original BIM model, then the resulting BIM model shall be referred to as a **ProBIM model**.

EXAMPLE In the Molecular Biology building in Aarhus University, the architect installed a blue acoustic panel on the corner of wall that visually contrasts with the wall, as presented in Figure 5. The SDI is that students will see the blue acoustic panel from the far end of the corridor, roughly at the location marked "A", and will be curious to explore further down the corridor and discover the small study with a table and chairs.

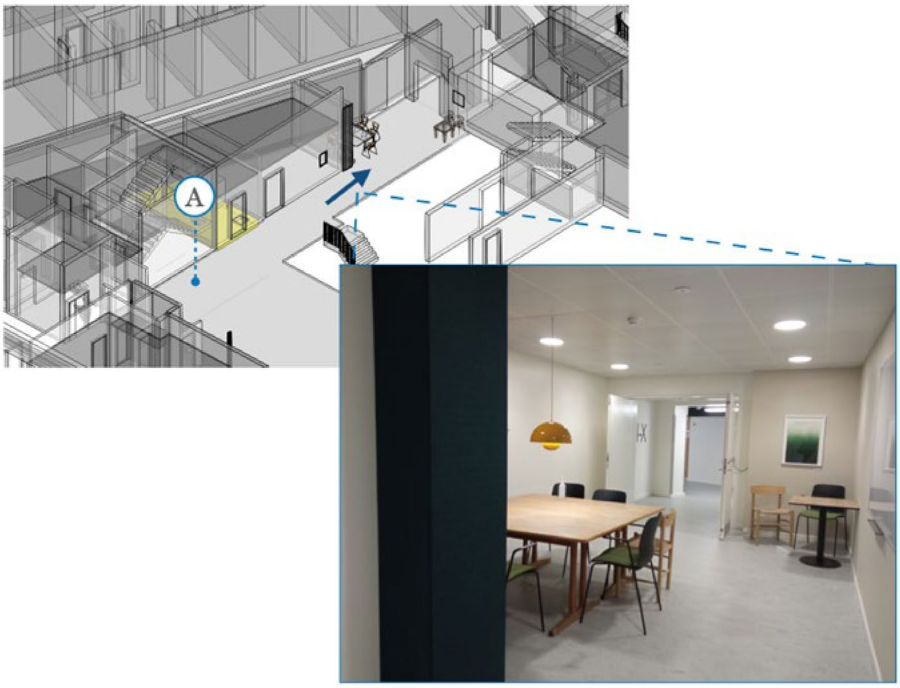


Figure 5 — A blue acoustic panel was installed to evoke curiosity in occupants and encourage exploration.

The *social requirement* of curiosity is represented by a 2D point placed at location "A". This requirement is satisfied if an SDI exists which has a goal-level social intention space that contains location "A".

This SDI is represented using the Product-Goal Causality Model, as presented in the UML instance diagram in Figure 6.

At the Product level, acoustic panel AP is asserted to be spatially *on* wall W. The acoustic panel AP is visible to an occupant (O) if they are located within the **Visible Space** (V), as shown in Figure 7(a). Moreover, slab (S) provides a surface on which occupants can move. The **Movement Space** (M) is derived from the surface of slab (S) by subtracting areas occupied by obstacles to movement, such as walls and furniture, as shown in Figure 7(b). The SDI of **Curiosity** (C) is spatially represented by the intersections of (V) and (M), that is, the regions where an occupant can both see the acoustic panel and move towards it, as shown in Figure 7(c).

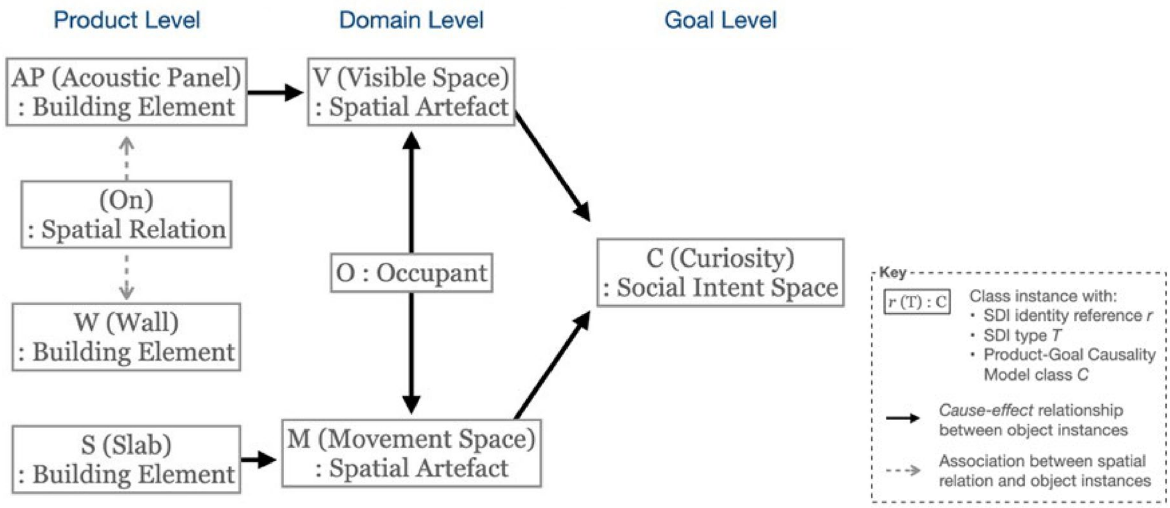


Figure 6 — UML instance diagram using the Product-Goal Causality Model classes to represent the example SDI of an acoustic panel evoking curiosity

a) **Visible Space** (V) in which occupant (O) can visually perceive the acoustic panel (AP).

b) **Movement Space** (M) in which occupant (O) is physically able to move. It is independent of visual access to the acoustic panel (AP)

c) **Curiosity Space** in which occupant (O) is intended to experience curiosity, i.e., being in a place where the panel (AP) can be seen (V) and approached (M) by the occupant (O).

Figure 7 — Example of Spatial Artifacts used to represent an SDI. Green coloured regions indicate spatial conditions related to the experience of curiosity evoked by the placement of an acoustic panel

NOTE In Figure 7 the Curiosity Space (C) overlaps with almost all of the Visible Space (V) due to spatial configuration, although this is not always the case. In some configurations, the Curiosity Space (C) differs significantly from the Visible Space (V), particularly when physical access is limited. For example, furniture such as a table and chairs placed at the end of a corridor may block movement, even though the acoustic panel remains visible from further away. Similarly, in open multi-level buildings, an occupant might see a visual target (such as an office door) from an upper floor but be unable to move into the space directly below. This highlights the importance of modelling the intersection between visibility and movement when defining spatial conditions for SDIs.

7 Social design intention (SDI) elicitation and modelling process

7.1 General

The SDI elicitation and modelling process is a four-stage process for identifying and recording SDIs of a building design (design-stage), or an existing building (post-construction). It aims to be a tool that provides a systematic, structured way for design teams, building owners, and other stakeholders to identify and digitalise SDIs, i.e. providing a bridge between design teams and building designs on one side, and the Product-Goal Causality Model on the other. The process can be employed during the design phase of a building, or retroactively after construction to “upgrade” the BIM model of an existing physical building with SDIs. It is not a requirement that all SDIs shall be identified and modelled according to this process.

The process is undertaken by:

— one or more *process facilitators* who observe or conduct interviews and analyse the gathered data;

— one or more *participants* who are interviewed to elicit the SDIs.

The participants are:

— professionals who were involved in the design process of the building that are aware of the social intentions that underlie design decisions taken (for example, architects, architect engineers/computation designers, anthropologists, real estate developers that hired architects for retrofitting, interior designers, consultants and specialists that advised on aspects of the design, a museum director who oversaw an extension of the museum, and so on);

— architects and other design professionals who have sufficient professional knowledge and relevant experience with the typology of the building (for example, to retroactively identify SDIs from an existing building when the original design team is no longer available).

Figure 8 illustrates the sequence of the four process stages, and the documents and content produced as output after completion of each stage.

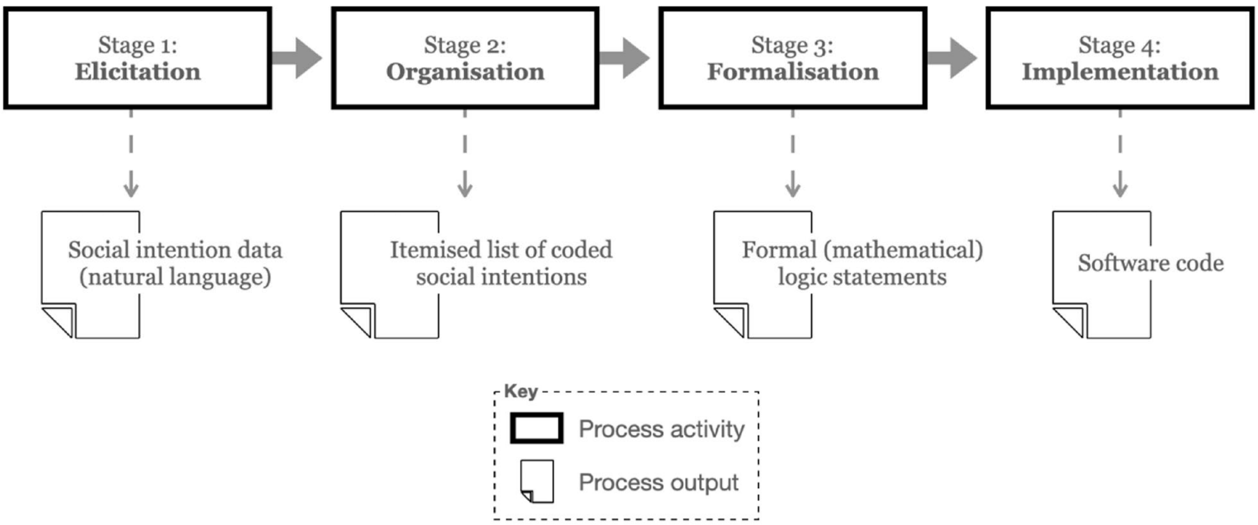


Figure 8 — Four stages of the social intention elicitation and modelling process

7.2 Elicitation stage

The elicitation stage shall be undertaken in the form of a semi-structured interview with a narrative and anecdotal approach, i.e. the facilitator shall encourage the participants to primarily tell the facilitator about the building through the interview. This typically leads to stories about how the participants intend the building to impact occupants (in the case of design-stage elicitation) or how participants judge what they determine to be design decisions made to impact occupants (in the case of post-construction elicitation without the original design team participating).

7.3 Organisation stage

The organisation stage shall be undertaken by the process facilitators, with the involvement of participants in reviewing, assessing and approving the outputs to ensure that SDIs have been recorded accurately. In this stage, the interview data from the elicitation stage (e.g. in the form of transcripts) is analysed and sorted so that the output of this organisation stage is an itemised list of SDIs with each SDI components marked up according to the Product-Goal Causality Model levels and classes.

The process facilitator shall categorise the transcription into items containing two parts: socially oriented design intentions and design activities.

7.4 Formalisation stage

The formalisation stage shall be undertaken by the process facilitators. In this stage, the logical structure and meaning (semantics) of each organised SDI is represented explicitly, in the context of the BIM model. This includes:

— identifying the BIM model object that corresponds to each SDI building element;

— deciding on suitable geometric representations of each building element and SDI object based on the geometry data in the BIM model (e.g. 2D footprint, centre point, 3D mesh, etc.);

— deciding on suitable interpretations of qualitative spatial relations such as *above*, *on*, etc. on a case-by-case basis so that the interpretations are *fully tailored* to each SDI, and to the given BIM model.

If it is determined that there are no suitable BIM model objects for a given SDI building element, then the BIM model shall be edited to add a suitable BIM model object.

The primary effort in this stage is on systematically identifying implicit and ambiguous aspects of each SDI and systematically deciding how to represent them in a concrete, unambiguous way within a logically consistent network of cause-effect relations. This includes the categories of targeted building occupants, their relevant sensory experiences (such as sight) and afforded behaviours (such as movement), the social value that the design activity is trying to evoke, and the surrounding environment or situation.

7.5 Implementation stage

The Implementation stage shall be undertaken by process facilitators and consists of programming the formalised SDIs into a digital form that can be processed in software. The internal representation of SDIs shall conform to the class diagram presented in Figure 9.

This stage can be supported by an SDI specification software application, with a suitable Human-Computer Interface.

EXAMPLE ProSpect plugin for Autodesk Revit [5] is an example of a suitable product available commercially.[2]

SDI instances shall have a String identity reference that is unique among the set of SDIs for the building. Each SDI instance shall have a set of SDI Object instances and a set of SDI Relation instances.

[2] This information is given for the convenience of users of this document and does not constitute an endorsement by CEN of this product.

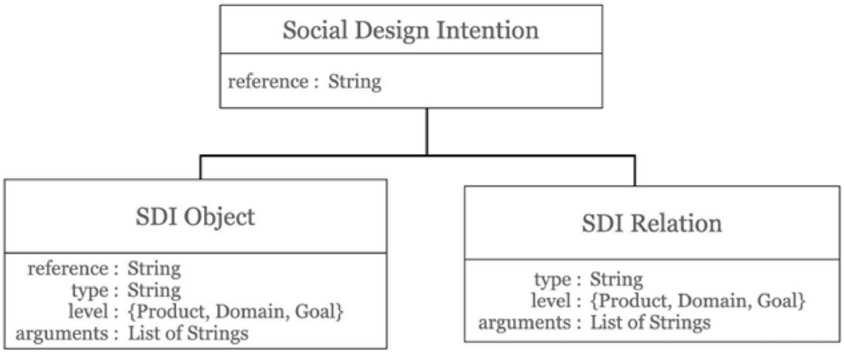


Figure 9 — Class diagram of the internal representation of SDIs in software

8 Analysing ProBIM models

8.1 General

Social intentions by way of installing physical artifacts in a building do not always lead to the intended outcome. Building population, management and operation all have a significant influence on how space is used. Determining that a social *intention* has been, or will be, realised as a social *value* in a building should not be viewed as a "fact" that can be proven. Rather, it is a claim that shall be justified by evidence using established *means of verification*. This process is referred to as *justifying an SDI*.

Part of the reason for documenting these social intentions in BIM at the design stage is to be able to conduct *post-occupancy/post-retrofit* verification that the actual design intent was achieved. Other means of verification are:

— demonstrating compliance with building regulations and national building standards;

— demonstrating compliance with established architectural design requirements (e.g. see [6]);

— applying scientifically-based frameworks that specialize in a particular social value (e.g. fall prevention frameworks for care facilities [7]; dementia-friendly residential care environments [8]; broader evidence-based design frameworks for healthcare facilities [9]; isovist-based privacy analysis [10]);

— analysing the outcomes of running specialised computational simulations on the design;

— conducting occupant studies using virtual reality (VR);

— demonstrating ecological validity of relevant scientific studies in architectural psychology (e.g. the EVAC framework [11]).

As illustrated in Figure 10, each SDI in a BIM model requires its own justification for the claim that it creates a social value, based on the above listed means of verification. However, the justifications for multiple different SDIs may be based on the same evidence where appropriate, i.e. a comprehensive set of agent-based simulations may be used to justify a number of different SDIs pertaining to orientation, egress, and accessibility, or a single comprehensive post-occupancy study may be used assess the veracity of multiple diverse SDIs in a building. The weight of these means of verification, and their use at specific stages of the design process, vary depending on the context.

It is not always possible to employ all the above means of verification to a given social intention: standards, frameworks, simulators, and relevant scientific studies simply may not exist.

One special and important means of verification is to formally verify SDI structure and SDI semantics, described in detail in the subsequent subclauses. They are important because:

— they can always be employed on *every* SDI (unlike the other means of verification listed above);

— they shall *necessarily be satisfied* for the justification of any SDI.

That is, a failure in either the structural or semantic aspects of an SDI indicates a fundamental failure of the underlying logic of an SDI. As such, satisfying structural and semantic requirements shall be a minimum threshold for justifying an SDI. Table 2 and Table 3 list the structural and semantic rules that determine whether an SDI is structurally and semantically sound.

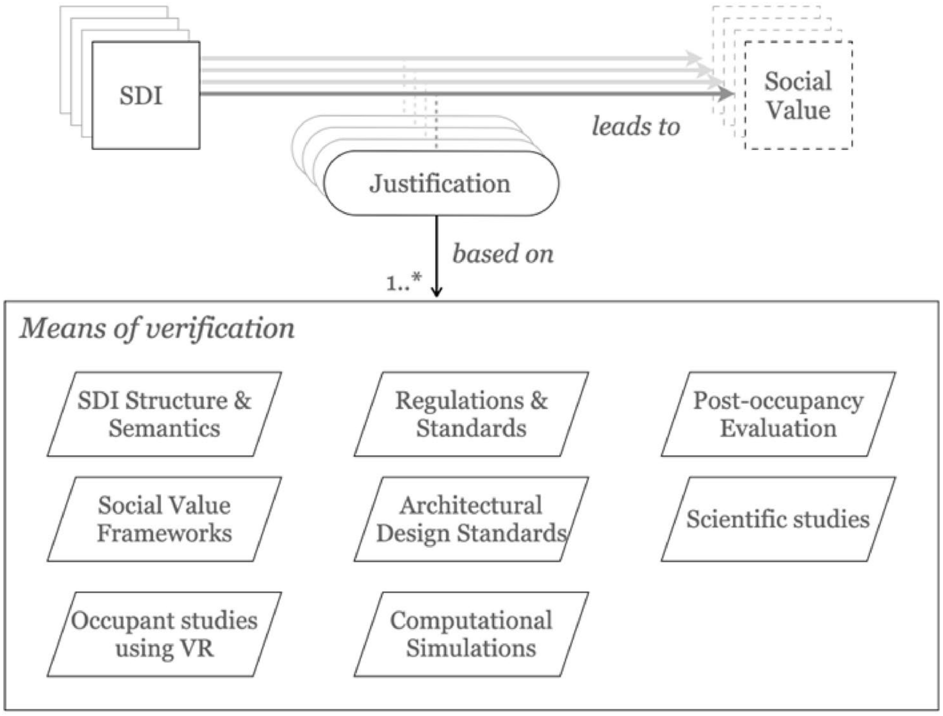


Figure 10 — Conceptual relationship between SDIs, the claim that an SDI leads to a social value in reality, and the means of verifying the claim

Table 2 — Structural rules that are necessary (but not sufficient) to justify SDIs.

Structural Rule	Description
No missing building elements	All building elements specified in the SDI also exist in the BIM model, uniquely referred to by a unique identifier.
No dangling objects	All objects specified in the SDI directly or indirectly cause a goal object.
Non-empty product level	At least one building element is specified in the product level.
Building elements are in product level	All building elements shall be assigned to the product level.
No causal cycles	Causal relationships between objects shall not create a causality cycle.
Unique references	Two objects specified in an SDI cannot have the same identifying reference label.
No missing references	Every reference label that is referred to by an object in an SDI shall be specified.
Correct building element arity	The number of arguments used to specify building elements shall be exactly two (specifying the object type and unique identifier).

Table 3 — Semantic rules that are necessary (but not sufficient) to justify SDIs.

Structural Rule	Description
Spatial relations hold	All defined spatial relations evaluate to *True* when assessed on the BIM model.
Non-void goal regions	The geometric representation of all derived goal objects of type Social Intent Space have positive area (for 2D regions) or volume (for 3D regions).
Social requirements are satisfied	For every social requirement (see Subclause 6.2), the specified requirement region is contained within at least one SDI goal-level object with the corresponding social intention type (e.g. sense of orientation).

8.2 Identifying conflicting SDIs

Different SDIs can overlap or conflict and contradict each other.

The intention of installing the blue acoustic panel in Figure 5 was to encourage discovery of the study area. A separate design intention could be described later that aims to isolate the study with minimal pass-through movement to create a calm study environment with minimal disruption.

Contradictions can also occur when statements are made at different scales.

EXAMPLE A design intention is made that “makes the floor quieter” together with a separate design intention that promotes social interaction at a particular location on the same floor: “this is the table at which people would meet and talk”. The question arises as to whether the table is inheriting the expected low noise levels of the floor, or whether it is an exception on that floor.

The framework in this CEN Workshop Agreement provides a way to identify when such conflicts occur, i.e. by testing whether two social intention spaces overlap each other on the floorplan, such that the intentions themselves are defined as contradictory by the design team. By explicitly modelling SDIs, design teams and other stakeholders can more effectively communicate their design decisions with their corresponding level of recommendation, prioritization, and significance based on context, building type, and occupant category. This helps to identify conflicts early in the design process and enables focused and meaningful negotiation to resolve such disputes.

Taking this further by establishing formal processes for resolving such conflicts is not within the scope of this specification.

9 Case studies

9.1 General

This clause presents a detailed case to illustrate how SDIs can be identified, modelled and digitalised in practice. Firstly, the case of applying the four activities in the SDI Elicitation and Modelling process to the Molecular Biology building at Aarhus University is presented. Secondly, a method is presented for injecting one of the SDIs into the BIM model of the Molecular Biology building using the Industry Foundation Classes (IFC) BIM standard.

9.2 Molecular biology building, Aarhus University

9.2.1 General

In 2024 a team of researchers at Aarhus University applied the ProFormalise social intention elicitation and modelling process to a number of existing buildings that had recently been renovated, including one building referred to here as the Molecular Biology building. This case is presented as a detailed example of how to apply the four process stages.

The Molecular Biology and Genetics department moved into a building complex consisting of four buildings in 2022 which was previously part of a hospital. The complex covers 23,724 m^2, and accommodates students, researchers, administrators and technical staff.

9.2.2 Elicitation stage

The elicitation activity was undertaken in the form of a semi-structured interview with two facilitators and one architect. An anecdotal method was employed so that the facilitators encouraged the participant to talk about the building through the interview. The interview was conducted in English.

The output of this stage was a voice-recording of the interview that was transcribed and analysed by the facilitators. Using a voice-recording was desirable as it enabled the facilitators and participant to focus on the dialogue without slowing down or pausing the interview to take written or typed notes.

The interview was planned beforehand by the process facilitators. They completed an interview guide and updated themselves on projects connected to the participant beforehand. During the interview, follow-up questions were used to ensure that the participant talked about the architectural choices intended to invoke the feeling or experience. This is typically a "how"- or "why"-question. Table 4 presents a generic interview guide as an example.

The facilitators paid particular attention to the order of the questions they asked to try to limit the re-invention of the stories delivered by the participant, and intentions in the building design choices.

Table 4 — Generic interview guide for elicitation stage activities

Question Type	Question examples
Main questions	— Which building and design projects have you been involved in? — Can you tell me a bit about the thought process behind the project?
Elaborating questions for each of the (potentially numerous) intentions in a building	— What was the intention here? — How was this intention integrated into the project? — Has the intention been successful? — Is the intention adding the expected value to the building? — Have you gotten any response from users?

Table 5 presents an extract from the transcription of the elicitation interview, aligned with the floor plan illustrated in Figure 11. This part of the interview describes the SDIs presented in Figure 5.

Table 5 — Excerpt from interview transcription in the Molecular Biology building.

Locations	Transcription
	[...] 01:15:54 Entering MolBio *[...]* 01:16:06 Facilitator It has really changed since it was a hospital. 01:16:08 Participant Yeah. Here was a glare problem. It was very white so you couldn't sit there. And also now it's a bit too much still but you can sit there now. *[...]*
(A)	01:17:59 Participant And this is the long corridor.
(B)	01:18:01 Participant With the focal point art at the end.
(B)	01:18:07 Participant From that you see this. So, this is sort of. Curiosity, what is behind this? Yeah. *[Referring to the blue acoustic panel]*
(B)	01:18:13 Participant And then they have this nice lit place with the same fixtures, yeah. *[...now the group is in a different part of the building]*
(C)+(D)	01:22:30 Participant Yeah. And it's actually pushed back. That one colour. Yeah, from the hole. And when you go out here. You can see. There's something interesting there, same colour and something leaving it. That way. What is it? curiosity (Colour wrapping around a corner)
(D)+(E)	01:22:47 Participant A bit of attention there, and then you get treated.

	There is actually additional place and additional daylight and again at the end of the corridor, something nice colours and something. Ohh, there's something behind that.
(D)	01:23:00 Facilitator Yeah, there's like colour block. Almost points like to the right. So, you want to see, OK, what? What's at the other end because one end has art maybe the other one has as well.
(D)+(B)	01:23:10 Participant Yeah. Yeah. So, the same design intent as the acoustic panels that sort of wrapped the corner.

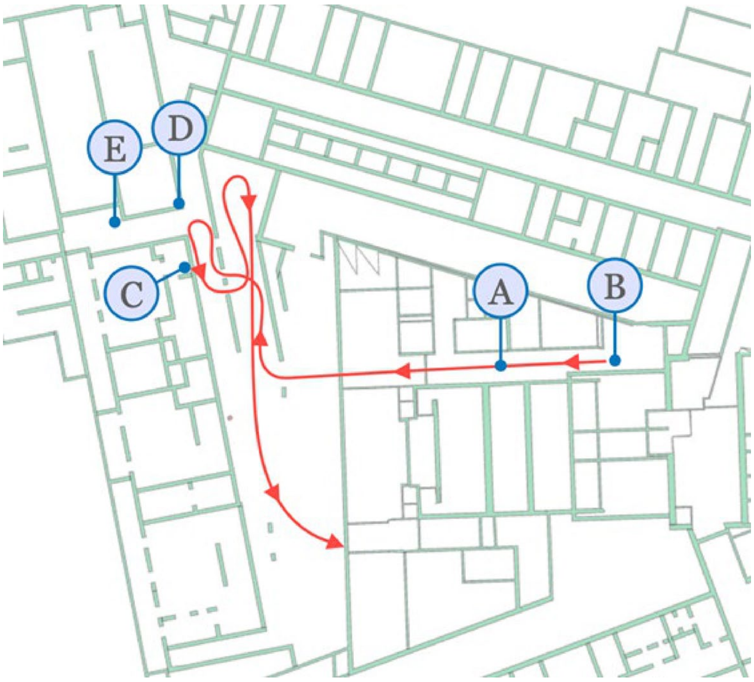


Figure 11 — Floor plan of the Molecular Biology building, with the interview path illustrated by the red line (see Locations in Table 5)

9.2.3 Organisation stage

The organisation stage was undertaken by the process facilitators. The interview data from the elicitation stage (e.g. in the form of transcripts) was analysed and sorted into an itemised list of SDIs with each SDI components marked up according to the Product-Goal Causality Model levels and classes.

The facilitators categorised the transcription into items containing two parts: socially oriented design intentions and design activities following the three sub-stages:

1) Identification of social intents: parts of the transcribed interview were marked-up when the participant stated a socially oriented design intention or an architectural or design-oriented decision.

2) Systematization and data entry: the intentions were added to a database of collected intentions for the building project (in the form of a spreadsheet).

3) Validation: the systematized intents were sent to the participant for review, assessment and approval of whether the systematized intents accurately reflect and encompass what the participants meant during the interview.

Table 6 presents a spreadsheet extract as an example of the output of the organizing activity.

Table 6 — Extract of the spreadsheet that resulted from the organisation activity in the Molecular Biology case

Building	Intention/Social Value	Activity	Interview	Timestamp	Quotes
AU MolBio	The building users will feel curiosity about what is around the corner	Coloured acoustic panel along a corner in a hallway. The panel is wrapping the corner and are sticking a bit out from the wall.	Participant - 011223 Audio file 2	01:18:07 - 01:18:13 01:22:47 - 01:23:20	"From that you see this. So this is sort of. Curiosity, what is behind this? " A bit of attention there, and then you get treated. [...] So the same design intent as the acoustic panels that sort of wrapped the corner.

9.2.4 Formalisation stage

In formalisation stage the logical structure and meaning (semantics) of each organised SDI was represented explicitly, in the context of the BIM model of the Molecular Biology building.

The formal representation of the SDI *structure* was in the form of a set of functions (for SDI objects) and predicates (for SDI relations) using first-order logic notation (i.e. predicate calculus):

— Each SDI object was represented as a *function*, e.g. V= VisibleSpace(O, AP).

— Each SDI relation was represented as a *predicate*, e.g. On(AP, W).

The function and predicate names were carefully chosen to reflect the intended meaning of objects and relations in each SDI, e.g. Artwork(..), Sofa(..), AcousticPanel(..), Above(..), WrapsAround(..), Large(..), Adjacent(..).

As an example, Table 7 presents the formalisation of the SDI on creating curiosity via the installation of an acoustic panel.

Table 7 — Formalisation of the SDI for creating curiosity via an acoustic panel

Product Level	Domain Level	Goal Level
AP = AcousticPanel(“0Mhmd”) W = Wall(“0RcWm”) On(AP, W) S = Slab(“eMI93”)	O = Occupant() V = VisibleSpace(AP,O) M = MovementSpace(M,O)	C = Curiosity(Intersection(M,V))

The formal semantic interpretation of SDI objects and relations was represented in the form of computational statements.

NOTE The statement is executed following imperative programming semantics, i.e. stateful variable-value map and assignment statements. The function returns the result of executing the statement.

The representations each took the form:

<Function/Predicate Name> (*<Arguments>*) == *<Statement>*

EXAMPLE 1 The following predicate implementation defines the *On* spatial relation used in the acoustic panel SDI. The predicate *On* holds (is True) for two BIM model objects A, B if the distance between the two 2D footprints is less than 0.1 metres.

On(A,B) ==

AGeom := Footprint(A) ;

BGeom := Footprint(B) ;

Distance(AGeom, BGeom) < 0.1

EXAMPLE 2 The following function implementation defines the *MovementSpace* used in the acoustic panel SDI, as shown in Figure 12. Given slab S and occupant O, the movement space geometry is constructed by firstly collecting all the BIM model walls and furniture on the same building floor (i.e. building storey) as the slab, which are the obstacles to movement. The 2D footprints of each of these obstacles are then derived and enlarged (buffered) by a small amount, namely 0.1 meters. The movement space geometry is then taken to be the difference between the footprint of the slab and the merged (unioned) footprints of the obstacles.

MovementSpace(S,O) ==

Floor := FloorOfIfcObject(S) ;

Walls := IfcObjectsOnFloor("IfcWall", Floor) ;

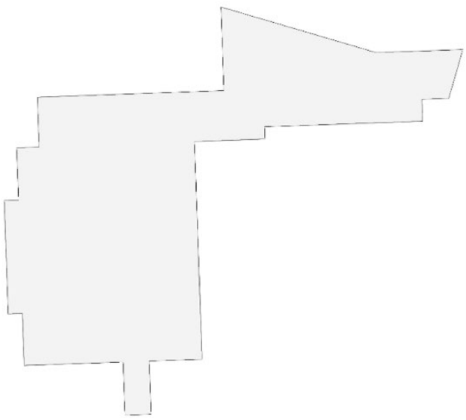
Frn := IfcObjectsOnFloor("IfcFurniture", Floor) ;

Obs := Walls + Frn ;

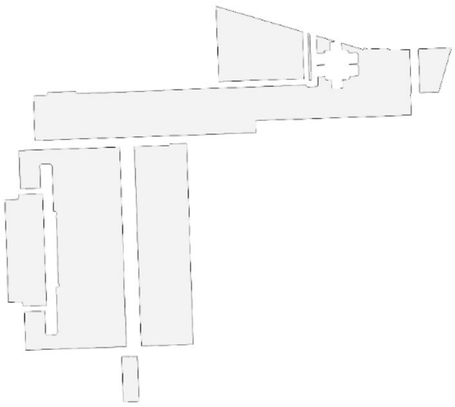
ObsGeoms := Map(Footprint, Obs) ;

ObsGeoms := Map(Buffer, ObsGeom, 0.1) ;

Diff(Footprint(S), Union(ObsGeom))



a) 2D footprint of the slab referred to in the SDI



b) The slab footprint subtracted by the merged footprints of the obstacles

Figure 12 — Defining the MovementSpace function as 2D footprint of the slab subtracted by footprints of obstacles

9.2.5 Implementation stage

The Implementation stage consisted of programming the formalised SDIs into instances of classes in the Python programming language.

9.3 Integrating SDIs into industry foundation classes (IFC) BIM models

This Subclause presents an approach for natively representing SDIs in BIM models that conform to the Industry Foundation Classes (IFC) Version 4.3 standard. The term "native" here means that the SDI can be exported into a BIM model following the IFC standard in a way that fully complies with the current official standard, i.e. no extensions or modifications to the IFC standard are required.

This was achieved as follows:

— Each SDI concept is represented as an instance of an IFC class. The IFC classes have been carefully selected so that the definition of the IFC class corresponds with the intended meaning of the represented SDI concept. Each SDI is modelled as an IfcGroup instance, G, and is associated to the project building in the IFC model via a relationship IfcRelReferencedInSpatialStructure.

— All spatial artefacts are modelled as instances of IfcSpatialZone, and are related to the project building via the relation IfcRelContainedInSpatialStructure. The Name attribute is a String of the SDI type and SDI identity reference, and the Description is the String 'Spatial Artifact'.

— The corresponding IFC object for each SDI object (including the spatial artifacts) is associated with group G via a relationship IfcRelAssignsToGroup.

— Each spatial artefact is assigned to the set of objects from which it is directly caused-by via the relationship IfcRelAssignsToProduct. The Name attribute of the relation instance is 'CauseEffect' to classify the usage of the relation.

The geometric representation of each spatial artefact object is modelled as an IFC representation:

— 2D points are modelled as IfcSphere with the height value (z coordinate) being taken as the value corresponding to 2,2 m above the top surface of the slab on which occupants move.

— 2D footprints are extruded to form 3D regions as an instance of IfcPolygonalFaceSet, with a height of 2,2 m.

EXAMPLE Figure 13 shows an export of the SDI for creating curiosity via the installation of an acoustic panel.

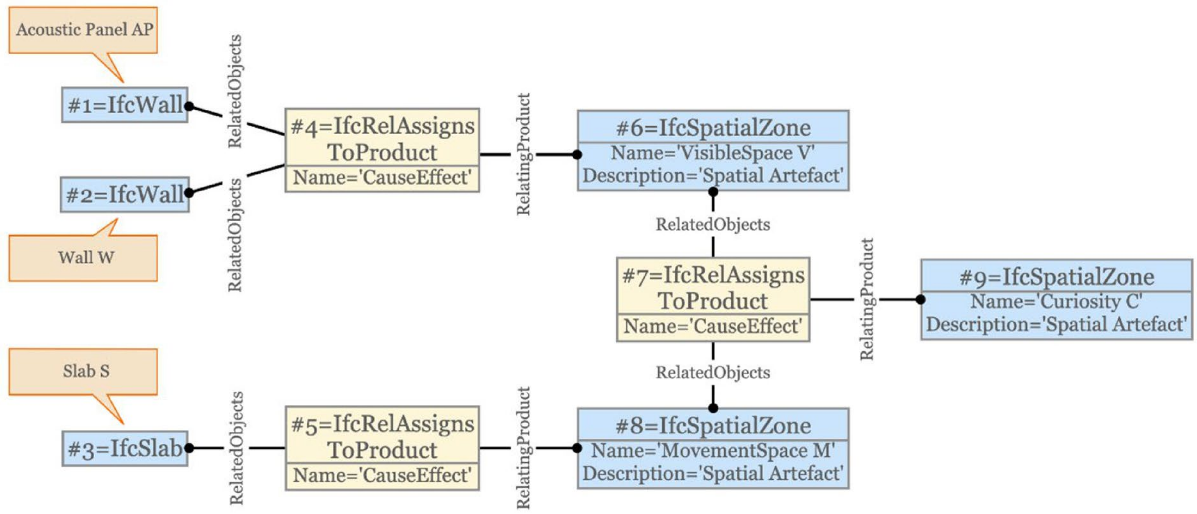
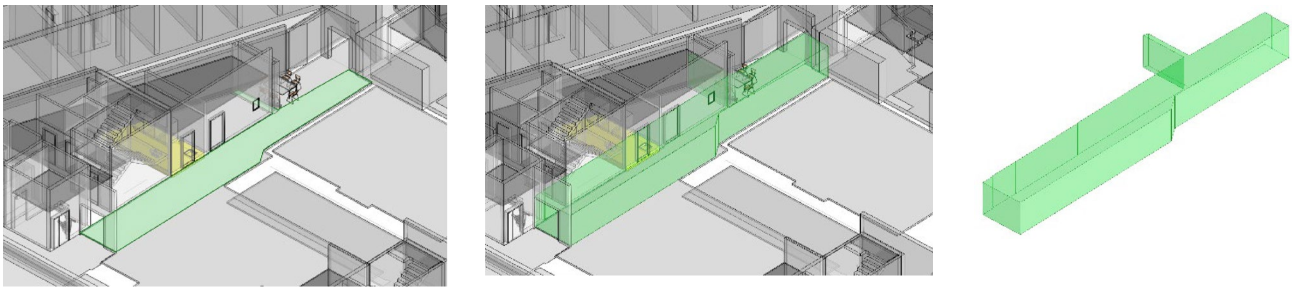


Figure 13 — Exporting the SDI for creating curiosity by installing an acoustic panel in IFC

Figure 14 shows how the 2D footprint of the visible space is represented as a 3D region in IFC.



a) 2D polygon footprint of the acoustic panel visible space

b) Representation as a IfcPolygonalFaceSet 3D mesh

c) Viewing the 3D mesh in isolation

Figure 14 — Representing the 2D footprint of the acoustic panel visible space as a 3D geometry in IFC

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