



UNIVERSIDAD JOSÉ ANTONIO PÁEZ

**DISEÑO DE INSTRUMENTO DE MEDICIÓN GENERAL DE LA
SUSTENTABILIDAD DE UNA VIVIENDA UNIFAMILIAR
BASADO EN LA NORMA ISO 20887:2020 PARA LA EMPRESA
INVERSIONES GRACA 1802 C.A.**

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**REPÚBLICA BOLIVARIANA DE VENEZUELA
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FACULTAD DE INGENIERÍA
ESCUELA DE INGENIERÍA CIVIL**

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INVERSIONES GRACA 1802 C.A.**

**Trabajo de grado presentado como requisito para optar al título de
INGENIERO CIVIL**

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San Diego, a los siete días del mes de Abril de 2021.



FI-L-001-2021-ICR (TG)

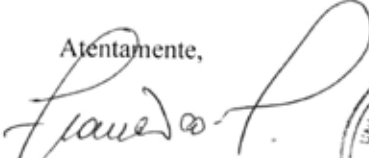
Valencia, 19 de julio de 2021

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Presente-

Cumplo con informarle que la Comisión de Trabajo de Grado y Pasantías de la Facultad de Ingeniería en su reunión N° 01-2021 de fecha 24-05-2021 aprobó el proyecto de trabajo de grado titulado **DISEÑO DE INSTRUMENTO DE MEDICIÓN GENERAL DE LA SUSTENTABILIDAD DE UNA VIVIENDA UNIFAMILIAR BASADO EN LA NORMA ISO 20887:2020 PARA LA EMPRESA INVERSIONES GRACA C.A.** Presentado por usted (es) como requisito para optar al título de Ingeniero Civil.

Se ratifica la designación del Ing. Zhandra López C.I: 18.106.232 Como Tutora Académica que la asesorara en el desarrollo de este proyecto.

Atentamente,


Dr. Francisco Gelanzé Sevilla
Decano



c.c. Coordinación de Pasantías y Trabajo de Grado (1).

GF/fm

AGRADECIMIENTOS

Más que agradecimientos, un reconocimiento a los que aún sin saberlo, son constantes imprescindibles; sin orden específico y nada determinístico, con un margen de error porque sería mezquino reducir tanto a un par de párrafos.

En un principio agradezco por la fe que vive en mi, como motor de inspiración y dedicación, propietaria de *la milla extra*.

A Carolina y Leonel, porque aunque el ensayo y error fue nuestro único método posible, los objetivos se lograron. Gracias por las herramientas, el amor y los principios, pero más aún por el criterio.

A mis abuelos, por ser inspiración de tantos, ser ejemplo y representación de trabajo en equipo.

A Pablo, por la incondicionalidad, apoyo y complicidad.

A Sophie, mi soulmate, compañera de vida y joven gurú.

A Alonso, por la década de hermandad elegida.

A la Nueva Orden Jedi, Eduardo, Ricardo, Jean, Luis y Jose.

A Valeria, por hacer el camino más que ameno y la decisión mutua de permanecer, las risas, el apoyo.

A mis profesores, quienes en sus capacidades hicieron su trabajo y de algún modo una lección quedó; Fidias, Ulises, Carpio, Manuel, por la dedicación y vocación; Luis Enrique, por los conocimientos, inspiración, el ejemplo y especialmente por la amistad; Zhandra, por el apoyo y guía en la última etapa.

Al extraño que más conozco, por el intercambio diario, los criterios conjuntos, el sentimiento recíproco y sin duda la compañía clave que aunque tardía en el proceso, fundamental.

A M. Pawtroski por la lealtad y compañía, el lenguaje universal del amor.

A la Universidad de Carabobo, por la formación.

A la Universidad José Antonio Páez, por la titulación.

Por resumir, y dejar carta abierta, a los que cada día están, conscientes o no. Por los intercambios voluntarios y las casualidades fortuitas. La gratitud es cosa de todos los días, sin caducidad, en renovación constante.

DEDICATORIA

A la niña que atravesó incontables veces el boulevard, subió y bajó muchas escaleras, se sentó por horas en una plaza donde caían mangos y aún así nunca aprendió a jugar truco.

We did it girl.



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ACEPTACIÓN DEL TUTOR

Quien suscribe, Ingeniero. Zhandra Lopez titular de la cédula de identidad N° 18.106.232, en mi carácter de tutor del trabajo de grado presentado por la ciudadana Sarah Robles, titular de la cédula de identidad N°27.014.265, titulado **“DISEÑO DE INSTRUMENTO DE MEDICIÓN GENERAL DE LA SUSTENTABILIDAD DE UNA VIVIENDA UNIFAMILIAR BASADO EN LA NORMA ISO 20887:2020 PARA LA EMPRESA INVERSIONES GRACA 1802 C.A.”**, presentado como requisito parcial para optar al título de Ingeniero Civil, , indico que acepto la tutoría del mencionado proyecto durante su etapa de desarrollo hasta su elaboración y evaluación según las condiciones que establezca la Coordinación de Pasantías y Trabajo de Grado de la Facultad de Ingeniería de la Universidad José Antonio Páez.

Ing. Zhandra Lopez
C.I.: 18.106.232

En San Diego, a los siete días del mes de Abril de 2021.

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Fecha: marzo 2021

RESUMEN

Los problemas ambientales son tan antiguos como la existencia del hombre, y actualmente la construcción de viviendas e infraestructuras representa uno de los mayores impactos que los seres humanos hacen en el medio ambiente, englobando una serie de causantes de dicho efecto desde sus inicios hasta su momento operacional. Si bien se han encaminado acciones para frenar el creciente impacto ambiental de la actividad urbana, la incorporación del principio de sustentabilidad (el cuál se basa en conservar los recursos naturales y desarrollar fuentes alternas de energía, mientras se reduce la contaminación y los daños al medio ambiente) en el diseño de la política de vivienda y como elemento determinante de la calidad de la misma, es muy reciente; y su práctica aún no se aprecia en el macro de las construcciones del desarrollo urbano. En este orden de ideas, en el presente proyecto se propone un Instrumento de medición general de la sustentabilidad de una vivienda unifamiliar basado en la norma ISO 20887:2020 para la empresa Inversiones Graca 1802 C.A. El tipo de investigación se encuentra bajo los parámetros de un proyecto factible y se estructura en cuatro fases alineadas con los objetivos específicos planteados, donde en la fase I se determinará, según la norma ISO 20887:2020, los principios de sustentabilidad en la construcción. En la fase II se agruparán por categorías los ítems a considerar según los principios obtenidos de la norma. En la fase III se asignará una ponderación a cada ítem. Por último, en la fase IV se implementará el instrumento mediante la evaluación de una vivienda unifamiliar.

Descriptor: Instrumento de Medición, Sustentabilidad, Norma ISO 20887.

INTRODUCCIÓN

El desarrollo en la construcción de viviendas e infraestructuras a lo largo del tiempo ha ido representando uno de los mayores impactos que los seres humanos tienen en el medio ambiente, englobando una serie de causantes de dicho efecto desde sus inicios hasta su momento operacional.

A pesar de haberse aplicado acciones para frenar el creciente impacto ambiental negativo de la actividad urbana, la incorporación del principio de sustentabilidad (cuyo propósito radica en conservar los recursos naturales y desarrollar fuentes alternas de energía, mientras se reduce la contaminación y los daños al medio ambiente) en el diseño de la política de vivienda y como elemento determinante de la calidad de la misma, es muy reciente; y su práctica aún no se aprecia como el denominador común de las construcciones del desarrollo urbano. A su vez, la consciencia colectiva sobre el tema aún debe ser reforzada, como la educación respecto al mismo.

Una vivienda con principios de sustentabilidad es aquella que sigue un nuevo paradigma de construcción y de vida, una conciencia de responsabilidad ambiental, en donde lejos de impactar negativamente al entorno, lo favorece al crear un desarrollo sostenible que sea generador y regulador de los recursos naturales, aprovechando al máximo los recursos tanto en su construcción como en su etapa operativa.

Por otra parte, y en relación a los principios bajo los cuales se basan las características sustentables de una infraestructura, la Norma ISO 20887 es una norma de sostenibilidad en edificios y obras de ingeniería civil. La misma significa un beneficio para los usuarios de dos formas: extendiendo la vida de la construcción a través de una adaptabilidad efectiva que lo hace adecuado para otro uso; y mediante la optimización de sus recursos al final de su vida útil mediante el desmontaje, la reutilización, el reciclaje y la eliminación efectiva de sus diversos materiales.

La empresa Inversiones Graca 1802 C.A., tiene el compromiso y responsabilidad social de incurrir en la conciencia ambiental y disminuir el impacto que sus actividades en el ámbito constructivo significan para el entorno. En tal sentido, se propone un instrumento de medición

general de la sustentabilidad de una vivienda unifamiliar basado en la norma ISO 20887-2020.

En relación a lo expuesto, el presente trabajo investigativo se abordará bajo la siguiente estructura: el capítulo I corresponderá al planteamiento del problema y los objetivos bajo los cuales se basa la investigación: en el capítulo II se expondrán los antecedentes y las bases teóricas que sustentan el presente trabajo, en el capítulo III se establecerá el marco metodológico correspondiente al tipo de diseño y nivel de investigación, así como la población y muestra junto a las técnicas e instrumento de recolección y análisis de datos, finalizando con las fases de la investigación; por último, el capítulo IV se determinan los recursos (humanos, institucionales, materiales y de tiempo) para llevar a cabo el proyecto investigativo.

CAPÍTULO I

EL PROBLEMA

1. Planteamiento del problema

Los problemas ambientales son tan antiguos como la existencia del hombre, quien con su interacción genera en muchas ocasiones un impacto negativo en el medio ambiente, hoy en día a mayor escala (o proporción) debido a una intrincada red de causales, de forma más menos general el estilo de vida que se ha ido adoptando suele acarrear ciertas características no tan favorables para el ambiente, como alteración de ecosistemas, el constante aumento de residuos, entre otros.

A su vez, se hacen presentes también ciertos factores influyentes en el impacto ambiental como lo son el elevado crecimiento demográfico, el aumento y desarrollo tecnológico, la creciente urbanización, entre otros. Los cuales, en conjunto a lo mencionado anteriormente en relación al estilo de vida, se hacen evidentes en un punto en común, como lo es la vivienda.

Se podría decir que la construcción de viviendas e infraestructuras es uno de los mayores impactos que los seres humanos hacen en el medio ambiente, englobando una serie de causantes de dicho efecto desde sus inicios hasta su momento operacional.

Si bien se han encaminado acciones para frenar el creciente impacto ambiental de la actividad urbana, la incorporación del principio de sustentabilidad (el cuál se basa en conservar los recursos naturales y desarrollar fuentes alternas de energía, mientras se reduce la contaminación y los daños al medio ambiente) en el diseño de la política de vivienda y como elemento determinante de la calidad de la misma, es muy reciente; y su práctica aún no se aprecia en el macro de las construcciones del desarrollo urbano. Asimismo, la consciencia colectiva sobre el tema aún debe ser reforzada, como la educación

respecto al tema.

Debido a la falta de conocimientos y material estructurado, se hace cuesta arriba diseñar o planificar la construcción o funcionamiento de una vivienda sustentable. Por otra parte, suele existir un concepto errado que relaciona sustentabilidad con incremento económico, dejando así por un lado aspectos menores, como diseños integrales, aprovechamiento de servicios, entre otros; que al ser considerados de manera global aportan un carácter sostenible a la obra en cuestión.

2. Formulación del problema

¿Cómo se puede evaluar la sustentabilidad de las viviendas unifamiliares construidas por la empresa Inversiones Graca 1802 C.A. según los criterios de la norma ISO 20887:2020?

3. Objetivos de la Investigación

3.1. Objetivo General

Desarrollar un instrumento de medición general de la sustentabilidad de una vivienda unifamiliar basado en la norma ISO 20887:2020 para la empresa Inversiones Graca 1802 C.A.

3.2. Objetivos Específicos

- Identificar los factores que aportan condición sustentable a una vivienda unifamiliar.
- Organizar por categorías y procesos los factores de estudio
- Ponderar según carácter de sustentabilidad los factores de estudio.
- Analizar eficacia del instrumento mediante el estudio de una vivienda unifamiliar.

4. Justificación de la investigación

La toma de consciencia sobre la importancia del compromiso y responsabilidad con el medio ambiente se hace cada vez más evidente, siendo considerada en ámbitos como la construcción. Una visión necesaria, considerando que esta industria tiene altos índices de consumo de energía y de

producción de gases invernadero. Dado esto, iniciativas que tengan como objetivo fomentar el desarrollo urbano sustentable, el consumo prudente de energía, entre otros, son solo algunos ejemplos para entender la importancia de una construcción sustentable.

Se entiende como construcción sustentable aquella cuyo principal objetivo es reducir el impacto ambiental generado por su actividad. Por eso, resulta imprescindible considerar con extremo detalle tanto el tipo de materiales que se utiliza, como la forma de ejecución. En este escenario, la construcción sustentable, por ejemplo, es una solución que consume menos agua y genera menos CO₂.

Por todo lo expuesto, se ha desarrollado una propuesta en pro de la construcción sustentable, la cual ayuda a analizar los factores requeridos para minimizar el impacto ambiental tanto del proceso constructivo como de la fase operacional de la vivienda. Manteniendo los estándares de seguridad, eficiencia y comodidad, fundamentando sus bases en la norma vigente ISO 20887:2020.

5. Alcance

El presente trabajo de investigación comprende dentro de su marco de estudio el análisis generalizado de sustentabilidad de viviendas unifamiliares, y tiene un carácter descriptivo correlacional.

Cabe destacar que se trata sobre el desarrollo de un instrumento de medición general, siendo así un baremo de sustentabilidad según el criterio de la norma ISO 20887:2020 y no un manual de construcción sustentable.

CAPÍTULO II

MARCO TEÓRICO

El presente proyecto se llevó a cabo mediante la revisión de trabajos anteriores similares con objetivos alineados con los que acá se exponen, los mismos representan los antecedentes que servirán como punto de referencia para aclarar algunos conceptos y dar relevancia a los aspectos a tratar. A continuación, se presentan los antecedentes consultados.

1. Antecedentes

Arango E., (2017) realizó un trabajo de grado titulado “**Diseño De Vivienda de Interés Social Sustentable**”. En la Universidad Libre Seccional Pereira. Esta investigación plantea realizar un diseño sismo-resistente de viviendas de interés social basándose en los principios de ingeniería estructural sostenible. Asimismo, procura el estudio de la dinámica estructural, estabilidad e ingeniería de los materiales con el fin de justificar la selección de los mismos, quienes a su vez poseen carácter sustentable.

Este trabajo de grado tiene cierta similitud con el proyecto elaborado en lo referente a fundamentos teóricos utilizados, ya que los mismos sirven de base para la investigación en cuestión, así como los principios de construcción sustentable. Además, trata la estructura de una vivienda unifamiliar de carácter sustentable.

Posteriormente a la evaluación que realizan dentro del trabajo investigativo sobre materiales alternativos que le aporten el carácter sustentable a las construcciones en cuestión, llegan a una principal conclusión sobre el manejo eficiente del diseño estructural, constructivo y bioclimático de la vivienda de interés social sustentable y como generan reducción en costos de servicios como energía, agua y gas, siendo un impacto positivo para la calidad de vida, y una aminoración del impacto negativo de la actividad humana con el medio ambiente.

Por otra parte, Mirenzi, F., y Simionato, J., (20157) realizaron un trabajo

investigativo el cual titularon **“Desarrollo De Vivienda Eco-Sustentable: Análisis Económico-Financiero, Social y Ecológico Versus Vivienda Regular”**. En la Pontificia Universidad Católica Argentina, para optar al título de ingeniero industrial. La presente investigación tiene como objetivo identificar los factores en los cuales coinciden y difieren una vivienda regular de una eco-sustentable, con el interés de realizar un análisis tanto desde el aspecto económico como social.

Este trabajo de investigación se relaciona con el proyecto abordado ya que se orienta en la relación que existe entre una vivienda eco-sustentable y una regular, lo cual a su vez establece ítems comparativos entre ambas modalidades. Además de contar con cierta similitud en las bases teóricas donde exponen el significado y lo que le otorga a una vivienda el carácter sustentable.

Una vez establecidas las comparaciones de las viviendas eco-sostenibles y una vivienda regular, en este trabajo investigativo se plantearon ciertos objetivos con el fin de fomentar el cambio y demostrar que se puede lograr la sustentabilidad en el modelo de construcción. Algunos de los objetivos fueron: el incremento de la eficiencia de las instalaciones y el diseño, la reducción de emisiones en CO₂ en ton/año, la reducción de consumo de recursos energéticos, en forma de gas, electricidad y otros combustibles, reducción de demanda y consumo de agua en m³ x persona/año, el aprovechamiento del nivel de iluminación natural, y promover la concientización en el comportamiento de los ocupantes y eficacia de políticas de reciclaje y reutilización. Si bien el caso fue evaluado y aprobado para una vivienda urbana, pudo ser replicado en otras locaciones, estando así en vías de construcciones más sustentable y en sintonía con una de las tendencias y preocupaciones más importantes del mundo de hoy en día, lo cual es la preservación del entorno ambiental.

Por último, Susunaga, Jorge., (2014) en la Universidad Católica de Colombia realizó un trabajo de grado para optar al título de Especiales en Gerencia de Obras el cual tituló **“Construcción Sostenible, una Alternativa para la Edificación de Viviendas de Interés Social y Prioritario”**. En el mismo trata asuntos referentes a los principales sistemas de construcción de viviendas de interés sociales prioritario

sostenibles, los cuales llevan relación con este proyecto en cuanto a los atributos que otorgan la característica sustentable.

Luego de que se establecieron diferencias estructurales entre la construcción sostenible frente a la construcción tradicional, basándose en los siguientes en dos aspectos: Uno, en que las soluciones son integrales y buscan atender las necesidades de energía, de agua, adecuado manejo de materiales, calidad del ambiente interior, bienestar de las personas, entre otros. Dos, ya no se mira solamente el proceso de construcción de un edificio, y se olvida lo que sucede después, sino que ahora es un círculo en donde hay que pensar desde que se planea el edificio, se diseña, se construye, se opera, se demuele, o qué pasa si cambia de uso. El trabajo investigativo concluye que hoy en día, los edificios sostenibles pueden ser desarrollados a un precio similar a los edificios convencionales y las inversiones pueden ser recuperadas a través de ahorros en los costos operacionales y, con las características de diseño adecuadas, se obtienen lugares con muy buenas características para ser habitados. Asimismo, que los residuos de construcción y demolición como nuevos materiales para la construcción, son un aporte en el campo ambiental, pues al reciclarlos se evita tanto degradar el suelo natural con la extracción de materias primas vírgenes, como con la disposición final de escombros.

2. Bases Teóricas

Según Bavaresco (2006) las bases teóricas tienen que ver con las teorías que brindan al investigador el apoyo inicial dentro del conocimiento del objeto de estudio, es decir, cada problema posee algún referente teórico, lo que indica, que el investigador no puede hacer abstracción por el desconocimiento, salvo que sus estudios se soporten.

Se hace necesario definir y establecer una serie de fundamentos teóricos que sustenten y expliquen los términos relacionados a la construcción sustentable, como son: vivienda sustentable, vivienda unifamiliar, norma ISO 20887, para así poder interpretar con basamento y criterio teórico los resultados obtenidos en la investigación.

2.1. Vivienda Sustentable

Se puede definir como aquella que sigue un nuevo paradigma de construcción y de vida, una conciencia de responsabilidad ambiental, en donde lejos de impactar negativamente al entorno, lo favorece al crear un desarrollo sostenible que sea generador y regulador de los recursos naturales, aprovechando al máximo los recursos tanto en su construcción como en su etapa operativa.

Algunas características que más resaltan en este tipo de vivienda pueden ser:

- **Menor Costo:** La inversión final es más económica que la de una casa convencional. Asimismo, suele existir un ahorro económico durante toda la etapa operacional, recuperándose así la inversión en un plazo menor al regular. Los gastos de mantenimiento también suelen ser menores pues los recursos como el agua y la luz se trabajan de manera renovable.
- **Materiales Renovables:** Los materiales de construcción deben provenir, en su mayoría, del medio ambiente y estar libres de agentes tóxicos. La madera, el bambú, la piedra, el corcho y la tierra son algunos de los elementos más utilizados por ser abundantes y con un bajo costo.
- **Arquitectura Bioclimática:** Esta forma de arquitectura pretende minimizar el consumo de energía y de recursos naturales necesarios para que la casa cumpla con unos requisitos de habitabilidad básicos. Así, se busca reducir al mínimo el consumo de energía externa, las emisiones de CO₂ y gases de efecto invernadero derivadas del uso de la vivienda, y minimizar el impacto ambiental en general. Para ello, el diseño y construcción de la casa debe tener en cuenta los recursos naturales disponibles en el emplazamiento e intentar optimizar su aprovechamiento. Algunas de las medidas más básicas para conseguir todo esto pasan por prestar atención a la localización y orientación geográfica de la vivienda para un aprovechamiento óptimo de la energía lumínica y calorífica del sol, para facilitar el uso de corrientes de aire cruzadas de cara a ventilar y refrigerar la casa, etc. También es

importante trabajar para conseguir un buen aislamiento en la vivienda, de cara a minimizar los intercambios de energía con el exterior y a permitir una correcta aclimatación térmica de la vivienda que suponga el mínimo gasto energético posible.

2.2. Vivienda Unifamiliar

Son aquellos inmuebles en los que habita una sola familia, tal y como su propio nombre indica. En este sentido deben ser diferenciadas de viviendas colectivas o multifamiliares, concebidas como un conjunto residencial o de finca urbana.

2.3. Norma ISO 20887

ISO 20887, es la norma de sostenibilidad en edificios y obras de ingeniería civil. Diseño para desmontaje y adaptabilidad. Principios, requisitos y orientación, ayuda a los propietarios, arquitectos, ingenieros y cualquier otra parte involucrada en el ciclo de vida de una obra civil a mejorar su sostenibilidad, ahorrando tiempo y recursos durante el proceso.

Esta norma significa un beneficio para los usuarios de dos formas: extendiendo la vida de la construcción a través de una adaptabilidad efectiva que lo hace adecuado para otro uso; y mediante la optimización de sus recursos al final de su vida útil mediante el desmontaje, la reutilización, el reciclaje y la eliminación efectivos de sus diversos materiales.

El resultado es una reducción de las emisiones de carbono a través del uso óptimo de la construcción, menores costos a través de una vida útil más larga y un mejor uso de los recursos, así como menos desechos que ingresan al vertedero.

Ayudará a obtener el valor potencial completo de la obra a lo largo de su ciclo de vida, desde reparaciones y renovaciones hasta la reutilización, el reciclaje y la eliminación adecuada de sus componentes cuando ya no se pueda usar. Además, este enfoque apoya la economía circular, contribuyendo así a un mundo más sostenible.

2.4. Construcción Sostenible

El concepto de construcción sustentable refiere a diferentes estrategias posibles de ser desarrolladas durante la construcción de inmuebles destinadas fundamentalmente a

minimizar los impactos ambientales (negativos) de las obras en y para todas las fases del ciclo de vida de los mismos.

Lo novedoso, entre otras cosas, es que incluye a las etapas de planificación, diseño, construcción, mantenimiento, renovación, utilización y eliminación o reconstrucción. Cabe destacar que no se trata simplemente de un nuevo “estilo arquitectónico”, sino de aplicar una serie de “nuevos criterios constructivos” como el de la correcta orientación de los ambientes, la elección y procedencia de los materiales, el tamaño de las aberturas y su protección a la radiación solar, etc.

Dichos criterios, se relacionan fundamentalmente con el consumo de energía, el uso de fuentes de energía renovables y de materiales y productos de construcción más amigables con el ambiente. En igual sentido, además, se vinculan con aspectos como el de la gestión de residuos, del agua y de otros factores directamente involucrados con los impactos ambientales que generan muchas de las actividades desarrolladas en/por la Industria de la Construcción.

2.5. Bioconstrucción

La bioconstrucción debe entenderse como la forma de construir respetuosa con todos los seres vivos. Es decir, la forma de construir que favorece los procesos evolutivos de todo ser vivo, así como la biodiversidad. Garantizando el equilibrio y la sustentabilidad de las generaciones futuras.

Para ello se deben de tener en consideración:

- Gestión del suelo
- Gestión del agua
- Gestión del aire
- Gestión de la energía
- Consumo y desarrollo local

2.6. Principios de Bioconstrucción

Los principios de la bioconstrucción consideran que debemos ser conscientes (y es nuestra responsabilidad para con las futuras generaciones) de que todo lo que un ser

vivo realiza repercute en los demás, de tal manera que una acción nunca permanece aislada, sino que provoca reacciones, tangibles o no, a mayor o menor plazo de tiempo, en todo lo que la rodea, extendiéndose su efecto del mismo modo que las ondas que provoca una piedra al caer en el agua. Así todas nuestras acciones son importantes, inciden en el resto de los seres y del planeta y repercuten mucho más allá de ellas mismas. Esta conciencia de que el planeta es nuestra casa y es nuestra responsabilidad cuidarlo, preservarlo y mantenerlo a él y a los seres que lo habitan en óptimas condiciones para producir salud y felicidad, debe irse trasluciendo en toda actividad humana.

3. Definición de Términos

Emisión de CO2

La emisión de CO₂, o dióxido de carbono, se trata de la propagación de un gas incoloro, denso y poco reactivo, que forma parte de la capa de la atmósfera más cercana a la tierra. Tiene un gran impacto en el llamado efecto invernadero y su concentración ha aumentado en los últimos 160 años.

Medio Ambiente

Se trata del conjunto de elementos abióticos (energía solar, suelo, agua y aire) y bióticos (organismos vivos) que integran la delgada capa de la Tierra llamada biosfera, sustento y hogar de los seres vivos.

Normas ISO

Son documentos que especifican requerimientos que pueden ser empleados en organizaciones para garantizar que los productos y/o servicios ofrecidos por dichas organizaciones cumplen con su objetivo. ISO se refiere a las siglas de *International Organization for Standardization*. El objetivo perseguido por dichas normas es asegurar que los productos y/o servicios alcancen la calidad deseada.

Responsabilidad Ambiental

Este término se refiere al grado de compromiso que las personas, tienen hacia el entorno que les rodea, aunque también incluye a organizaciones, empresas y otros agentes.

Desarrollo Sostenible

De acuerdo a su definición, el desarrollo sostenible busca satisfacer las necesidades de las generaciones presentes sin comprometer las posibilidades de las generaciones del futuro, contando con tres factores claves: sociedad, economía y medio ambiente. Asimismo, es un método pensado a largo plazo y con beneficios progresivos, que se deberán llevar a cabo de manera permanente.

Desarrollo Sustentable

El desarrollo sustentable está enfocado únicamente en los recursos naturales y el medio ambiente, tratando de preservarlos, conservarlos y protegerlos, pensando en el futuro inmediato del entorno natural, con la finalidad de no afectar a las generaciones venideras, pero continuar beneficiando a la sociedad actual.

Infraestructura

Se denomina infraestructura a aquella realización humana diseñada y dirigida por profesionales de Ingeniería Civil, Arquitectura, Urbanistas, etc., que sirven de soporte para el desarrollo de otras actividades y su funcionamiento, necesario en la organización estructural de las ciudades y empresas.

Vivienda Multifamiliar

Una vivienda multifamiliar es aquella en la que una construcción vertical u horizontal está dividida en varias unidades de viviendas integradas que comparten el terreno como bien común.

CAPÍTULO III

MARCO METODOLÓGICO

Balestrini M., (2006) define el marco metodológico como “La instancia referida a los métodos, las diversas reglas, registros, técnicas y protocolos con los cuales una teoría y su método calculan las magnitudes de lo real” (Pág. 125).

1. Tipo De Investigación

Para conocer los parámetros de un proyecto factible se puede citar al Manual de Trabajos de Grado de Especialización, Maestrías y Tesis Doctorales de la UPEL (2005), donde se expone que un Proyecto Factible:

Consiste en la investigación, elaboración y desarrollo de una propuesta de un modelo operativo viable para solucionar problemas, requerimientos o necesidades de organizaciones o grupos sociales; puede referirse a la formulación de políticas, programas, tecnologías, métodos o procesos. El proyecto debe tener apoyo en una investigación de tipo documental, de campo o un diseño que incluya ambas modalidades (Pág. 16).

Es por ello que todo proyecto factible, tiene como principal característica el desarrollo de las siguientes etapas: investigación y diagnóstico inicial, planteamiento y fundamentación teórica de la propuesta, diseño general y detallado de la propuesta, elaboración de estudios de factibilidad y, por último, conclusiones sobre la viabilidad de la ejecución del proyecto en cuestión.

El presente trabajo tiene como objetivo desarrollar un instrumento de medición general de la sustentabilidad de una vivienda unifamiliar, de tal manera que se encuentra bajo los parámetros de un Proyecto Factible, con sus bases en la norma ISO 20887:2020

2. Diseño de Investigación

Según Arias F. (2006) “La investigación documental es un proceso basado en la búsqueda, recuperación, análisis, crítica e interpretación de datos secundarios, es decir, los obtenidos y registrados por otros investigadores en fuentes documentales:

impresas, audiovisuales o electrónicas. Como en toda investigación, el propósito de este diseño es el aporte de nuevos conocimientos” (Pág. 27).

Según Arias F. (2006) “La investigación de campo es aquella que consiste en la recolección de datos directamente de los sujetos investigados, o de la realidad donde ocurren los hechos (datos primarios), sin manipular o controlar variable alguna, es decir, el investigador obtiene la información, pero no altera las condiciones existentes. De allí su carácter de investigación no experimental” (Pág. 31)

El diseño de la presente investigación, el autor no controlará las variables, lo que significa que las mismas se obtendrán sin intervención del autor. Por lo tanto, este proyecto se clasifica como documental, cuyo objetivo es diseñar un instrumento de medición para evaluar la sustentabilidad de una vivienda de carácter unifamiliar.

3. Nivel de Investigación

Según Arias F. (2006) “La investigación descriptiva consiste en la caracterización de un hecho, fenómeno, individuo o grupo, con el fin de establecer su estructura o comportamiento. Los resultados de este tipo de investigación se ubican en un nivel intermedio en cuanto a la profundidad de los conocimientos se refiere” (Pág. 24).

En referencia a la cita mencionada, el trabajo que se presenta tendrá un enfoque descriptivo, ya que a lo largo de la investigación se elaborará, analizará, describirá e interpretará la información dada de la empresa con el fin de recolectar los datos necesarios para realización de la investigación descriptiva.

4. Población y Muestra

4.1. Población

Según Arias F. (2006) “La población, o en términos más precisos población objetivo, es un conjunto finito o infinito de elementos con características comunes para los cuales serán extensivas las conclusiones de la investigación. Ésta queda delimitada por el problema y por los objetivos del estudio” (Pág. 81). La población definida serán viviendas unifamiliares seleccionadas por la empresa Inversiones Graca 1802 C.A.

4.2. Muestra

Según Arias F. (2006) “La muestra es un subconjunto representativo y finito que se extrae de la población accesible” (Pág. 83).

La muestra de este proyecto se basa en el prototipo de vivienda unifamiliar estipulado por la empresa.

5. Técnicas e Instrumentos de Recolección de Datos

5.1. Técnicas de Recolección de Datos

Según Arias F. (2006), menciona: “Un instrumento de recolección de datos es cualquier recurso, dispositivo o formato (en papel o digital), que se utiliza para obtener, registrar o almacenar información.” (Pág. 68).

Por otra parte, Arias F. (2006) también menciona: “La revisión documental es un proceso basado en la búsqueda, recuperación, análisis, crítica e interpretación de datos secundarios; es decir, los obtenidos y registrados por otros investigadores en fuentes documentales: impresas, audiovisuales o electrónicas.”

La técnica de recolección de datos a emplear será el análisis de contenido, refiriéndose a la norma ISO 20887:2020, mediante una revisión documental.

5.2. Instrumentos de Recolección de Datos

En cuanto a los instrumentos, Arias (2006), establece que “los instrumentos de recolección de datos pueden definirse como “cualquier recurso, dispositivo o formato (en papel o digital), que se utiliza para obtener, registrar o almacenar información”.

Los instrumentos de recolección de datos que serán utilizados serán cuadro de registro y clasificación de las categorías.

6. Técnicas de Análisis de Datos

Según Arias (2006), “en este punto se describen las distintas operaciones a las que serán sometidos los datos que se obtengan”.

El análisis de los datos comenzará por la organización y categorización de los datos recolectados del material teórico que fundamenta el proyecto, mediante un cuadro de registro.

7. Fases de la Investigación

Fase I: Determinación, según la norma ISO 20887:2020, de los principios de sustentabilidad en la construcción.

En esta primera fase se llevará a cabo un análisis de la norma, con el fin último de determinar los principios de sustentabilidad en la construcción que se considerarán para la elaboración del instrumento, según los criterios requeridos a su vez por la empresa Inversiones Graca 1802 C.A.

Fase II: Agrupación por categorías los ítems a considerar según los principios obtenidos de la norma ISO 20887:2020.

En esta fase se formularán los ítems a evaluar con el instrumento, basados en los principios seleccionados, y categorizados por grupos respectivamente.

Fase III: Asignación de ponderación a cada ítem.

Esta fase número tres de la investigación consiste en atribuirle una ponderación a los ítems anteriormente categorizados. Para ello se tomaron en cuenta los criterios a considerar por parte de la empresa Inversiones Graca 1802 C.A, con el fin de satisfacer sus necesidades respecto al instrumento.

Fase IV: Implementación del instrumento mediante la evaluación de una vivienda unifamiliar.

Como última fase, se evaluará una vivienda unifamiliar seleccionada por la empresa Inversiones Graca 1802 C.A, con el propósito de hacer uso del instrumento elaborado analizando el carácter de sustentabilidad que la misma posee.

CAPÍTULO IV

RESULTADOS

El presente capítulo expone los resultados obtenidos en cada una de las actividades propuestas en las fases metodológicas de la investigación, las cuales fueron definidas en el anterior capítulo.

4.1 Fase I: Determinación, según la norma ISO 20887:2020, de los principios de sustentabilidad en la construcción.

Se seleccionaron los principios de sustentabilidad aplicables a los criterios considerados por la empresa Inversiones Graca 1802, C.A. Los mismos son aplicables a viviendas unifamiliares construidas principalmente con bloques.

A continuación se presentan los principios de sustentabilidad:

Tabla 1. Principios de Sustentabilidad

Principio
El tiempo útil de la vida de servicio de la infraestructura está entre 35-50 años. (Ref. Norma ISO 20887:2020 Anexo C C.13)
El mayor porcentaje de los espacios son aptos para su uso constante sin cambios estructurales. (Ref. Norma ISO 20887:2020 Anexo C C.2)
El mayor porcentaje de los espacios diseñados para usos múltiples cumplen su función sin cambios estructurales. (Ref. Norma ISO 20887:2020 Anexo C C.3)
La estructura puede expandirse proporcionalmente al terreno verticalmente sin alterar las fundaciones y sistema estructural. (Ref. Norma ISO 20887:2020 Anexo C C.4)
La estructura puede expandirse proporcionalmente al terreno horizontalmente dentro de los límites de diseño y regulación municipal (porcentaje de construcción permitida). (Ref. Norma ISO 20887:2020 Anexo C C.4)
No existe accesibilidad a componentes y servicios sin daños significantes al material circundante. (Ref. Norma ISO 20887:2020 Anexo C C.5)

Principio
Acceso limitado a componentes y servicios con daños significativo al más del 50% del material circundante. (Ref. Norma ISO 20887:2020 Anexo C C.5)
Acceso limitado a componentes y servicios con daños menores al más del 50% del material circundante. (Ref. Norma ISO 20887:2020 Anexo C C.5)
Mayormente accesible a componentes y servicios con daños menores al menos del 50% del material circundante. (Ref. Norma ISO 20887:2020 Anexo C C.5)
Mayormente accesible a componentes y servicios con solo daños menores al menos del 25% del material circundante. (Ref. Norma ISO 20887:2020 Anexo C C.5)
Accesibilidad total a componentes y servicios con el trabajo mínimo y sin daños al material circundante. (Ref. Norma ISO 20887:2020 Anexo C C.5)
Los componentes del diseño se caracterizan por una aplicación paralela en vez de secuencial de montaje/desmontaje. (Ref. Norma ISO 20887:2020 Anexo C C.6)
Los componentes de diseño se encuentra en una jerarquía abierta de distintos módulos. (Ref. Norma ISO 20887:2020 Anexo C C.6)
La capa asociada a obra gris se encuentra integrada de forma independiente. (Ref. Norma ISO 20887:2020 5.3.3)
La capa asociada a servicios eléctricos se encuentra integrada de forma independiente. (Ref. Norma ISO 20887:2020 5.3.3)
La capa asociada a servicios mecánicos se encuentra integrada de forma independiente. (Ref. Norma ISO 20887:2020 5.3.3)
La capa asociada a acabados se encuentra integrada de forma independiente. (Ref. Norma ISO 20887:2020 5.3.3)
La simplicidad de diseño no aplica. (Ref. Norma ISO 20887:2020 5.3.6)
La simplicidad de diseño baja. (Ref. Norma ISO 20887:2020 5.3.6)
La simplicidad de diseño media. (Ref. Norma ISO 20887:2020 5.3.6)
La simplicidad de diseño alta. (Ref. Norma ISO 20887:2020 5.3.6)
Mayormente se usan elementos prefabricados que reducen trabajo en sitio. (Ref. Norma ISO 20887:2020 5.3.7)
Predominan dimensiones estándares. (Ref. Norma ISO 20887:2020 5.3.7)
Los componentes y conexiones empleados tienen cualidades estándares (tipo, tamaño y material) (Ref. Norma ISO 20887:2020 5.3.7)

Principio
Se emplea un diseño modular. (Ref. Norma ISO 20887:2020 5.3.7)
Predominan materiales y/o sistemas con propiedades reusables y vida útil prolongada. (Ref. Norma ISO 20887:2020 5.3.7)
Predominan materiales y/o sistemas con propiedades de restauración. (Ref. Norma ISO 20887:2020 6)
Predominan materiales y/o sistemas con componentes reciclados. (Ref. Norma ISO 20887:2020 6)
Existe un manejo adecuado de los desechos reutilizables o reciclables. (Ref. Norma ISO 20887:2020 6)
Building Information Modeling (BIM) (Ref. Norma ISO 20887:2020 6)
Existe un manual de desmontaje y adaptabilidad de la infraestructura. (Ref. Norma ISO 20887:2020 6)
Existe un informe con información de manufactura de los materiales y productos utilizados (propiedades, contacto del fabricante, proveedor y garantía). (Ref. Norma ISO 20887:2020 6)
Existe un informe detallado de conexiones y componentes (tipo, medidas, materiales).
En caso de no ser estándares, se adjunta un manual paso a paso de montaje y desmontaje de los mismos. (Ref. Norma ISO 20887:2020 6)

Fuente: Norma ISO 20887:2020

Elaborado por: Sarah Robles

Apartados a Considerar Norma ISO 20887:2020

4.1.1 C.13 Durability

Durability is not listed as a DfD/A principle in this document, but it is a key consideration that impacts DfD/A decision-making. Metrics for durability can include the cost of maintenance as a percentage of the purchase price, the service life (years) of a given product compared to alternative products that serve the same function at the same performance level and the “material intensity per standardized unit of service”.

4.1.2 C.2 Versatility

Versatility can be measured by the percentage of usable space that has multiple uses on a daily, weekly, or monthly basis, without requiring changes to the main features of the space.

4.1.3 C.3 Convertibility

Convertibility can be measured by the percentage of usable space that has been designed to be converted easily to multiple uses.

4.1.4 C.4 Expandability

Expandability can be assessed in terms of the number of additional floors or percentage of additional floor space possible without major alteration to the foundation and structural system. The percentage of reserve load bearing capacity can also be used to assess expandability.

4.1.5 C.5 Ease of access to components and services

An ordinal or interval rating scale for the relative accessibility provided by design options can be created. In this way, design options can be ranked. An example might be a 0 to 5 scale, with each point given a clear definition, for example:

- 0) no accessibility without significant damage to surrounding materials”;
- 1) limited accessibility with some significant damage to more than 50 % the surrounding materials;
- 2) limited accessibility with minor damage to more than 50 % of surrounding materials;
- 3) mostly accessible with minor damage to less than 50 % of the surrounding materials;
- 4) mostly accessible with only minor damage to less than 25 % of the surrounding materials;
- 5) full accessibility with minimal work and no damage to surrounding materials”.

A “yes or no” assessment can be made for each connection type, depending on whether it is exposed or not.

4.1.6 C.6 Independence

While independence is a difficult characteristic to quantify, an ordinal or interval rating scale for the relative independence of design options can be created. In this way, design options can be ranked. An example is a 0 to 5 scale, with each point given a clear definition, e.g., “0 — no consideration to lifespan of component, hierarchy and modularity, sequential assembly” to “5 — parallel assembly and open, modular hierarchy”.

4.1.7 5.3.3 Independence

Independence is the quality that allows parts, components, modules and systems to be removed or upgraded without affecting the performance of connected or adjacent systems.

Maximizing independence of the functional requirements of parts, components, modules and systems is key for optimizing disassembly for both re-use and upgrade. Modularization overlaps between adaptability and disassembly when modules achieve functional independence.

4.1.8 5.3.6 Simplicity

Simplicity is the quality of an assembly or system that is designed to be straightforward, easy to understand and meet performance requirements with the least amount of customization.

As a design principle, simplicity reduces the number of elements, components (subcomponents), or materials to the minimum required to execute the intended function. Experience shows that simplicity will generally reduce the likelihood of failure or breakdown and facilitate repair. Design options include limiting the use of decorative details, minimize the quantity and diversity of materials used, while working within a client’s aesthetic parameters (e.g., using a standard and limited colour palette). One of the aims of simplicity is to remove barriers to disassembly.

4.1.9 5.3.7 Standardization

Standardization is concerned with the use of common components, products, or processes to satisfy a multitude of requirements.

Standardized parts, which make it easier for contractors to disassemble structures while using efficient and repetitive techniques, should be considered. Standardization can support aspects of simplicity, adaptability and further re-use. Standardized parts can also allow for easier transportation, storage, and re-use.

4.1.10 6 Documentation and information

Documentation that supports adaptability and disassembly of the construction works shall be available and maintained throughout its life. This requires that DfD/A details and instructions are recorded and transferred across the built asset life cycle.

Disassembly manuals shall be prepared, submitted, and incorporated in shop drawings and documentation on the materials used during construction and refurbishment and material marking is needed. Furthermore, a copy of this material shall be made available to parties that need it for reference. If changes are made or additional information is developed at any stages of the life cycle, documentation and models shall be updated accordingly.

4.2 Fase II: Agrupación por categorías los ítems a considerar según los principios obtenidos de la norma ISO 20887:2020.

Cada principio de sustentabilidad expuesto en la fase 1 fue agrupado en una categoría, con el objetivo de darle una estructura al instrumento.

4.2.1 Durabilidad

Hace referencia a la vida útil de la infraestructura considerando principalmente los materiales empleados. La empresa Inversiones Graca 1802, C.A. estableció el tiempo de vida útil a considerar según las características de la vivienda a estudiar, la cual pertenece al grupo de viviendas unifamiliares construidas empleando bloques.

4.2.2 Versatilidad y Convertibilidad

Hace referencia a aquella infraestructura apta para diferentes usos, o modificable, sin alteraciones estructurales relevantes. La versatilidad y convertibilidad facilitan la alternativa de usos de los espacios de la vivienda a lo largo de su vida útil, permitiendo así modificaciones que satisfagan los requerimientos del usuario.

4.2.3 Expandibilidad

Hace referencia a la capacidad del diseño o de las características del sistema que admite incremento del espacio de la infraestructura. Se considera a partir de la disposición de incremento superficial horizontal o vertical en proporción al terreno disponible.

4.2.4 Acceso a Componentes y Servicios

Hace referencia al nivel de exposición de los componentes y servicios de la infraestructura. La exposición de los mismos implica un fácil acceso con el menor porcentaje de daño a la infraestructura lo que permite un eficiente montaje y desmontaje de los servicios y componentes, o la modificación de los mismos.

4.2.5 Independencia del Diseño

Hace referencia a la dinámica de ejecución del diseño de la infraestructura. Tanto la forma jerárquica en que está definido, como el sistema secuencial de la puesta en práctica del mismo.

4.2.6 Integración Independiente de Capas

Hace referencia a la estructuración aisladas entre sí de las cuatro capas fundamentales de la infraestructura. La independencia entre los sistemas de diseño de la infraestructuras, o capas, permite una facilidad de ajuste, removimiento, reemplazo o mejora de los mismos sin comprometer componentes aledaños.

Las cuatro capas consideradas son:

4.2.6.1 Obra Gris

Incluye toda la parte estructural de la infraestructura, tanto fundaciones como superestructura y revestimiento.

4.2.6.2 Servicios Eléctricos

Incluye toda la parte de cableados y componentes del sistema eléctrico de la

infraestructura.

4.2.6.3 Servicios Mecánicos

Incluye tuberías, ductería, sistemas de calefacción, aires acondicionados, entre otros afines.

4.2.6.4 Acabados

Incluye enseres, artefactos, dispositivos, cielo raso, revestimiento de suelos, entre otros afines.

4.2.7 Simplicidad del Diseño

Hace referencia a la cualidad sencilla de la infraestructura, fácil interpretación y ejecución, así como la menor cantidad de ítems personalizados. La simplicidad garantiza la reducción al mínimo de materiales para la funcionalidad de la infraestructura, como un mejor rendimiento en la ejecución y la facilidad de reparaciones futuras.

4.2.8 Estandarización

Hace referencia al uso de componentes y proceso comunes, con características prediseñadas. La estandarización facilita la instalación eficaz de componentes y servicios, así como también el mantenimiento futuro y desmontaje. Por otra parte, se reduce al mínimo la cantidad de herramientas necesarias durante la instalación y se optimiza el tiempo de trabajo.

4.2.9 Materiales y/o Sistemas

Hace referencia a las cualidades que poseen los materiales a emplear y el modo de uso de los mismos. El porcentaje de materia reusable o reciclable que posee, su capacidad de restauración, tiempo de vida útil estimado, y el manejo adecuado de los desechos generados.

4.2.9 Documentación

Hace referencia a la de data soporte de la información esencial sobre los aspectos de la infraestructura. Abarca tanto los análisis estructurales, como la información de manufactura, montaje/desmontaje, y características de los componentes, materiales y servicios.

Tabla 2. Categorización de Principios de Sustentabilidad

Categoría	Principio
<p>Durabilidad Hace referencia a la vida útil de la infraestructura considerando principalmente los materiales empleados.</p>	<p>El tiempo útil de la vida de servicio de la infraestructura está entre 35-50 años.</p>
<p>Versatilidad y Convertibilidad Hace referencia a aquella infraestructura apta para diferentes usos, o modificable, sin alteraciones estructurales relevantes.</p>	<p>El mayor porcentaje de los espacios son aptos para su uso constante sin cambios estructurales.</p>
	<p>El mayor porcentaje de los espacios diseñados para usos múltiples cumplen su función sin cambios estructurales.</p>
<p>Expandibilidad Hace referencia a la capacidad del diseño o de las características del sistema que admite incremento del espacio de la infraestructura.</p>	<p>La estructura puede expandirse proporcionalmente al terreno verticalmente sin alterar las fundaciones y sistema estructural.</p>
	<p>La estructura puede expandirse proporcionalmente al terreno horizontalmente dentro de los límites de diseño y regulación municipal (porcentaje de construcción permitida).</p>
<p>Acceso a Componentes y Servicios Hace referencia al nivel de exposición de los componentes y servicios de la infraestructura.</p>	<p>No existe accesibilidad sin daños significantes al material circundante.</p>
	<p>Acceso limitado con daños significante al más del 50% del material circundante.</p>
	<p>Acceso limitado con daños menores al más del 50% del material circundante.</p>
	<p>Mayormente accesible con daños menores al menos del 50% del material circundante.</p>
	<p>Mayormente accesible con solo daños menores al menos del 25% del material circundante.</p>
	<p>Accesibilidad total con el trabajo mínimo y sin daños al material circundante.</p>
<p>Independencia del Diseño Hace referencia a la dinámica de</p>	<p>Los componentes se caracterizan por una aplicación paralela en vez de secuencial de montaje/desmontaje.</p>

Categoría	Principio
ejecución del diseño de la infraestructura.	Los componentes se encuentra en una jerarquía abierta de distintos módulos.
Integración Independiente de Capas Hace referencia a la estructuración aisladas entre sí de las cuatro capas fundamentales de la infraestructura.	Obra gris. Servicios eléctricos. Servicios mecánicos. Acabados.
Simplicidad del Diseño Hace referencia a la calidad sencilla de la infraestructura, fácil interpretación y ejecución, así como la menor cantidad de ítems personalizados.	No aplica. Baja. Media Alta
Estandarización Hace referencia al uso de componentes y proceso comunes, con características prediseñadas.	Mayormente se usan elementos prefabricados que reducen trabajo en sitio. Predominan dimensiones estándares. Los componentes y conexiones empleados tienen cualidades estándares (tipo, tamaño y material) Se emplea un diseño modular.
Materiales y/o Sistemas Hace referencia a las cualidades que poseen los materiales a emplear y el modo de uso de los mismos.	Predominan materiales y/o sistemas con propiedades reusables y vida útil prolongada. Predominan materiales y/o sistemas con propiedades de restauración. Predominan materiales y/o sistemas con componentes reciclados. Existe un manejo adecuado de los desechos reutilizables o reciclables.
Documentación Hace referencia a la data soporte de la información esencial sobre los aspectos de la	Building Information Modeling (BIM) Existe un manual de desmontaje y adaptabilidad de la infraestructura.

Categoría	Principio
infraestructura.	Existe un informe con información de manufactura de los materiales y productos utilizados (propiedades, contacto del fabricante, proveedor y garantía)
	Existe un informe detallado de conexiones y componentes (tipo, medidas, materiales).
	En caso de no ser estándares, se adjunta un manual paso a paso de montaje y desmontaje de los mismos.

Fuente: Norma ISO 20887:2020

Elaborado por: Sarah Robles

4.3 Fase III: Asignación de ponderación a cada ítem.

La ponderación atribuida a cada principio de sustentabilidad fue definida en base a los criterios proporcionados por la empresa Inversiones Graca 1802, C.A. establecidos en esquemas de sustentabilidad testados por la misma, los cuales hacen referencia a viviendas unifamiliares construidas con bloques.

Las celdas marcadas en amarillo representan principios no excluyentes, mientras que las marcadas en azul representan principios con carácter excluyentes entre sí.

Tabla 3. Instrumento De Medición General De La Sustentabilidad De Una Vivienda Unifamiliar Basado En La Norma Iso 20887:2020 Para La Empresa Inversiones Graca 1802 C.A.

Categoría	Principio	%
Durabilidad	El tiempo útil de la vida de servicio de la infraestructura está entre 35-50 años.	10
Versatilidad y Convertibilidad	El mayor porcentaje de los espacios son aptos para su uso constante sin cambios estructurales.	5
	El mayor porcentaje de los espacios diseñados para usos múltiples cumplen su función sin cambios estructurales.	5

Categoría	Principio	%
Expandibilidad	La estructura puede expandirse proporcionalmente al terreno verticalmente sin alterar las fundaciones y sistema estructural.	5
	La estructura puede expandirse proporcionalmente al terreno horizontalmente dentro de los límites de diseño y regulación municipal (porcentaje de construcción permitida).	5
Acceso a Componentes y Servicios	No existe accesibilidad sin daños significantes al material circundante.	0
	Acceso limitado con daños significante al más del 50% del material circundante.	2
	Acceso limitado con daños menores al más del 50% del material circundante.	4
	Mayormente accesible con daños menores al menos del 50% del material circundante.	6
	Mayormente accesible con solo daños menores al menos del 25% del material circundante.	8
	Accesibilidad total con el trabajo mínimo y sin daños al material circundante.	10
Independencia del Diseño	Los componentes se caracterizan por una aplicación paralela en vez de secuencial de montaje/desmontaje.	5
	Los componentes se encuentra en una jerarquía abierta de distintos módulos.	5
Integración Independiente de Capas	Obra gris.	2.50
	Servicios eléctricos.	2.50
	Servicios mecánicos.	2.50
	Acabados.	2.50
Simplicidad del Diseño	No aplica.	0
	Baja.	2.5
	Media	5

Categoría	Principio	%
	Alta	10
Estandarización	Mayormente se usan elementos prefabricados que reducen trabajo en sitio.	2.50
	Predominan dimensiones estándares.	2.50
	Los componentes y conexiones empleados tienen cualidades estándares (tipo, tamaño y material)	2.50
	Se emplea un diseño modular.	2.50
Materiales y/o Sistemas	Predominan materiales y/o sistemas con propiedades reusables y vida útil prolongada.	2.50
	Predominan materiales y/o sistemas con propiedades de restauración.	2.50
	Predominan materiales y/o sistemas con componentes reciclados.	2.50
	Existe un manejo adecuado de los desechos reutilizables o reciclables.	2.50
Documentación	Building Information Modeling (BIM)	2.50
	Existe un manual de desmontaje y adaptabilidad de la infraestructura.	2.50
	Existe un informe con información de manufactura de los materiales y productos utilizados (propiedades, contacto del fabricante, proveedor y garantía)	2.50
	Existe un informe detallado de conexiones y componentes (tipo, medidas, materiales).	2.50
	En caso de no ser estándares, se adjunta un manual paso a paso de montaje y desmontaje de los mismos.	2.50
	TOTAL(%)	100

Elaborado por: Sarah Robles

Los resultados obtenidos con el instrumento en cuestión representan un porcentaje de sustentabilidad respecto a la norma ISO 20887:2020 basado en los criterios considerados por la empresa Inversiones Graca 1802, C. A.

4.3 Fase IV: Implementación del instrumento mediante la evaluación de una vivienda unifamiliar.

A continuación se presentan los resultados obtenidos al emplear el instrumento de medición de sustentabilidad general basado en la norma ISO 20887:2020 en una vivienda unifamiliar establecida por la empresa Inversiones Graca 1802, C.A. La vivienda en cuestión se encuentra en la zona norte de Valencia, específicamente en la urbanización Trigal Norte.

Tabla 4. Resultados de Análisis de Vivienda Unifamiliar Empleando Instrumento De Medición General De La Sustentabilidad De Una Vivienda Unifamiliar Basado En La Norma Iso 20887:2020 Para La Empresa Inversiones Graca 1802 C.A.

Categoría	Principio	%
Durabilidad	El tiempo útil de la vida de servicio de la infraestructura está entre 35-50 años.	10
Versatilidad y Convertibilidad	El mayor porcentaje de los espacios son aptos para su uso constante sin cambios estructurales.	5
	El mayor porcentaje de los espacios diseñados para usos múltiples cumplen su función sin cambios estructurales.	5
Expandibilidad	La estructura puede expandirse proporcionalmente al terreno verticalmente sin alterar las fundaciones y sistema estructural.	5

Categoría	Principio	%
	La estructura puede expandirse proporcionalmente al terreno horizontalmente dentro de los límites de diseño y regulación municipal (porcentaje de construcción permitida).	-
Acceso a Componentes y Servicios	No existe accesibilidad sin daños significantes al material circundante.	-
	Acceso limitado con daños significante al más del 50% del material circundante.	-
	Acceso limitado con daños menores al más del 50% del material circundante.	-
	Mayormente accesible con daños menores al menos del 50% del material circundante.	-
	Mayormente accesible con solo daños menores al menos del 25% del material circundante.	8
	Accesibilidad total con el trabajo mínimo y sin daños al material circundante.	-
Independencia del Diseño	Los componentes se caracterizan por una aplicación paralela en vez de secuencial de montaje/desmontaje.	5
	Los componentes se encuentra en una jerarquía abierta de distintos módulos.	5
Integración Independiente de Capas	Obra gris.	2.50
	Servicios eléctricos.	2.50
	Servicios mecánicos.	2.50
	Acabados.	2.50
Simplicidad del Diseño	No aplica.	-
	Baja.	-
	Media	-
	Alta	10

Categoría	Principio	%
Estandarización	Mayormente se usan elementos prefabricados que reducen trabajo en sitio.	-
	Predominan dimensiones estándares.	-
	Los componentes y conexiones empleados tienen cualidades estándares (tipo, tamaño y material)	2.50
	Se emplea un diseño modular.	-
Materiales y/o Sistemas	Predominan materiales y/o sistemas con propiedades reusables y vida útil prolongada.	-
	Predominan materiales y/o sistemas con propiedades de restauración.	-
	Predominan materiales y/o sistemas con componentes reciclados.	2.50
	Existe un manejo adecuado de los desechos reutilizables o reciclables.	-
Documentación	Building Information Modeling (BIM)	-
	Existe un manual de desmontaje y adaptabilidad de la infraestructura.	-
	Existe un informe con información de manufactura de los materiales y productos utilizados (propiedades, contacto del fabricante, proveedor y garantía)	-
	Existe un informe detallado de conexiones y componentes (tipo, medidas, materiales).	-
	En caso de no ser estándares, se adjunta un manual paso a paso de montaje y desmontaje de los mismos.	-
	TOTAL(%)	68

Elaborado por: Sarah Robles

CONCLUSIONES

Con el desarrollo de la presente investigación, se pudo analizar lo expuesto a inicios de la misma respecto a la manera de evaluar la sustentabilidad de viviendas unifamiliares construidas por la empresa Inversiones Graca 1802, C.A., según los criterios establecidos en la norma ISO 120887:2020. Dichos criterios abarcan tanto la fase previa correspondiente a la planificación de un proyecto, como a la fase operacional de la vivienda, ya que pueden emplearse para trazar la dinámica de la construcción en base a los mismos con el fin de llevar a cabo una obra lo más sustentable posible, como para evaluar la sustentabilidad general basada en los criterios de la norma que posee una vivienda unifamiliar.

La fase I fue destinada a la lectura y análisis de la norma ISO 280887:2020 para extraer los principios de sustentabilidad expuestos en la misma y que a su vez fuesen aplicables en el escenario contemplado, el cual se encuentra definido por las características de viviendas unifamiliares construidas por la empresa Inversiones Graca 1802, C.A.. Tales principios constituyen la base del instrumento diseñado (Ver Tabla 1).

Posteriormente, y en la secuencia establecida, se dio paso a la fase II. En ella, se categorizó cada principio según los criterios que abordaban. Asimismo, se definió a nivel conceptual cada categoría para una mejor interpretación del instrumento (Ver Tabla 2).

Luego, en la fase III se le asignó una ponderación a cada principio en según criterios proporcionados por la empresa, los cuales tienen base en esquemas de sustentabilidad testeados por Inversiones Graca 1802, C.A. en viviendas de carácter unifamiliar y construidas con bloques.

Finalmente, cumpliendo con la Fase IV, se realizó una evaluación con el instrumento de medición de sustentabilidad general basado en los principios establecidos en la norma ISO 20887:2020 de una vivienda unifamiliar construida por la empresa Inversiones Graca 1802, C.A. En dicha evaluación se obtuvo un 68% en los resultados arrojados por el instrumento (Ver Tabla 3).

RECOMENDACIONES

A continuación se presentan una serie de recomendaciones expresadas a la empresa Inversiones Graca 1802, C.A. por parte de la investigadora Robles C., Sarah respecto al instrumento de medición diseñado:

- Implementar el instrumento en la fase inicial del proyecto, de manera tal que el diseño a realizar y las consideración a tomar para la futura construcción estén alineados a los principios de sustentabilidad general de la norma ISO 20887:2020.
- Ampliar el alcance del instrumento a viviendas multifamiliares, con el fin de abarcar mayor número de construcciones a las cuales atribuirle un porcentaje de sustentabilidad general en función al criterio de la norma ISO 20887:2020.
- Añadir subcategorías en el instrumento con la incorporación de criterios de otras normas ISO con escenarios específicos para distintos tipos de construcciones civiles.
- Utilizar el instrumento como una guía para abordar la norma ISO 20887:2020, con el objetivo de profundizar en ella.

REFERENCIAS

Bibliográficas

- Arango E., (2017) **Diseño De Vivienda de Interés Social Sustentable**. Universidad Libre Seccional Pereira.
- Arias, F. (2006) **El proyecto de investigación, Introducción A La Metodología Científica**. 5ta Edición. Caracas: Episteme C.A.
- Arias, F. (2006) **El proyecto de investigación, Introducción A La Metodología Científica**. 6ta Edición. Caracas: Episteme C.A.
- Balestrini, Miriam. (2006) **Como Se Elabora El Proyecto De Investigación: (Para Los Estudios Formulativos O Exploratorios, Descriptivos, Diagnósticos, Evaluativos, Formulación De Hipótesis Causales, Experimentales Y Los Proyectos Factibles)**. 7ma Edición. Imprenta: Caracas: Consultores Asociados.
- Bavaresco, Aura. (2006) **Proceso Metodológico En La Investigación. Como Hacer Un Diseño De Investigación**. 5ta Edición, Editorial De La Universidad Del Zulia-Maracaibo.
- ISO 20887:2020. **Sustainability in buildings and civil engineering works — Design for disassembly and adaptability — Principles, requirements and guidance**. First edition 2020-01.
- Manual de Trabajos de Grado de Especialización, Maestrías y Tesis Doctorales** (2005). UPEL.
- Mirenzi F, Simionato JP. (2015) **Desarrollo De Vivienda Eco-Sustentable: Análisis Económico-Financiero, Social Y Ecológico Versus Vivienda Regular**. Universidad Católica Argentina. Facultad de Ciencias Fisicomatemáticas e Ingeniería.
- Susunaga, Jorge. (2014) **Construcción Sostenible, Una Alternativa Para La Edificación De Viviendas De Interés Social Y Prioritario**. Universidad Católica de Colombia.
- Tobías, M. **El hombre contra la tierra. Población y biosfera al final del milenio**. Barcelona: Ediciones Flor del Viento, 1996. Obra de carácter divulgativa.

Electrónicas

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Anexos

Anexo A:
Norma ISO 20887:2020

**Sustainability in buildings and
civil engineering works — Design
for disassembly and adaptability
— Principles, requirements and
guidance**

*Développement durable dans les bâtiments et ouvrages de génie
civil — Conception pour la démontabilité et l'adaptabilité —
Principes, exigences et recommandations*





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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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This document was prepared by Technical Committee ISO/TC 59, *Buildings and civil engineering works*, Subcommittee SC 17, *Sustainability in buildings and civil engineering works*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Applying the principles of design for disassembly and adaptability (DfD/A) to the service life planning of buildings and civil engineering works can make a positive contribution to sustainable development. While service life planning is a design process that seeks to ensure that the service life of a constructed asset will equal or exceed its design life, design for disassembly and adaptability is a strategy to optimize both the service life and the design life. The strategy does not suggest overbuilding to meet a vast number of unknowns that a constructed asset might encounter.

Introducing aspects of design for disassembly can be used to reduce and/or prevent waste and increase resource efficiency by encouraging alternative considerations at the project definition phase. The application of adaptability concepts and principles can minimize the need for unnecessary removal and new construction, by repurposing or modifying constructed assets to renew their service life, and result in constructed assets that are able to accommodate a larger variety of uses. From a broader perspective, the recovery and subsequent reuse or recycling of disassembled construction materials and components will support the evolving concept of a circular economy.

The design and construction industry has often trusted/depended upon traditional assembly methods, products, and processes that typically do not consider deconstruction. As such, during a renovation or demolition project, products and materials are often not easily salvaged for reuse, recycling or energy recovery, and therefore, become waste that is landfilled.

Incorporating DfD/A concepts early in the planning and design phase will increase the likelihood that activities during the stages of use, maintenance (including repair, replacement, refurbishment), and end-of-life (e.g., disassembly, reuse, recycling, disposal) will be conducted more efficiently from a total resource perspective (i.e., time and associated costs, labour costs, materials, and energy).

Design for disassembly devises explicit methods, prior to construction, for optimal recovery of specific products and materials without damaging either that which is being removed or surrounding components. The adaptability aspects of DfD/A support the continued use of constructed assets by allowing for and accommodating substantial change (e.g., demographics, social, economic, and technological conditions and physical surroundings and needs) within an existing or expanded physical asset. Designing for adaptability means designing for both present and future uses, encouraging the use of phased developments and matching supply with demand in a timely fashion. The decision to use these methods is usually considered in conjunction with the investment rate of return over time and risk.

Successful application of DfD/A principles will require their integration into the early phases of a project, when it is still cost-effective to do so. Implementation of DfD/A will require compromises and trade-offs to make choices that can be constrained by factors such as technical complexity, lack of resources and time, risk of obsolescence and limited information on costs or relative environmental burdens over the total life cycle. Therefore, it is important that all parties involved in the design, product supply, construction, commissioning, operation and decommissioning aspects have sufficient knowledge and understanding to implement the intended results. Designers have the major role in considering DfD/A to facilitate the best technical, economic and environmental opportunities. Clients often drive the design team to consider and implement DfD/A elements within a project. The supporting supply chain, including product suppliers, constructors, facility managers and those decommissioning constructed assets also need to adapt their approaches to optimize the design intentions which relate to DfD/A.

This document is intended to provide a framework of the DfD/A principles and the key issues that should be considered by the different actors, particularly designers involved in the project. It is equally important that this knowledge base is continually added to by those implementing these principles, and associated activities, for example, by knowledge sharing through the creation of case studies and associated journal articles.

This document is one in a suite of documents dealing with sustainability in construction works that includes the following, in addition to this document:

- a) ISO 15392, *Sustainability in buildings and civil engineering works — General principles*;

- b) ISO/TS 12720, *Sustainability in buildings and civil engineering works — Guidelines on the application of the general principles in ISO 15392*;
- c) ISO/TR 21932, *Sustainability in buildings and civil engineering works — A review of terminology*;
- d) ISO 21929-1, *Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for buildings*;
- e) ISO/TS 21929-2, *Sustainability in building construction — Sustainability indicators — Part 2: Framework for the development of indicators for civil engineering works*;
- f) ISO 21931-1¹⁾, *Sustainability in building construction — Framework for methods of assessment of the environmental performance of construction works — Part 1: Buildings*;
- g) ISO 21931-2, *Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 2: Civil engineering works*;
- h) ISO 16745-1, *Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 1: Calculation, reporting and communication*;
- i) ISO 16745-2, *Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 2: Verification*;
- j) ISO 21930, *Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services*;
- k) ISO 21678²⁾, *Sustainability in buildings and civil engineering works — Indicators and benchmarks — Principles, requirements and guidelines*.

This document deals with environmental, social and economic aspects of sustainability. The relationship among the suite of documents is elaborated in [Figure 1](#).

1) Revision under preparation.

2) Under preparation. Stage at the time of publication: ISO/FDIS 21678:2020.

	environmental aspects	social aspects	economic aspects	technical aspects	functional aspects
ISO/TC59/SC17	environmental aspects	social aspects	economic aspects	technical aspects	functional aspects
	ISO 15392 General principles				
	ISO TS 12720 Guideline on the application of ISO 15392				
	ISO TR 21932 Terminology				
Principles	ISO 21929-1 Framework for the development of Indicators – Part 1: Buildings				
	ISO 21929-2 Framework for the development of Indicators – Part 2: CEW				
	ISO 21931-1 Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment – Part 1: Buildings				
Buildings (Parts 1) +	ISO 21931-2 Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment – Part 2: Civil Engineering Works				
	ISO 20887 Design for Disassembly and adaptability - Principles, requirements and guidance				
Civil Engineering Works, CEW (Parts 2)	ISO 16745-1+2 Carbon metric of an existing building during use stage. Part 1: Calculation, reporting, communication. Part 2: Verification				
	ISO 21678 Methodological principles for the development of benchmarks for sustainable buildings				
Products	ISO 22057 Enabling use of Environmental Product Declarations (EPD) at construction works level using building information modelling (BIM)				
	ISO 21930 Core rules for environmental product declarations of construction products and services				

Figure 1 — Suite of related documents for sustainability in buildings and civil engineering works

Sustainability in buildings and civil engineering works — Design for disassembly and adaptability — Principles, requirements and guidance

1 Scope

This document provides an overview of design for disassembly and adaptability (DfD/A) principles and potential strategies for integrating these principles into the design process. This document provides information for owners, architects, engineers, and product designers and manufacturers to assist in their understanding of potential DfD/A options and considerations, and for other parties who are responsible for financing, regulating, constructing, transforming, deconstructing, or demolishing construction works.

This document is applicable to all types of buildings (e.g. commercial, industrial, institutional, and residential), civil engineering works (e.g., dams, bridges, roads, railways, runways, utilities, pipelines) and their constituent parts. It can be used for new construction, refurbishment and renovation, and in the design of incremental improvements in, or complete redesign of, buildings, building systems, civil engineering works, and their constituent parts.

This document also provides guidance on measuring performance regarding each DfD/A principle and related objectives.

This document is intended to be used in conjunction with and following the principles set out in ISO 15392 and the ISO 15686 series.

This document does not set specific levels of performance for the disassembly or adaptability of constructed works, however, it does include requirements that are mandatory for the implementation of specific DfD/A principles that are applicable when these principles are adopted.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6707-1, *Buildings and civil engineering works — Vocabulary — Part 1: General terms*

ISO 15392, *Sustainability in buildings and civil engineering works — General principles*

ISO 15686-1, *Buildings and constructed assets — Service life planning — Part 1: General principles and framework*

ISO/TR 21932, *Sustainability in buildings and civil engineering works — A review of terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6707-1, ISO/TR 21932 and the following apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

**3.1
accessibility**

ability for ease of access to *components* (3.7) for *disassembly* (3.12), *refurbishment* (3.29), *replacement* (3.32), or upgrade

Note 1 to entry: Within the context of this document, this definition does not directly apply to accessibility for people with additional, specialized needs.

**3.2
adaptability**

ability to be changed or modified to make suitable for a particular purpose

[SOURCE: ISO 6707-1:2017, 3.7.3.79]

**3.3
assembly**

set of related *components* (3.7) attached to each other

Note 1 to entry: Examples of assemblies include the total building envelope or the individual walls, roofs, or parapets and bearing or cable assemblies for bridges.

[SOURCE: ISO 6707-1:2017, 3.3.5.5, modified — Note 1 to entry has been added.]

**3.4
building**

construction works (3.9) that has the provision of shelter for its occupants or contents as one of its main purposes, usually partially or totally enclosed and designed to stand permanently in one place

[SOURCE: ISO 6707-1:2017, 3.1.1.3, modified — Note 1 to entry has been removed.]

**3.5
circular economy**

economy that is restorative and regenerative by design, and which aims to keep products, *components* (3.7) and materials at their highest utility and value at all times, distinguishing between technical and biological cycles

[SOURCE: ISO 20400:2017, 3.1]

**3.6
civil engineering works**

infrastructure

civil engineering project, US

construction works (3.9) comprising a structure, such as a dam, bridge, road, railway, runway, utilities, pipeline, or sewerage system, or the result of operations such as dredging, earthwork, geotechnical processes, but excluding a *building* (3.4) and its associated site works

Note 1 to entry: Associated site works related to buildings are sometimes considered as civil engineering projects, for example particularly in the US.

[SOURCE: ISO 6707-1: 2017, 3.1.1.2, modified — "infrastructure" has been added as an admitted term; Note 1 to entry has been modified.]

**3.7
component**

product manufactured as a distinct unit to serve a specific function or functions

EXAMPLE Nails, cladding anchors, reinforcing bars and membranes (basic units) or reinforced concrete slabs, windows and doors (complex units).

Note 1 to entry: Components can be manufactured, prefabricated, or built or formed on site, and can be basic or complex units.

Note 2 to entry: A complex unit can also be considered an *assembly* (3.3), depending on the context.

3.8**constructed asset**

anything of value that is constructed or results from construction operations

[SOURCE: ISO 15686-1:2011, 3.2]

3.9**construction works**

everything that is constructed or results from construction operations

Note 1 to entry: This includes *buildings* (3.4), *civil engineering works* (3.6), structures, landscaping, external works, and other types of construction works within a built environment.

Note 2 to entry: From an economic perspective, completed construction works are typically referred to as a *constructed asset* (3.8).

[SOURCE: ISO 6707-1:2017, 3.1.1.1, modified — The original Note 1 to entry has been removed; two notes to entry have been added; the US synonym 'construction' has been deleted as an admitted term.]

3.10**convertibility**

ability to accommodate a substantial change(s) in user needs by making modifications

3.11**demolition**

removal by destructive methods

EXAMPLE Demolition by pushing or pulling, fragmenting by crushing or shearing, implosion or rapid progressive failure of *construction works* (3.9) or their component parts.

3.12**disassembly**

non-destructive taking-apart of a *construction works* (3.9) or *constructed asset* (3.8) into constituent materials or *components* (3.7)

Note 1 to entry: This process can be applied to a product, *module* (3.23), system, component, or *assembly* (3.3).

[SOURCE: ISO 15392:—, 3.11, modified — Note 1 to entry has been added.]

3.13**design for disassembly**

approach to the design of a product or *constructed asset* (3.8) that facilitates *disassembly* (3.12) at the end of its useful life, in such a way that enables *components* (3.7) and parts to be reused, recycled, recovered for energy or, in some other way, diverted from the waste stream

Note 1 to entry: The definition is derived from ISO 14021:2016, 7.4.1.

3.14**design life**

service life (3.36) intended by the designer

Note 1 to entry: As stated by the designer to the client to support specification decisions.

[SOURCE: ISO 15686-1:2011, 3.3, modified — The abbreviated term "DL" and two deprecated terms have been removed.]

3.15**durability**

ability of a *constructed asset* (3.8) or any of its *components* (3.7) to perform its required functions in its service environment over a specified period of time without unforeseen maintenance or *repair* (3.31)

Note 1 to entry: Preventive or routine maintenance are foreseen measures intended to increase functional *service life* (3.36).

[SOURCE: ISO 17738-1:2017, 3.6, modified — The word "building" has been replaced with "constructed asset"; the word "specified" has been added; the reference to "cost" has been deleted; Note 1 to entry has been added.]

3.16

expandability

ability of a design or the characteristic of a system to accommodate a substantial change that supports or facilitates the addition of new space, features, capabilities and capacities

Note 1 to entry: Expandability is a form of scalability. Similarly, contraction can also be a beneficial capability that is a form of scalability.

3.17

exposed connection

connection that is left accessible for *disassembly* (3.12) or modification

3.18

independence

quality that allows parts, *components* (3.7), *modules* (3.23) and systems to be removed or upgraded without affecting the performance of connected or adjacent systems

Note 1 to entry: This can relate to functional, physical and structural independence, as well as the degree of independence.

3.19

inherent finish

condition of material left in its most basic state without contamination by an applied finish

Note 1 to entry: An applied finish can reduce or prevent reuse or recycling.

3.20

life cycle assessment

compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

Note 1 to entry: Core rules for the development of Type III environmental product declarations, based on life cycle assessment, for construction products are addressed in ISO 21930.

[SOURCE: ISO 14040:2006, 3.2, modified — The abbreviated term "LCA" has been removed; Note 1 to entry has been added.]

3.21

life cycle costing

methodology for systematic economic evaluation of life-cycle costs over a period of analysis, as defined in the agreed scope

Note 1 to entry: Life cycle costing can address a period of analysis that covers the entire life cycle or (a) selected stage(s) or periods of interest thereof.

[SOURCE: ISO 15686-5:2017, 3.1.8]

3.22

modular

composed of *modules* (3.23) for easy construction or arrangement and adaptation or *disassembly* (3.12)

[SOURCE: ISO 7176-26:2007, 4.8.11, modified — References to "modules", "adaptation" and "disassembly" have been added.]

3.23

module

set of standardized parts or independent units

Note 1 to entry: Modularization can be key to *disassembly* (3.12) in many types of *civil engineering works* (3.6).

Note 2 to entry: A module could be a type of complex *assembly* (3.3).

3.24 obsolescence

loss of ability of an item to perform satisfactorily due to changes in *performance requirements* (3.25)

[SOURCE: ISO 15686-1:2011, 3.14]

3.25 performance requirement

performance criterion
minimum acceptable level of a critical property

[SOURCE: ISO 15686-1:2011, 3.19]

3.26 recyclability

ability of component parts, materials or both to be separated and reprocessed from products and systems and subsequently used as material input for the same or different use or function

3.27 recyclable

characteristic of a product or associated *component* (3.7) that can be diverted from the waste stream through available processes and programmes and can be collected, processed and returned to use in the form of raw materials or products

Note 1 to entry: Whilst many products, components and materials are technically recyclable, in practice, recycling facilities might not be readily available or economically feasible to use.

Note 2 to entry: Recycling infrastructure for the material should exist in at least 60 % of locations where the product is sold. See Reference [21].

Note 3 to entry: The definition is derived from ISO 14021:2016, 7.7.1.

3.28 refurbishability

ability to restore the aesthetic and functional characteristics of a product, *building* (3.4) or other *constructed asset* (3.8) to a condition suitable for continued use

3.29 refurbishment

modification and improvements to an existing *building* (3.4) or *civil engineering works* (3.6) in order to bring it up to an acceptable condition

[SOURCE: ISO 6707-1:2017, 3.5.1.45, modified — The GB synonym “renovation” has been deleted as an admitted term; reference to “plant” has been deleted.]

3.30 remanufacturability

ability of a product to be disassembled and refabricated at the end of its useful life in a manner that provides restoration to a condition suitable for resale

3.31 repair

returning a product, *component* (3.7), *assembly* (3.3), or system to an acceptable condition by renewal or *replacement* (3.32) of worn, damaged, or degraded parts

[SOURCE: ISO 6707-1:2017, 3.5.1.47, modified — The word “item” has been replaced with “product, component, assembly, or system”; “through the” has been replaced with “by”; reference to “mending” has been deleted.]

3.32

replacement

change of parts of an existing item to regain its functionality

3.33

reusability

ability of a material, product, *component* (3.7) or system to be used in its original form more than once and maintain its value and functional qualities during recovery to accommodate reapplication for the same or any purpose

3.34

re-use

use of products or *components* (3.7) more than once for the same or other purposes without reprocessing

Note 1 to entry: Reprocessing does not include preparation for re-use, such as removal of connectors, cleaning, trimming, stripping of coatings, packaging, etc.

3.35

reversible connection

connection that can be disconnected and/or disassembled for easy alterations and additions to structures

Note 1 to entry: This is applicable to *components* (3.7), *assemblies* (3.3), *modules* (3.23) or systems within a *constructed asset* (3.8).

3.36

service life

period of time after installation during which a facility or its component parts meet or exceed the *performance requirements* (3.25)

[SOURCE: ISO 15686-1:2011, 3.25]

3.37

service life planning

service life design (deprecated)

design process of preparing the brief and the design for the *building* (3.4) and its parts to achieve the *design life* (3.14)

Note 1 to entry: Service life planning can, for example, reduce the costs of building ownership and facilitate maintenance and *refurbishment* (3.29).

[SOURCE: ISO 15686-1:2011, 3.24]

3.38

simplicity

quality of an *assembly* (3.3) or system that is designed to be straightforward, easy to understand and meet *performance requirements* (3.25) with the least amount of customization

EXAMPLE Using as few *components* (3.7) as possible, simple assembly steps and maintenance requirements.

3.39

usable space

area of rooms on all floors of a *building* (3.4), either assigned to or available for assignment to an occupant or specific use or necessary for the general operation

3.40

versatility

ability to accommodate different functions with minor system changes

4 Decision-making framework

4.1 General

Not all DfD/A principles are equally applicable or suitable in all situations. Therefore, the careful consideration of which principles should be adopted for each construction project, is part of the DfD/A design and implementation process.

The ease of execution and cost benefit analysis as well as the potential for change or obsolescence shall be considered. Guidance on the impact of, and methods to consider, obsolescence within the service life planning process is provided in ISO 15686-1:2011, Clause 7.

4.2 Developing the client brief

The client brief is very important, since this sets out the vision, technical and functional requirements for the construction works, which will have an impact on the most applicable design approaches. To be most effective, the realization of the client brief should be a collaborative process between the client and the designer.

NOTE 1 For a civil engineering works project, the client brief can also be referred to as the “project definition” or “functional specification”.

It is important to challenge the functional specification for a construction works and how it stands the test of time and change. At the conceptual design phase, it is possible to provide more details of the timing of the delivery of the functions, which might lead to phased/staged development or alternative independent delivery mechanism.

The following needs to be established to help direct the subsequent design and service life planning process:

- required service life of the construction works — this can be highly variable from a temporary structure to infrastructure with several-hundred-year service life requirements;
- expected use(s) of the construction works over its required service life — is it going to be a single use type, such as a dwelling; or is there likely to be multiple use types, such as commercial, retail and leisure;
- consideration of staged development to meet the changing demand or alternative uses;
- ownership of the asset — for example, a public sector long-term infrastructure asset versus a speculative commercial building with multiple tenants; this could also be relevant if leasing of products or systems form part of the business model;
- operation of the asset — who will maintain the asset and be responsible for documentation storage and transfer of information;
- any specific options, targets, benchmarks and objectives relating to adaptability, disassembly or outcomes depending on these, such as re-use potential or reduction of life cycle impacts;
- review of the regulatory and policy environment, including compliance requirements and incentive programs;
- review of foreseeable economic and market risks;
- likelihood of obsolescence;
- length of supply contracts (e.g. power or energy contract) for civil engineering works.

NOTE 2 Forms of obsolescence include functional, technological, and economic and can vary from highly likely or planned obsolescence to less likely or lesser degrees of predictability as determined through research and consultation.

4.3 Design strategies

4.3.1 General considerations

The application of DfD/A principles and their relevance and priority shall take into account the client brief and its requirements. The principles are not mutually exclusive, both between and within aspects of disassembly and adaptability.

The first priority is to determine current and potential functional, service life, regulatory, policy and other requirements. When assessing DfD/A design, system, element, component and material options, there should be an assessment of the potential trade-offs between impacts using scenario building and approaches like life cycle costing and life cycle assessment.

The following project characteristics, which could influence the scope and applicability of DfD/A, should be considered on a project specific basis:

- 1) location physical context — potential and allowance for change due to economic conditions, land-use zoning, demographics, topography and ecology and remoteness of location;
- 2) location cultural context — labour vs. material costs, formal patterns of style and prescribed methods of construction, conservation requirements;
- 3) owner-type — owner occupant, developer, investor, corporate, government;
- 4) use type(s) — buildings: institutional, healthcare, residential, retail, commercial, educational, industrial, warehouse/storage; civil engineering works: e.g. flood defense, water supply, energy supply, transportation;
- 5) typologies — buildings: e.g. high-rise, low-rise, detached; civil engineering works: industrial process infrastructures, linear infrastructures (including above and below ground), dams and other fluvial works, maritime works and public spaces;
- 6) construction technologies — e.g. air-supported structure, balloon frame construction, cable stayed bridge, composite construction, curtain wall building, folded-plate structure, framed building, platform frame construction, post and beam construction, precast concrete, steel-framed building;
- 7) construction materials — e.g. concrete, masonry, steel, heavy timber, light-wood framing or a combination thereof;
- 8) size — footprint and height, plot space, right of way width; space programme — space types and allocations, spatial organization, etc.;
- 9) design life — proposed life of "first-use" and any anticipated "further use" identified by the client;
- 10) performance goals related to environmental, social and economic sustainability targets;
- 11) performance goals related to construction, function and operation;
- 12) climate change potential effects or other hazard zone requirements (e.g. wind, flooding, earthquake), which can add requirements for strengthening or alternatively enhanced adaptability or disassembly for major repair;
- 13) schedule — time to construct and/or disassemble the construction works, time to in-service date can drive alternatives;
- 14) Service environment — factors that could influence deterioration or additional inspection and maintenance.

[Table 1](#) provides examples of scenarios that illustrate how the context, which stems from the client brief and understanding of the present and future use of the construction works, could influence the applicability of DfD/A principles. These are example scenarios; they are context specific and will not necessarily be applicable to the context of other projects.

Table 1 — Examples of interactions between design context and DfD/A principles

	Scenario description/Context	
	<i>Short term (required service life <20 years) with multiple ownership</i>	<i>Long term (required service life >60 years) with minimal change in ownership</i>
Application of disassembly principles	High relevance for reversible connections and independence, repurposing, easily reusable materials	High relevance for durability, standardisation of components, repair and upgrade or easily reusable and recyclable materials
Application of adaptability principles	Low relevance for longer term strategies but improving versatility and convertibility could reduce impacts if repurposing is likely	High relevance, such as expandability of highway capacity, and versatility of public transport hubs in line with future technology shifts

4.3.2 Durability considerations

Durability and adaptability are closely related; and both aspects need to be considered and balanced. If a material is durable but is likely to go out of fashion or become obsolete quickly, it is possible that it will be discarded long before the end of its useful life. By minimizing the maintenance or replacement of a product, there is a potential for reduced environmental impacts over the life cycle. This provides an efficient use of resources and helps to divert materials from landfill. However, if a building is destroyed long before the end of its required service life, and DfD/A has not been properly integrated into the design, the material and energy components that have gone into the structure will not have been used to their fullest extent. If not properly considered, durable materials could obstruct replacement and adaptability, depending on their degree of integration with other products or systems that hinder disassembly (i.e., independence based on component life expectancy).

Requirements for durability can vary across constructed assets and from one component to another within a construction works. These components are selected according to the intended use, cost, and the frequency, difficulty, and extent of maintenance, replacement, and repair. Requirements for durability are expressed in terms of service life. The service life of the construction works provides one basis for determining the service life of the systems and components. The general principles and framework for service life planning are found in ISO 15686-1. Other documents within the ISO 15686 series describe the procedures to be used to assess, predict and apply service life information throughout the life cycle.

Maintenance requirements shall be assessed to ensure that a product will maintain its aesthetic and functional value. Creation and adherence to routine maintenance or preventative maintenance programs is paramount.

Materials with a high durability rating that require less frequent maintenance, repair, or replacement should be selected. In some cases, however, it might be possible to reduce overall environmental burdens by designing for a shorter life, and for easier disassembly and re-use of components and materials (e.g., with temporary structures).

The durability of materials or subsystems within the context of the design life of the constructed asset shall be considered. If the expected design life is short, the importance of durability can be offset by other principles (e.g., accessibility, independence, simplicity, ease of re-use, and recyclability).

Assess the service environment to determine the factors that could influence the rate of material or assembly deterioration and determine resilience requirements. Manufacturers' warranties can be used to provide a marginal measure of a product's durability.

4.4 Levels and scope of analysis

4.4.1 General

The primary goal of DfD/A is to design constructed assets that can adapt to changing requirements or can be disassembled for re-use or recycling considering the various layers and constituent materials (e.g., elements and components). It might not be practical to consider that an entire building or civil

engineering works should be disassembled and re-used, as some components (e.g., a ventilation system), might be obsolete by the time it is disassembled, and undesirable for re-use.

The three design for adaptability principles and seven design for disassembly principles specified in [5.2](#) and [5.3](#) shall be considered for major elements, major components and the construction works as a whole, so as to determine the overall efficacy of the design to accommodate future uses and material recovery or re-use.

Each of the principles elaborated in [Clause 5](#) should be examined to each of the five levels of analysis set out in [4.4.2](#) to [4.4.6](#).

The five levels of analysis should be an integral part of the design, construction and information management processes throughout the life cycle of the constructed asset.

4.4.2 Systems

Analysis at this level is generally applied to adaptable construction works that can change to suit changing requirements. In some cases, entire modular buildings can undergo wholesale disassembly, movement, and re-use.

Also at the highest level, it is possible to find alternative concepts that phase the development, such as twinning lines, or adding temporary features or functional constraints to meet short term capacity requirements, e.g., snow loads, or lowered spring breakup road allowances for gross vehicle weight.

4.4.3 Elements

Analysis at this level focuses on a major structural part of a construction works, e.g., a roof, foundation, wall, or raised flooring system, bridge girders, as well as designs for modular and panelised elements that are readily fit into common dimensional standards.

4.4.4 Component or assembly

At this level, analysis is focused on combinations of several subcomponents that are often non-structural, e.g., valves, solar panels; “layers” or different systems are designed to allow upgrading, repair, and replacement. The replaced products can then enter the recycling loop or be used again in some form.

NOTE [Annex A](#) provides an example of how components or assemblies can be assessed for each DfD/A principle.

EXAMPLE 1 A carpet system consisting of carpet, backing, and adhesive.

EXAMPLE 2 Non-load bearing internal partitions.

4.4.5 Subcomponent

Analysis of subcomponents breaks down a component into its smaller pieces, e.g., the duct system of a heating or cooling system; the glazing used for curtain walls; gaskets in piping systems, or controllers and software in a fire protection system.

4.4.6 Material

When a product has been stripped back to its most basic materials, these can be re-used or, at a minimum, serve as a feedstock in the recycling process to produce other materials.

5 Principles of design for disassembly and adaptability

5.1 General

This document and the principles of design for disassembly and adaptability shall be used in conjunction with the principles set out in ISO 15392 and ISO 15686-1.

The DfD/A principles fall into two categories: those related to adaptability and those related to disassembly. Generally, adaptability principles deal with changes in functional use of space for buildings and changes in functional requirements for other constructed assets, while disassembly principles deal with the material resources.

NOTE 1 In this clause the definition of each principle is repeated for emphasis and clarity.

Not all of the principles are necessarily relevant in all situations or contexts. Wherever a principle is applied, the requirements provided within this document shall be followed and the related guidance should be considered.

NOTE 2 See [Annex C](#) for guidance on measuring performance related to DfD/A objectives.

5.2 Adaptability principles

5.2.1 General

Adaptability is necessary to accommodate changes in use type, demographics, user needs or due to the need for adaptation to external factors, such as climate change, for resilience or future proofing. The initial cost may be balanced against the future cost of adaptation.

The needs of users might also change with respect to limitation of physical abilities during the course of time. In case of residences, an adaptable building can enable users to live an independent life in their familiar surroundings for as long as possible. Adaptability falls into two categories;

- specific — for known/expected adaptation, and
- general — for unknown potential future adaptations.

Also, adaptations can be sequential, occurring over time (often non reversible), or parallel, able to perform various functions, typically repeatable over a period of time. Specific adaptations in both parallel and sequential modes are less abstract and more clearly defined in functional requirements and typically take precedence over general adaptations.

If the principles of universal design are taken into account at the outset (e.g. by respecting the space needed for manoeuvring a walking frame or wheelchair, the door width, the absence of thresholds or the installation of ramps and lifts), it can avoid the need for costly conversion at a later date.

Design principles for adaptability that shall be considered are

- a) versatility; ([5.2.2](#)),
- b) convertibility; ([5.2.3](#)), and
- c) expandability ([5.2.4](#)).

5.2.2 Versatility

Versatility is the ability to accommodate different functions with minor system changes.

Versatile structures and spaces facilitate alternative uses over the course of a day or week with minor system changes. In designing for versatility for specific adaptation, it is important to consider the needs of the targeted users. For example, having one space that accommodates many uses can reduce the overall building footprint, required floor area, costs, and resources. For general adaptations, leading

to potential future adaptations, it is possible to look beyond the boundaries of the current user/owner immediately occupying the space to seek potential partnerships with outside interests that could use it at times when it would otherwise go unused, potentially cutting costs and reducing the need to construct more single-use structures and assets. This type of versatility can result in measurable benefits by increasing building utilization. One of the aims of versatility is to reduce strip-out and fit-out over the life cycle.

A construction system in which parts of the constructed asset are interchangeable to some extent and not necessarily unique to a single application, should be considered. This will allow alterations in the layout through the relocation of components, without significant modification.

EXAMPLE 1 A gymnasium can double as a community theatre or arts centre if it is provided with portable seating and has acoustic panels integrated into the ceilings and walls.

EXAMPLE 2 Day-to-day or intraday changes in use can be made by dividing a room with folding partitions or by placing a removable floor over a pool.

EXAMPLE 3 Parking lots can be used as temporary farmers markets or public plazas for events.

Versatility can also apply to products and components.

EXAMPLE 4 A common connection device can be highly versatile and used in multiple assemblies throughout a building.

EXAMPLE 5 A dividing partition can also function as a conduit for utilities.

EXAMPLE 6 A pipeline that can batch various products or processes can create important variations in products.

5.2.3 Convertibility

Convertibility is the ability to accommodate substantial changes in user needs by making modifications.

In regard to buildings, convertibility is related to versatility, in that both principles involve using single spaces for multiple uses. However, convertibility is achieved by designing the space or fit-up to facilitate minor, non-structural modifications to interior spaces (e.g., partitions, ceiling, and finishes) or furnishings to suit changing needs, either on an infrequent or irregular basis or at a future point in time. Convertibility for multiple uses can improve the profitability of a space, as well as reducing the need for other facilities, thereby reducing resource and energy use.

Convertibility can be related to versatility in civil engineering works, however, conversions are more often sequential, and rarely revert back to the original use (e.g., coal fired power plant being converted to natural gas).

In some exceptional cases, structural components can be rapidly converted to suit changing needs. Such long-term designs involve building in redundancy in the short term, but forgoing the need to demolish the existing construction works or construct a new one for a purpose that can be met, with some creativity, with the existing structure.

NOTE Convertibility can also accommodate increased loading.

Designing for convertibility should include the following considerations:

- a) Long spans and post-and-beam construction reduce interior structural elements and allow for structural stability when removing partitions and envelope elements, while allowing for flexibility of interior fit-ups.
- b) The design of the structure accommodates the widest variety of interior design, fit-up, and building adaptation possible.
- c) Base/support elements (the rudimentary shell of a building) are constructed in a generic way to facilitate a wide range of infill possibilities.

- EXAMPLE 1 An articulated, sound-dampening divider within a room can be extended to create two smaller rooms.
- EXAMPLE 2 Sports facilities can be converted to accommodate non-sports events such as concerts or fairs.
- EXAMPLE 3 An office building can be designed and constructed to enable conversion to residential occupancy.
- EXAMPLE 4 Lightweight wall components that can easily be removed or added can be used to modify facility spaces.
- EXAMPLE 5 A natural gas pipeline is converted to an oil pipeline to accommodate shifts in energy needs.
- EXAMPLE 6 A boiler or prime mover fuel system converts from natural gas to propane depending on energy pricing.

5.2.4 Expandability

Expandability is the ability of a design or the characteristic of a system to accommodate a substantial change that supports or facilitates the addition of new space, features, capabilities and capacities.

In regard to buildings, expandability involves designing to allow for either vertical or horizontal additions in floor space. Expanding vertically can require consideration of structural allowances in the foundation and superstructure to bear larger loads or allow for the ability to easily increase the load bearing capacity of the structure without major disruptions to the occupants. For expanding horizontally, the design shall facilitate the disassembly of existing walls, envelope, or partitions so that space can be expanded without significant damage and materials can be re-used, either on the existing project or another. Designing in this way will also facilitate the reduction of space, as necessary, as well as evaluating the potential for increased space requirements in the future. Designing for expansion can require redundancy, e.g., foundation allowances for vertical and horizontal expansions (additional loads and footprint size, respectively).

In regard to civil engineering works, expandability includes changes (both increase and decrease) to capacity, including various operating modes, throughput, and bearing load by minor revamps or major development phasing.

EXAMPLE 1 Vertical columns can be designed to accommodate an additional floor level on the top of the existing structure.

EXAMPLE 2 Bridges can be designed to accommodate additional lanes of traffic below or alongside the original bridge deck.

EXAMPLE 3 Twinning railways or temporary modules can be used during peak demand.

5.3 Disassembly principles

5.3.1 General

These principles apply to assemblies and systems within a constructed asset that can be disassembled at the end-of-life, or renovated, with the potential for components to be used for other purposes. The disassembly principles that shall be considered are:

- a) ease of access to components and services;
- b) independence;
- c) avoidance of unnecessary treatments and finishes;
- d) supporting re-use (circular economy) business models;
- e) simplicity;
- f) standardization; and

- g) safety of disassembly.

Practices that can support the principles are:

- a) When possible, materials and components, which can be easily, safely, and more cost-effectively replaced or removed and transported, should be used.
- b) A means of handling components during disassembly should be provided. Handling during disassembly can require points of connection for lifting equipment or temporary supporting devices.
- c) Components that are sized to suit the intended means of handling should be used. Various possible handling options at all phases of assembly, disassembly, transport, reprocessing, and reassembly should be considered.
- d) Spare parts, and on-site storage for them, should be provided, particularly for custom-designed parts, to allow broken or damaged components to be easily disassembled and replaced, and to facilitate minor alterations to the design.

5.3.2 Ease of access to components and services

Ease of access in design allows for a material, component, or connector of an assembly, especially those with the shortest anticipated life cycle, to be easily approached, with minimal damage to and impact on it and adjacent assemblies. Ease of access reduces replacement time and the generation of unnecessary waste during the replacement or maintenance of materials or components. Ease of access is closely related to independence and is often related to uncoupling "layers" of a building or components of construction works that have significantly different lifespans.

Ease of access to parts and components of the building or civil engineering works should be provided for ease of disassembly and adaptability. If possible, recovery of components without the use of specialized equipment should be allowed for.

NOTE Accessibility in terms of ease of entry and use of a building or construction works and its services and facilities by all potential users with the widest range of capabilities is implicitly taken into account by the principles set out in this document.

Exposed connections are left accessible for disassembly or modification of components, assemblies, or systems within a constructed asset.

By making the connections more visible, it will be more apparent where steps have been taken to promote ease of disassembly. Where such connections are not visible, there is an increased risk that disassembly techniques which optimise material and product re-use will not be planned or subsequently adopted in deconstruction or strip out of the construction works.

Connections should

- a) be exposed wherever possible;
- b) leave necessary room on all sides to accommodate disassembly options including associated disassembly equipment (e.g. pulling heat exchanger bundle, space for extracted heat exchanger bundle and lifting equipment).

5.3.3 Independence

5.3.3.1 General

Independence is the quality that allows parts, components, modules and systems to be removed or upgraded without affecting the performance of connected or adjacent systems.

Maximizing independence of the functional requirements of parts, components, modules and systems is key for optimizing disassembly for both re-use and upgrade. Modularization overlaps between adaptability and disassembly when modules achieve functional independence.

Independence has to do with designing building systems or “layers” to stand independently, to facilitate the removal, adjustment, replacement, or upgrade of components. It is particularly important to think in terms of “layers” when planning from a temporal perspective for functionality and upgrades. Components of constructed assets have different design lives, and these variations need to be factored into the design. For example, the shell might require a service life that varies from 50 to 100 years, while the services might be expected to last 15 years and the interior fit-out elements perhaps 5 years.

For buildings and some civil engineering works, the three principal “layers” related to the constructed asset can be identified as follows:

- a) shell and core — structure of constructed asset, including foundation, superstructure, and envelope;
- b) mechanical and electrical services — pipes, ducts, cables, machinery, elevators, etc.;
- c) fit-out — partitioning, ceiling, floor coverings, fixtures and finishes.

The challenge is to achieve independence of layers without compromising the integration and functional performance of systems and materials, e.g., controlling heat and moisture.

Independence aims to decouple the main systems within a building or civil engineering works. The advantages are the re-use of systems, spatial adaptability, and functional adaptability. A separation of structure from enclosure will greatly facilitate adaptation and disassembly. Disassembly of a system depends upon the separation between components that are arranged within a system. The advantages are re-use of components and adaptability of the system’s functionality. Disassembly at the component level deals with separation between elements and materials, and its main advantage is in the adaptability of the component’s functionality, re-use of the elements, and recycling of the materials.

Materials or components should be removable without disrupting other components or materials. Where this is not possible, the most reusable parts of the assembly should be made the most accessible, to allow for maximum recovery of those components and materials.

The “layers” of the building shall be separated from each other to facilitate adaptation and disassembly. Separating long-lived components from short-lived components will facilitate adaptation and reduce the complexity of disassembly, allowing specific types of materials to be removed one at a time, thus facilitating the collection process for recycling or upgrading.

5.3.3.2 Reversible connections

Reversible connections can be disconnected and/or disassembled for easy alterations and additions to structures.

The use of reversible connections instead of fixed fasteners to connect products or components can allow for easier disassembly. Not only can the material be used again but the connectors (e.g., screws, bolts) can also be re-used. Other methods of disassembly include selecting materials that are fastened by a tongue-and-groove connection rather than by an adhesive compound, which can produce a permanent connection that contaminates the material and affects its re-use and ultimate recyclability.

By making products easier to take apart, so that constituent components are not harmed, elements can be re-used directly, so long as they meet performance requirements. Materials can also be readily separated by material type and then serve as inputs for other products through recycling processes. Poured and welded (wet, chemical, or fixed) connections of otherwise demountable elements decrease the potential for disassembly.

Elimination of the need for caulking and sealants, e.g., by using mechanical- instead of chemical-based water protection in the connections, will ease removal of components for repair and replacement.

Connections should

- a) leave necessary room on all sides to accommodate disassembly options;
- b) require the same standard tools for assembly as well as disassembly;
- c) use universally recognized connection methods that do not damage the materials being connected or the surrounding areas;
- d) minimize interdependency of different materials, products, components or systems.

Fewer types of connections should be used. A mix of bolts, screws, and nails requires constant shifting from one tool to another. Fewer connectors and consolidation of the types and sizes of connectors will reduce the need for multiple tools and constant change from tool to tool.

Joints and connectors should be designed to withstand repeated use, so as to minimize damage and deformation of components and materials during repeated assembly and disassembly procedures.

Assembly technologies that are compatible with standard building practice should be used. Specialist technologies will make disassembly difficult and can require specialist labour and equipment that make the option of re-use more difficult.

5.3.4 Avoidance of unnecessary treatments and finishes

Choice of finishes can limit the options for reusing or recycling the substrate, particularly if potentially hazardous substances are included. To support disassembly, finishes that can prevent the substrate from being re-used or recycled should be avoided. Finishes should serve a specific purpose, e.g. for fire and/or corrosion protection.

There might be recyclable or reusable materials that can be used either on the exterior or in the interior of a constructed asset that will have suitable inherent finishes in their “natural state”, so that there is no need to use paint, veneer, or other finishes.

EXAMPLE Cedar wood, stone, and copper roofing.

5.3.5 Supporting re-use (circular economy) business models

5.3.5.1 General

This principle is concerned with supporting the market for re-used, refurbished, remanufactured and recycled materials and products now and in the future, in support of circular economy business models. Design approaches to provide resources for future construction works should facilitate the use of secondary materials and resources in buildings and infrastructure. Wherever possible, the following approaches should be adopted, as appropriate for a specific context.

NOTE ISO 21930 addresses end-of-life approaches for construction products that relate to possible end-of-life scenarios as outlined in [Annex B](#).

5.3.5.2 Reusability

Reusability is the ability of a material, product, component or system to be used in its original form more than once and maintain its value and functional qualities during recovery to accommodate reapplication for the same or any purpose.

Consideration shall be given to the re-use potential of materials, products, components and systems. A consideration of the service life in the re-used application compared to the residual service life of the product or material in the original application shall be factored into this approach.

Materials should be selected for which it can be anticipated that a market will exist for their re-use in the future, and for which facilities exist for any required handling or processing. To facilitate future re-use, materials should be selected that can be re-used in the same application and in the original

form, without repair beyond expected maintenance. This approach is intended to achieve the economic and environmental benefits associated with disassembly. The ultimate reusability depends on the value of the material and extent to which it can retain that value and function after being removed or disassembled.

5.3.5.3 Refurbishability

Refurbishability is the ability to restore the aesthetic and functional characteristics of a product, building or other constructed asset to a condition suitable for continued use.

The refurbishing of products can reduce the consumption of natural resources.

Depending on the intended design life of the construction works, refurbishability can also help reduce operating and maintenance costs. The supplier shall make information available on how a product is refurbishable.

The use of construction components that can be refurbished, allowing for an increase in their service life, shall be considered.

EXAMPLE Wood flooring, carpet tiles.

NOTE In this context, components or modules rebuilt and returned to service as part of a routine maintenance program, is considered refurbishment.

5.3.5.4 Remanufacturability

Remanufacturability is the ability of a product to be disassembled and refabricated at the end of its useful life in a manner that provides restoration to a condition suitable for resale.

Remanufacturing differs from refurbishing in that ownership of the product is transferred to the original manufacturers or to another party that provides the restoration services. Remanufacturable products are designed in a manner that allows for complete upgrading: products can be inspected and assembled to their individual elements, and damaged pieces can be repaired or replaced. The product is therefore restored to an “as new” condition for resale by the fabricator.

The use of construction components that revert to the ownership of the original manufacturer (e.g. via take back programs) can reduce waste and lower costs.

EXAMPLE Carpet assemblies.

5.3.5.5 Increased recycling

The use of recycled materials, either directly or as feedstock within a manufactured product, supports the market for recycling of waste materials from the built environment and other sectors. This can reduce reliance on primary non-renewable materials, costs and environmental burdens. Recycling produces both economic and environmental benefits (e.g., reduced energy, water, and natural resource consumption and reduced emissions) by replacing virgin materials with recycled materials within the life cycle. The costs and impacts of transportation of recycling shall be considered.

Consideration shall be given to the use of materials, products, components and systems that have recycled content. Recycled materials might be available as the result of full or partial demolition, deconstruction, disassembly, strip out and other removal of assets. The application of pre-demolition or pre-refurbishment audits can help to identify possible materials and products to be incorporated into subsequent recycling initiatives. Recycling efficiency is optimized with homogeneous material. Recycled products, or products that contain a proportion of recycled content, might also be available from third-party suppliers.

5.3.5.6 Future recycling (recyclability)

Recyclability is the ability of component parts, materials or both to be separated and reprocessed from products and systems and subsequently used as material input for the same or different use or function.

A material is recyclable if it can be diverted from the waste stream and, through existing processes, facilities, and markets, returned to the economy. If a material is readily recyclable, a portion of its initial cost can be recovered at the end of its useful life through separation and resale as a recyclable commodity.

Consideration shall be given to the practical recyclability of materials, products, components and systems. This should include consideration of the current economic value, recovery infrastructure, and markets for the recycled materials.

NOTE Composite materials can pose a challenge, as it is often difficult to separate their individual constituents for recycling at the end of their life.

5.3.6 Simplicity

Simplicity is the quality of an assembly or system that is designed to be straightforward, easy to understand and meet performance requirements with the least amount of customization.

As a design principle, simplicity reduces the number of elements, components (subcomponents), or materials to the minimum required to execute the intended function. Experience shows that simplicity will generally reduce the likelihood of failure or breakdown and facilitate repair. Design options include limiting the use of decorative details, minimize the quantity and diversity of materials used, while working within a client's aesthetic parameters (e.g., using a standard and limited colour palette). One of the aims of simplicity is to remove barriers to disassembly.

While taking into account functional and technical requirements, the number of types of materials components should be minimized. The more homogeneous the materials of a structure, the simpler it is to sort materials on site for re-use and recycling. For components, this can help reduce the tools and techniques required for disassembly simplifying the process of sorting on site and making the potential for reprocessing more attractive, due to the larger quantities of the same or similar items.

EXAMPLE Consolidation of plumbing and electrical service points within a building has the benefit of reducing the length of lines and also reduces the potential points of entanglement and conflict with other elements (walls, ceilings, and roofs).

5.3.7 Standardization

Standardization is concerned with the use of common components, products, or processes to satisfy a multitude of requirements.

Standardized parts, which make it easier for contractors to disassemble structures while using efficient and repetitive techniques, should be considered. Standardization can support aspects of simplicity, adaptability and further re-use. Standardized parts can also allow for easier transportation, storage, and re-use.

Due to the interchangeability of standardized parts and components, standardization facilitates simplicity, adaptability and further re-use in both design and the various phases of constructed assets.

Selecting standard-size material can accommodate re-use and upgrading, since materials can be purchased with greater ease (and more cost effectively) when they are of standard dimension. Standard sizes also cut down on the creation of on-site off-cut waste for everything from timber, plywood, masonry, and insulation panels to floor tiles. Using standard dimensions needs to be reconciled with the client's requirements and the sizing requirements imposed by logistics, ergonomics, and functional needs.

Design should consider optimization of materials such as modular construction or prefabrication to reduce materials use. Prefabricated elements or components and a system of mass production should be used to reduce site work and allow greater control over component quality and conformity.

There are a number of aspects relating to standardisation, including:

- i) dimensions — such as standard height and sizes that allow for multiple types of use;
- ii) components — such as standard lengths/spans to facilitate further re-use and ease of replacement;
- iii) connections — such as connecting parts which can be separated using readily available and standard tools;
- iv) modularity — such as volumetric pods which can be slotted together, added to or taken away to promote adaptable living or working environments.

Modular design, and components and preassembled subassemblies that are compatible with other systems both dimensionally and functionally, should be used.

5.3.8 Safety of disassembly

Safety of disassembly is of paramount importance. Any component, module or system to be disassembled requires a disassembly plan that is considered at the onset of design to ensure its effectiveness.

NOTE 1 A good practice is to revisit the original disassembly plan at the time of execution to ensure all new conditions are considered including, but not limited to, inaccurate as-builts, wear or damage to structural components, presence of hazardous wastes, changing regulations, weather, error and omissions.

In the design context, safety of disassembly is concerned with easy access to accurate information on the original materials and assembly methods used for an asset, together with details of any subsequent major renovation. This information can support the correct disassembly sequencing that has been designed into the built asset to support further re-use and recycling.

Documentation that supports safe disassembly shall be maintained and available throughout the life of the constructed works (see [Clause 6](#) for further information).

NOTE 2 The principles and approaches outlined above can support safer disassembly in the following ways:

- accessibility — can facilitate disassembly thereby reducing risk of injury and handling difficulties;
- exposed connection — can help make decisions in the absence of full documentation, such as detailed drawings;
- reversible connections — can enable controlled and non-destructive disassembly;
- interdependence — can enable easier removal of separate parts, potentially reducing loads and improving the working environment;
- avoidance of unnecessary finishes — can reduce the risk of exposure to chemicals and removes the element of doubt where there are similar finishes that could be hazardous to health or not;
- simplicity — can reduce the number of elements, components and materials that could require different approaches, thus reducing time and equipment requirements;
- standardisation — can enable experience of similar systems to be used in the disassembly process, rather than having to potentially deal with elements not previously encountered;
- durability — can provide fewer instances of breakage upon removal.

6 Documentation and information

6.1 General

Documentation that supports adaptability and disassembly of the construction works shall be available and maintained throughout its life. This requires that DfD/A details and instructions are recorded and transferred across the built asset life cycle.

Disassembly manuals shall be prepared, submitted, and incorporated in shop drawings and documentation on the materials used during construction and refurbishment and material marking is needed. Furthermore, a copy of this material shall be made available to parties that need it for reference. If changes are made or additional information is developed at any stages of the life cycle, documentation and models shall be updated accordingly.

6.2 Design details

Sufficient information (see [Table 2](#)) shall be generated in the design phase documenting specific disassembly methods, material composition, recovery methods, and adaptable design features. Design details shall include specific disassembly drawings, sequences and methods of construction, and the size, strength, and material of every component involved in the assemblies.

A disassembly/adaptability manual shall be completed at the construction documentation phase and included in the commissioning process. A DfD/A section may be added to the operating manual. Details of specific adaptations should be clearly outlined. General adaptations should be noted along with the rationale for the impact on functionality, noting interconnections, interactions, and interdependencies.

6.3 Material constituents and manufacturers

Products and materials should be traceable to a specific manufacturer or supplier, with contact details, such as product manufacturer websites, included in the construction documentation. This information shall be maintained so that manufacturers can be contacted to assist in a situation where clarification is required (e.g., the separation of materials for future use or recycling).

Material constituents should be recorded to aid in the evaluation of the material or components for reusability or recyclability at the time of disassembly, environmental impacts associated with materials, as well as identifying potentially hazardous materials (specific handling requirements related to hazardous materials should be identified throughout their life cycle).

NOTE Environmental product declarations can be a source of end-of-life information and scenarios for recycling and re-use.

Materials and components should be labelled with their engineering properties so that items can be properly identified and managed at the end of their service life.

6.4 Connection detailing

Connection detailing, especially for reversible connections, should be well documented for the aspect of assembly and disassembly. Connection details are typically documented in detail design documents such as shop drawings and shall include standard descriptions such as the type of connection and connectors, size and material. In case of non-standard connections, step-by-step assembly and disassembly instructions should be provided.

Information on any required tools and necessary handling spaces shall be provided in appropriate documentation. Required tools should be retained onsite where needed for a bespoke connection type.

Durable labels or short instructions with assembly and disassembly information should be considered for the elements close to the respective connections.

6.5 Data digitisation

Data digitisation, such as that required for building information modelling (BIM), can provide a means for capturing and transferring information in standardised formats and processes. BIM can also be used for evaluating alternative designs.

Where this data and information is transferred and forms part of the documentation available at points of adaptation and disassembly, use of BIM or an asset information model (AIM) can provide those involved in these processes a better view and understanding of the best approach to disassembly or adaptability.

EXAMPLE Bar coding, quick response (QR) codes, radio frequency identification device (RFID) tags, or references to more detailed documentation, will be appropriate in some cases. “Intelligent” electronic products that contain a computer chip such as a “green port”, can provide information to facilitate disassembly and re-use.

6.6 Information transfer and management

Transferring and updating relevant information and documentation over the asset life cycle is fundamental to achieving the original design objectives in relation to DfA/D. This includes updating documentation/information in the event of modification, which affect adaptability and/or disassembly.

Information about the disassembly process shall be retained. This shall be done, whenever possible, on the actual components themselves, as well as on permanent as-built drawings, in maintenance and operations manuals, and in other documents.

The information shall be periodically updated to record changes made over the course of time and take into consideration changing re-use and recycling options, market values, etc.

Documentation and information management are very important in realizing the DfD/A objectives. The following checklist items shall be used to demonstrate that the suggested activities have been adopted.

Table 2 — Information transfer checklist

<i>Documentation and information description</i>	<i>Metric</i>
DfD/A design details in drawings, specifications, disassembly plan	Yes/no
Disassembly/deconstruction plan, including disassembly sequencing information	Yes/no
Traceable inventory of materials, suppliers, warranties	Yes/no
Approach developed and embedded into handover and operation to ensure transfer and updating throughout the constructed asset's life	Yes/no
Components, products and constructed asset has directly accessible information pertaining to identification, warranties, services life, disassembly (e.g. bar code, RFID tagging)	Yes/no

7 Continuing implementation of DfD/A

7.1 General

It is important that all involved in the design, product supply, construction, commissioning, operation, refurbishment and decommissioning aspects have sufficient knowledge and understanding to implement the intended DfD/A results. Designers have the major role in considering design for disassembly and adaptability to facilitate the best economic and environmental opportunities. Clients often provide the drivers and the context for designers to adopt this role. The supporting supply chain, from product suppliers, to constructors, facility managers and those decommissioning constructed assets also have a role in supporting DfD/A.

7.2 Product and component suppliers

Those providing materials, products and systems to the construction sector can greatly influence the DfD/A principles laid out in this document. Evaluation of product characteristics and composition, methods of assembly and supporting information against these principles shall be undertaken to identify potential for improvement. Providing access to this information through a digital platform, such as BIM, should be considered.

Sector-based improvement strategies can also be developed, where input from the related supply chain should be considered. At minimum, this shall include representation from design, assembly (construction), disassembly, deconstruction, demolition, and resource management.

This document describes the development of different end-of-life approaches on the construction works or construction product level in [Annex B](#).

7.3 Construction

Most of the decisions pertaining to DfD/A will have been made already so there is an assumption that these would be carried through into the construction phase. Knowledge transfer between the design and construction teams to discuss the DfD/A intent and implementation measures, as well as any perceived challenges which might be encountered during the construction phase, should be undertaken. More detailed planning and atypical procurement could be necessary to deliver these decisions, so collaborative work as early as possible should be undertaken.

Where this is not achievable (e.g. for cost constraints or lack of availability of specified components), the constructors shall work with the design team to identify alternatives that are the next best solution and will minimise impact on other decisions taken to promote DfD/A. Documentation and models shall be updated accordingly.

7.4 Handover/commissioning

A critical aspect of handover is to ensure all appropriate documentation and modelling relevant to DfD/A is transferred to those owning and operating the asset, including training of building owners, their agents and facility managers. See [Clause 6](#) for further information on documentation that should be prepared and transferred.

7.5 Use stage

Routine or scheduled maintenance during the use stage of the asset life shall be established to ensure that the disassembly properties of components and elements are not compromised, including the following:

- documentation and information models are updated or transferred;
- maintenance requirements to optimise durability are complied with;
- unnecessary finishes and treatments are not applied.

NOTE Management and ownership changes can challenge document transfer protocol. Systems or checklists can be put in place to make sure documentation is not lost or out of date.

7.6 Refurbishment

Refurbishment offers the opportunity to embed DfD/A where they might not be incorporated into the asset already. In this instance, the previous steps from the client brief onwards should be considered, alongside the specific DfD/A principles.

In the case of refurbishment of an asset that includes aspects of DfD/A, it is recommended that these are fully exploited during the refurbishment process and retained and enhanced where possible. In

particular, alongside the risks outlined in [7.5](#) are further risks arising from significant refurbishment works, these include:

- reduced capacity for mixed or alternative use, such as creating fixed partitioning where there was previously a more flexible arrangement;
- partial demolition which reduces the capacity for expanding or converting;
- connections are covered or replaced with irreversible connections;
- reusable and recyclable materials and components are removed and there is no further use or a low-grade recovery or disposal route is taken;
- standardised elements are replaced with non-standardised ones.

7.7 End-of-life/decommissioning

Any design for disassembly approaches developed, maintained and retained during the asset life shall be fully transferred and communicated to and acknowledged by those commissioning or undertaking the dismantling of the asset. This shall be made available in the documentation, which had been updated and transferred during the operational phase, including any refurbishment.

For shorter-lived assets, it might be possible to gain and transfer information on how successful design for disassembly approaches were at this stage. This could then inform further projects in their design and products in their development.

[Annex B](#) describes the development of different end-of-life approaches for materials, products, components and systems on the construction works or construction product level.

7.8 Education and capacity building

As DfD/A benefits often take many years to observe over a full cycle, conscious promotion of such efforts is required. Therefore, an objective should be set to transfer knowledge from any project adopting the DfD/A principles set out in the standard to third parties. To facilitate this, an operation and maintenance plan and public relations plan shall be developed, implemented and disseminated.

Consideration should be given to the level (and development) of experience of clients, designers, product suppliers, constructors, asset managers, deconstructors and other supply chain actors involved in the constructed asset in the context of DfD/A and wider resource efficiency or supporting circular economy objectives. Relevant DfD/A information from previous projects should be clearly acknowledged, with the principles provided here acting as a checklist to ensure information gaps do not skew the focus of the project.

Where knowledge gaps (based on the specific DfD/A principles) exist an action plan for filling each gap should be developed and implemented. This could be through training, reading guidance or bringing additional resource into the project, such as an advisor with specific experience. For example, training on the maintenance of either the asset or the documentation should be provided.

Annex A (informative)

Feasibility assessment of design for disassembly options for elements or components/assemblies

[Table A.1](#) provides an example of how specific elements or components/assemblies can be assessed for each DfD/A principle. The example deals with building mechanical systems, which include ducting, diffusers, pipes, flexible tubing, and connectors. A similar DfD/A evaluation process can be applied to other elements and constructed assets. The tabular format can be used to assess and communicate early outline specifications to ensure DfD/A principles are being addressed and to identify opportunities for improvement. Different configuration or design options can be assessed or ranked using decision-making tools.

Table A.1 — Assessment of components/assemblies for specific DfD/A principles

Design for disassembly summary Mechanical/electrical — Mechanical	Versatility	Convertibility	Expandability	Standardization	Ease of access to components and services	Safety of disassembly	Simplicity	Supporting re-use (circular economy) business models	Independence/reversible connections	Avoidance of unnecessary treatments and finishes
Consider plastic fasteners where corrosion is an issue					X			X		
Use removable/adjustable fasteners: clips, ties, snap locks, clamp and hanger systems, worm clamps, tie wires, twist locks									X	
Use standardized screws with same-sized head				X			X	X	X	
Use corrosion-resistant and dielectric fasteners where appropriate										
Ensure access to one side					X				X	
Common driver; can use magnetized bit							X			
Use Robertson, Torx or Hex fasteners (avoid Phillips and slot screws) for reversibility							X		X	
Use standardized nut and bolt sizes	X			X			X			
Ensure access to two sides (to the nut and bolt)					X					
Common driver; can use magnetized bit				X			X			
Nuts and bolts provide reversible connections; use self-locking nuts to reduce parts required							X		X	
Use embedded nuts for one-sided bolt insertion and removal							X		X	
Two part — Hook and hanger										
Two-part system allows quick disconnect of the hanger from the permanently installed hook. Hanger requires only one tool.							X		X	
Ducts										
Flex duct										
Flexible ducts can be re-used and rerouted and are simple and easy to install	X		X				X		X	
Pre-insulated option is available							X			
Specify quick clamp connections									X	
Fibre ducting contains one component (consider the possibility of fibre emissions)							X			
Rectangular ducts (metal) have common format/size. Use common rectangular ducts where ducting systems are not expected to change frequently.	X		X							
Use reversible fasteners and seals for duct installation									X	
Only one component is required. Provides minimal size and weight and is reversible.							X		X	
Standardized; provides simple, reversible installation. Separate fasteners are not required.							X		X	

Table A.1 (continued)

Design for disassembly summary Mechanical/electrical — Mechanical	Versatilit ity	Convert- ibility	Expand- ability	Stand- ard- iza- tion	Ease of access to compo- nents and services	Safety of dis- assem- bly	Sim- plici- ty	Supporting re-use (cir- cular econo- my) business models	Inde- pend- ence/ reversi- ble con- nections	Avoidance of unneces- sary treat- ments and finishes
Specify modular, self-contained, plug-and-play, internally matched components	X		X				X		X	
For easy access, use open ladder raceways instead of conduit where possible. Install below suspended ceiling and/or HVAC where appropriate.					X					
Standardized labelling facilitates recognition										
Facilitate speed of recovery and recycling by using labels, tags, imprinted or engraved information										
Use colour-coded or alphanumeric (end-point) identification label or tags for all runs										
Label all circuits on distribution boxes for ease of identification. Match to electronic map/control panel.										
Use standardized flexible tubing that can be recovered and re-used	X									
Specify flexible tubing instead of rigid conduit to simplify installation and facilitate disassembly	X									
Use colour-coded flexible tubing to aid in quick identification										

Annex B (informative)

Developing end-of-life scenarios

Design for disassembly should enable the selection, collection, recycling/reprocessing and re-use of construction materials, products, components and systems, thereby contributing to the evolving concept of a circular economy. This concept depends on the efficient use of resources and the closing of the life cycle loop by avoiding waste, both in terms of amount and hazardous potential. The implementation of this concept depends on the provision of documented information according to [Clause 6](#) in order to support the application of the DfD/A principles in [5.3](#).

The assessment of the full life cycle of a construction product requires the development of scenarios at the level of buildings or civil engineering works, in alignment with the requirements of modules C1-C4 as described in ISO 21930. Although most removal methods involve more than one type of end-of-life scenario, the following methods can be defined:

- 1) demolish the construction works by destructive methods;
 EXAMPLE Implosion, high reach arm, wrecking ball.
- 2) disassemble and separate components of the construction works by removing parts (deconstruction, dismantlement);
- 3) selectively disassemble specific components of the construction works (partial deconstruction) and demolish the remainder of the construction works by destructive methods (partial demolition).

The development of end-of-life scenarios for construction works should take into account the decisions made during the design and construction stages of the life cycle. The development of end-of-life scenarios could also depend upon considerations such as:

- service life planning;
- proximity to other structures;
- environmental issues;
- hazardous waste content and other occupational health hazards;
- use of recyclable products;
- ease of deconstruction;
- recyclability of building products;
- adherence to the design guidance provided in this document;
- manufacturer take back programs;
- degree to which building materials can be separated, collected and prepared for re-use or recycling.

Modelling the life cycle of buildings requires a clear scenario at end-of-life (deconstruction/demolition respectively).

Modelling end-of life scenarios influences the provision of information at the product level when addressing the entire life cycle in an environmental product declaration (EPD) according to ISO 21930. This also applies to the determination of net benefits of building products beyond the system boundaries from Module D (future re-use, recycling and energy recovery), which should be realistic.

Therefore, the EPD should provide all potential scenarios for deconstruction/demolition (Module C1) at the building level.

NOTE End-of-life scenarios also encompass the replacement of products during the use stage (B4 in [Figure B.1](#)).

It is necessary to develop probable end-of-life scenarios for the construction works in order to model the full life cycle of building products used as part of the construction works. Information related to end-of-life scenarios of the construction works is required to develop cradle-to-grave environmental product declarations for construction products according ISO 21930. End-of-life scenarios at the construction works level are developed and documented under modules C1–C4 in [Figure B.1](#). End-of-life scenarios should reflect the existing technology and current practices applied in the region where the construction works is located.

End-of-life scenarios generally reflect the current treatment technology for reclaimed material available in the respective country (i.e. the region where the construction works is located). However, they should not use best or worst case assumptions but reflect average and realistic assumptions based on the present national state-of-the-art and common practice.

Construction works assessment information														
Construction works life cycle information within the system boundary											Optional supplementary information beyond the system boundary			
A1 - A3 PRODUCTION Stage <i>(Mandatory)</i>			A4 - A5 CONSTRUCTION Stage		B1 - B7 USE stage					C1 - C4 END-OF-LIFE Stage				D
A1	A2	A3	A4	A5	B1	B2	B3	B4*	B5	C1	C2	C3	C4	
Extraction and upstream production	Transport to factory	Manufacturing	Transport to site	Installation	Use	Maintenance (incl. production, transport and disposal of necessary materials)	Repair (incl. production, transport and disposal of necessary materials)	Replacement (incl. production, transport and disposal of necessary materials)	Refurbishment (incl. production, transport and disposal of necessary materials)	De-construction / Demolition	Transport to waste processing or disposal	Waste processing	Disposal of waste	Potential net benefits from reuse, recycling and/or energy recovery beyond the system boundary
			<i>Scenario</i>		<i>Scenario</i>					<i>Scenario</i>				<i>Scenario</i>
					B6 Operational energy use									
					<i>Scenario</i>									
					B7 Operational water use									
					<i>Scenario</i>									

^a Replacement information module (B4) is not applicable at the product level.

Figure B.1 — Common four life cycle stages and their information modules for construction products and construction works and the optional supplementary module D

Annex C (informative)

Measuring performance

C.1 General

Setting objectives relating to DfD/A can be meaningless if there is no mechanism to demonstrate the progress against these objectives compared to a business as usual scenario. Establishing the baseline performance in the business as usual scenario is therefore a priority to measuring the progress towards DfD/A and subsequent implementation. There are specific areas of performance, which could be measured, either in a quantitative or qualitative sense to determine the baseline scenario against which progress can be assessed.

This Annex provides brief guidance on approaches to measurement practices that can be adopted to set objectives, targets and monitor performance. Ways of ranking and aggregating the measures can also be envisaged as part of an assessment system but the development of such systems is outside the scope of this document.

The measurement approaches are set out in the order of the DfD/A principles without any indication of hierarchy. The selection of an appropriate set of performance metrics and targets will be most effective if it aligned with the specific principles planned and adopted during the development of the client brief.

The performance measures assessing each DfD/A principle can be assembled into a matrix or checklist to guide users in design for disassembly and adaptability; refer to [Annex A](#) for an example. In some situations, other tools will be required to perform more detailed analyses.

NOTE There are a number of research activities underway to facilitate integrated performance measurement, such as, “overall re-use potential and/or transformation capacity”, which could be used in the future to present a more holistic performance perspective.

Best practices include the use of a competency checklist (yes/no) indicating the completion of competency actions.

Best practices include the use of a dissemination plan and a checklist (yes/no) indicating the completion of actions set out in the dissemination plan.

C.2 Versatility

Versatility can be measured by the percentage of usable space that has multiple uses on a daily, weekly, or monthly basis, without requiring changes to the main features of the space.

C.3 Convertibility

Convertibility can be measured by the percentage of usable space that has been designed to be converted easily to multiple uses.

C.4 Expandability

Expandability can be assessed in terms of the number of additional floors or percentage of additional floor space possible without major alteration to the foundation and structural system. The percentage of reserve load bearing capacity can also be used to assess expandability.

A “yes or no” assessment of vertical expandability can be made if the structural design of the designated roof area allows for supported loads of at least one additional floor-level of a similar use-type.

Horizontal expandability can be assessed in terms of the amount or percentage of additional lot area not covered by the building area which is permitted to be built on.

NOTE Expandability can be constrained by structural design limits or municipal planning regulations.

C.5 Ease of access to components and services

An ordinal or interval rating scale for the relative accessibility provided by design options can be created. In this way, design options can be ranked. An example might be a 0 to 5 scale, with each point given a clear definition, for example:

- 0) no accessibility without significant damage to surrounding materials”;
- 1) limited accessibility with some significant damage to more than 50 % the surrounding materials;
- 2) limited accessibility with minor damage to more than 50 % of surrounding materials;
- 3) mostly accessible with minor damage to less than 50 % of the surrounding materials;
- 4) mostly accessible with only minor damage to less than 25 % of the surrounding materials;
- 5) full accessibility with minimal work and no damage to surrounding materials”.

A “yes or no” assessment can be made for each connection type, depending on whether it is exposed or not.

C.6 Independence

While independence is a difficult characteristic to quantify, an ordinal or interval rating scale for the relative independence of design options can be created. In this way, design options can be ranked. An example is a 0 to 5 scale, with each point given a clear definition, e.g., “0 — no consideration to lifespan of component, hierarchy and modularity, sequential assembly” to “5 — parallel assembly and open, modular hierarchy”.

Components that are

- a) dependent and fixed are characterized by
 - i) maximum integration;
 - ii) a hierarchy of assembly, which is not related to the component service life and expected time until obsolescence; and
 - iii) the application of sequential assembly sequences.
- b) independent are characterized by the
 - i) application of parallel instead of sequential assembly/disassembly; and
 - ii) creation of an open hierarchy of distinct modules.

C.7 Reversible connections

A “yes or no” assessment can be made for each connection type, depending on whether it is reversible. At the subcomponent or higher levels, one can measure the total percentage of connection types that can be reversed to recover materials.

C.8 Avoidance of unnecessary treatments and finishes

At a material level, a “yes or no” assessment is possible: is the material “unfinished” and recyclable or reusable? If the material finish does not inhibit its re-use or recyclability, it satisfies this criterion.

C.9 Supporting re-use (circular economy) business models

Some indicators which could be applied here include:

- percentage (by weight or volume) and value of reclaimed content;
- percentage (by weight or volume) and value of recycled content;
- for each material or component in the construction works:
 - practically reusable or not — based on disassembly requirements and service life versus design life of construction works; for a product to be deemed reusable, there needs to be an application that allows an end-user to economically re-use the product without extensive cleaning or restoration; Re-use can be graded on a continuum, ranging from re-use of the entire structure to re-use of selected materials;
 - practically recyclable or not — based upon ease of separation into material streams and current availability of reprocessing facilities for each material stream at expected grade (e.g. levels of contamination with other materials);
- for refurbishability, a “yes or no” assessment of a product is possible, based on specifics provided by the supplier;
- for remanufacturability, a “yes or no” assessment of a product is possible, based on specifics provided by the supplier.

C.10 Simplicity

Metrics for simplicity include the number of

- a) parts per element or component from a comparative perspective; and
- b) dimensions or sizes of similar materials (standardization).

C.11 Standardization

The level of standardisation within the built asset can be determined at various levels. This could be through a percentage of the overall build (cost, volume or mass), for each of the following categories:

- i) dimensions;
- ii) components;
- iii) connections;
- iv) modularity;
- v) interoperability.

C.12 Safety of disassembly

The checklist detailed in [Table 2](#) could be completed, alongside the following metrics:

- durability — service life of each structural element as a percentage of design life of constructed asset;

- accessibility — high, medium, low (through assessing numbers of elements achieving 0/1; 2/3; or 4/5 scores);
- exposed connection — percentage; yes or no;
- reversible connections — percentage; yes or no;
- interdependence — high, medium, low (through assessing numbers of elements achieving 0/1; 2/3; or 4/5 scores);
- avoidance of unnecessary finishes — percentage; yes or no, where applicable;
- simplicity — high, medium, low (based on simplicity assessment);
- standardization — high, medium, low (based on simplicity assessment).

C.13 Durability

Durability is not listed as a DfD/A principle in this document, but it is a key consideration that impacts DfD/A decision-making. Metrics for durability can include the cost of maintenance as a percentage of the purchase price, the service life (years) of a given product compared to alternative products that serve the same function at the same performance level and the “material intensity per standardized unit of service”.

EXAMPLE 1 Corrosion-resistant reinforcing steel is used instead of unprotected reinforcing steel.

EXAMPLE 2 If a bituminous roofing membrane lasts 30 years instead of 15, the waste generated per year of use is cut in half.

Bibliography

- [1] ISO 7176-26:2007, *Wheelchairs — Part 26: Vocabulary*
- [2] ISO/TS 12720, *Sustainability in buildings and civil engineering works — Guidelines on the application of the general principles in ISO 15392*
- [3] ISO 14021:2016, *Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling)*
- [4] ISO 14040:2006, *Environmental management — Life cycle assessment — Principles and framework*
- [5] ISO 15686 (all parts), *Buildings and constructed assets — Service life planning*
- [6] ISO 16745-1, *Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 1: Calculation, reporting and communication*
- [7] ISO 16745-2, *Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 2: Verification*
- [8] ISO 17738-1:2017, *Thermal insulation products — Exterior insulation and finish systems — Part 1: Materials and systems*
- [9] ISO 20400:2017, *Sustainable procurement — Guidance*
- [10] ISO 21929-1, *Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for buildings*
- [11] ISO/TS 21929-2, *Sustainability in building construction — Sustainability indicators — Part 2: Framework for the development of indicators for civil engineering works*
- [12] ISO 21930:2017, *Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services*
- [13] ISO 21931-1, *Sustainability in building construction — Framework for methods of assessment of the environmental performance of construction works — Part 1: Buildings*
- [14] ISO 21931-2, *Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 2: Civil engineering works*
- [15] CSA Z782, *Guideline for Design for Disassembly and Adaptability in Buildings*. CSA Group, 2006
- [16] BS 8887-2:2009, *Design for manufacture, assembly, disassembly and end-of-life processing (MADE). Terms and definitions*. British Standards Institution, 2009
- [17] MoRGAN C., Stevenson F. *Design and Detailing for Deconstruction, SEDA Design Guides for Scotland : No. 1*. SEDA, 2005
- [18] GosLing J., SASSI P., NAIM M., LARK R., *Adaptable buildings: a systems approach*. *Sustainable Cities and Society* 7, pp. 44–51, 2013
- [19] AdAMS K. *Outline methodology for design for deconstruction for residential buildings*. Building Research Establishment, United Kingdom
- [20] Crowther P. *Investigating design for disassembly through creative practice*. In *Intersections International Symposium*, 30 June 2014, Santa Verdiana Church, Florence, Italy (Unpublished)
- [21] *Design for deconstruction*. United States Environmental Protection Agency, 2007

- [22] Guy B., CIARIMBOLI N. *Design for Disassembly in the built environment: a guide to closed-loop design and building*. Hamer Center for Community Design and The Pennsylvania State University
- [23] DuRMiseVIC E., YeAng K., *Design for Disassembly (Dfd)*. *Archit Design*, **79**: 134–137, 2009
- [24] Chini A., ShuLTMann F. *Design for Deconstruction and Materials Reuse*. Proceedings of the CIB Task Group 39 — Deconstruction Meeting, CIB Report, Publication 272, Karlsruhe, Germany, 2002
- [25] Chini A. *Deconstruction and Materials Reuse*. Proceedings of the CIB Task Group 39 — Deconstruction Meeting, CIB World Building Congress, CIB Report, Publication 287, Gainesville, Florida, 2003
- [26] SchMIDT R.III, Austin S.A., Brown D., *Designing adaptable buildings*. 11th International DSM Conference, Greenville, South Carolina, 12–13 October 2013
- [27] Conejos S., Langston C., SMITH J., *AdaptSTAR model: A climate-friendly strategy to promote built environment sustainability*. *Habitat International*, **37**: 95–103, 2013
- [28] Langston C. *On archetypes and building adaptive reuse*. Bond University, 2011
- [29] *Buildings as Material Banks*. Retrieved from <http://www.bamb2020.eu/>
- [30] Federal Register, Vol. 77, Thursday, No. 197, October 11, 2012, Part VII, Federal Trade Commission, 16 CFR Part 260, Guides for the Use of Environmental Marketing Claims; Final Rule
- [31] HashEMIAN M. *Design for Adaptability*. Ph.D. Thesis. University of Saskatchewan, 2005

ICS 91.040.01

Price based on 35 pages

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Anexo B:

Minuta de Campo

**Instrumento De Medición General De La Sustentabilidad De Una Vivienda
Unifamiliar Basado En La Norma Iso 20887:2020 Para La Empresa Inversiones
Graca 1802 C.A.**

MEDICIÓN GENERAL DE SUSTENTABILIDAD

NORMA: ISO 20887:2020

ZONA: _____

TIPO VIVIENDA: UNIFAMILIAR

PROYECTO: _____

Categoría	Principio	%	
Durabilidad	El tiempo útil de la vida de servicio de la infraestructura está entre 35-50 años.	10	
Versatilidad y Convertibilidad	El mayor porcentaje de los espacios son aptos para su uso constante sin cambios estructurales.	5	
	El mayor porcentaje de los espacios diseñados para usos múltiples cumplen su función sin cambios estructurales.	5	
Expandibilidad	La estructura puede expandirse proporcionalmente al terreno verticalmente sin alterar las fundaciones y sistema estructural.	5	
	La estructura puede expandirse proporcionalmente al terreno horizontalmente dentro de los límites de diseño y regulación municipal (porcentaje de construcción permitida).	5	
Acceso a Componentes y Servicios	No existe accesibilidad sin daños significantes al material circundante.	0	
	Acceso limitado con daños significante al más del 50% del material circundante.	2	
	Acceso limitado con daños menores al más del 50% del material circundante.	4	
	Mayormente accesible con daños menores al menos del 50% del material circundante.	6	
	Mayormente accesible con solo daños menores al menos del 25% del material circundante.	8	
	Accesibilidad total con el trabajo mínimo y sin daños al material circundante.	10	
Independencia del Diseño	Los componentes se caracterizan por una aplicación paralela en vez de secuencial de montaje/desmontaje.	5	
	Los componentes se encuentra en una jerarquía abierta de distintos módulos.	5	
Integración Independiente de Capas	Obra gris.	2.50	
	Servicios eléctricos.	2.50	
	Servicios mecánicos.	2.50	
	Acabados.	2.50	
Simplicidad del Diseño	No aplica.	0	
	Baja.	2.5	
	Media	5	
	Alta	10	
Estandarización	Mayormente se usan elementos prefabricados que reducen trabajo en sitio.	2.50	
	Predominan dimensiones estándares.	2.50	
	Los componentes y conexiones empleados tienen cualidades estándares (tipo, tamaño y material)	2.50	
	Se emplea un diseño modular.	2.50	
Materiales y/o Sistemas	Predominan materiales y/o sistemas con propiedades reusables y vida útil prolongada.	2.50	
	Predominan materiales y/o sistemas con propiedades de restauración.	2.50	
	Predominan materiales y/o sistemas con componentes reciclados.	2.50	
	Existe un manejo adecuado de los desechos reutilizables o reciclables.	2.50	
Documentación	Building Information Modeling (BIM)	2.50	
	Existe un manual de desmontaje y adaptabilidad de la infraestructura.	2.50	
	Existe un informe con información de manufactura de los materiales y productos utilizados (propiedades, contacto del fabricante, proveedor y garantía)	2.50	
	Existe un informe detallado de conexiones y componentes (tipo, medidas, materiales).	2.50	
	En caso de no ser estándares, se adjunta un manual paso a paso de montaje y desmontaje de los mismos.		
TOTAL(%)		100	

EXCLUYENTE

NO EXCLUYENTE

Anexo C:

Minuta de Campo - Evaluación Vivienda

**Instrumento De Medición General De La Sustentabilidad De Una Vivienda
Unifamiliar Basado En La Norma Iso 20887:2020 Para La Empresa Inversiones
Graca 1802 C.A.**

MEDICIÓN GENERAL DE SUSTENTABILIDAD

NORMA: ISO 20887:2020

TIPO VIVIENDA: UNIFAMILIAR

ZONA: TRIGAL
 PROYECTO: QUINTA 92-111

Categoría	Principio	%	
Durabilidad	El tiempo útil de la vida de servicio de la infraestructura está entre 35-50 años.	10	10
	El mayor porcentaje de los espacios son aptos para su uso constante sin cambios estructurales.	5	
Versatilidad y Convertibilidad	El mayor porcentaje de los espacios diseñados para usos múltiples cumplen su función sin cambios estructurales.	5	10
Expandibilidad	La estructura puede expandirse proporcionalmente al terreno verticalmente sin alterar las fundaciones y sistema estructural.	5	5
	La estructura puede expandirse proporcionalmente al terreno horizontalmente dentro de los límites de diseño y regulación municipal (porcentaje de construcción permitida).	5	
Acceso a Componentes y Servicios	No existe accesibilidad sin daños significantes al material circundante.	0	8
	Acceso limitado con daños significante al más del 50% del material circundante.	2	
	Acceso limitado con daños menores al más del 50% del material circundante.	4	
	Mayormente accesible con daños menores al menos del 50% del material circundante.	6	
	Mayormente accesible con solo daños menores al menos del 25% del material circundante.	8	
	Accesibilidad total con el trabajo mínimo y sin daños al material circundante.	10	
Independencia del Diseño	Los componentes se caracterizan por una aplicación paralela en vez de secuencial de montaje/desmontaje.	5	10
	Los componentes se encuentra en una jerarquía abierta de distintos módulos.	5	
Integración Independiente de Capas	Obra gris.	2.50	10
	Servicios eléctricos.	2.50	
	Servicios mecánicos.	2.50	
	Acabados.	2.50	
Simplicidad del Diseño	No aplica.	0	10
	Baja.	2.5	
	Media	5	
	Alta	10	
Estandarización	Mayormente se usan elementos prefabricados que reducen trabajo en sitio.	2.50	2.50
	Predominan dimensiones estándares.	2.50	
	Los componentes y conexiones empleados tienen cualidades estándares (tipo, tamaño y material)	2.50	
	Se emplea un diseño modular.	2.50	
Materiales y/o Sistemas	Predominan materiales y/o sistemas con propiedades reusables y vida útil prolongada.	2.50	2.50
	Predominan materiales y/o sistemas con propiedades de restauración.	2.50	
	Predominan materiales y/o sistemas con componentes reciclados.	2.50	
	Existe un manejo adecuado de los desechos reutilizables o reciclables.	2.50	
Documentación	Building Information Modeling (BIM)	2.50	—
	Existe un manual de desmontaje y adaptabilidad de la infraestructura.	2.50	
	Existe un informe con información de manufactura de los materiales y productos utilizados (propiedades, contacto del fabricante, proveedor y garantía)	2.50	
	Existe un informe detallado de conexiones y componentes (tipo, medidas, materiales).	2.50	
	En caso de no ser estándares, se adjunta un manual paso a paso de montaje y desmontaje de los mismos.		
TOTAL(%)		100	68

EXCLUYENTE

NO EXCLUYENTE