UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO
FACULTAD DE ARQUITECTURA
CENTRO DE INVESTIGACIONES DE DISEÑO INDUSTRIAL

Diseño de una familia de paneles acústicos que sigue las pautas de la marca Kinnarps

Tesis Profesional que para obtener el título de Diseñador Industrial presenta:

Gabriel Juárez Mejía

Con la dirección de:
M.D.I. Vanessa Sattele Gunther

y la asesoría de:
M.D.I. Gustavo Víctor Casillas Lavín,
D.I. Jorge Vadillo López,
D.I. Miguel de Paz Ramírez,
D.I. Victor Manuel Valencia Sosa

"Declaro que este proyecto de tesis es totalmente de mi autoría y que no ha sido presentado previamente en ninguna otra Institución Educativa y autorizo a la UNAM para que publique este documento por los medios que juzgue pertinentes"

Ciudad Universitaria, CDMX
2021

CENTRO DE INVESTIGACIONES DE DISEÑO INDUSTRIAL

Programa de Egreso y Titulación

Aprobación de impresión

EP01 Certificado de aprobación de impresión de documento.

Coordinación de Titulación
Facultad de Arquitectura, UNAM
PRESENTE

El director de tesis y los cuatro asesores que suscriben, después de revisar la tesis del alumno

NOMBRE JUAREZ MEJIA GABRIEL No. DE CUENTA 312656221

NOMBRE TESIS DISEÑO DE UNA FAMILIA DE PANELES ACÚSTICOS QUE SIGUE LAS PAUTAS DE LA MARCA KINNARPS

OPCIÓN DE TITULACIÓN TESIS Y EXAMEN PROFESIONAL

Consideran que el nivel de complejidad y de calidad de LA TESIS, cumple con los requisitos de este Centro, por lo que autorizan su impresión y firman la presente como jurado del

Examen Profesional que se celebrará el día a las horas.

Para obtener el título de DISEÑADOR INDUSTRIAL

ATENTAMENTE
"POR MI RAZA HABLARÁ EL ESPÍRITU"
Ciudad Universitaria, D.F. a 21 de agosto de 2020

NOMBRE	FIRMA
PRESIDENTE M.D.I. VANESSA SATTELE GUNTHER	Vanessa Sattele
VOCAL D.I. JORGE VADILLO LÓPEZ	[firma]
SECRETARIO M.D.I. GUSTAVO VICTOR CASILLAS LAVÍN	[firma]
PRIMER SUPLENTE D.I. MIGUEL DE PAZ RAMÍREZ	[firma]
SEGUNDO SUPLENTE D.I. VICTOR MANUEL VALENCIA SOSA	[firma]

ARQ. MARCOS MAZARI HIRIART
Vo. Bo. del Director de la Facultad

Ficha técnica

El presente documento muestra el proceso y resultado del diseño de una familia de paneles acústicos, en colaboración con la marca Kinnarps. A continuación se presentan las principales características de dicho producto.

Mercado potencial del producto
Empresas privadas, escuelas, bibliotecas y hospitales, que estén interesados en la acústica de sus espacios de interior como lon son salas de juntas, salas de espera, bibliotecas y salones de clase. El sector principal es Europa del norte, sin embargo se busca integrar al producto en el portafolio de la marca global Kinnarps AB.

Valores de oferta (aportaciones de diseño)
Familia de paneles acústicos con tres tipos diferentes de estructuras que funcionan como bases donde dos, tres o cuatro paneles se pueden montar rápidamente con imanes. Se ofrece al cliente la posibilidad de elegir y combinar varios tipos de paneles en distintas posiciones, según el tipo de espacio que tengan.

Principios de funcionamiento
Se propone tener dos capas de diferentes materiales absorbentes, combinando relleno acústico Kinnarps, hecho de fibras de poliéster, en conjunto con fieltro de lana, que tiene un coeficiente de absorción de 0.70. Las bases además tienen unos separadores con el objetivo de generar un espacio de aire entre los paneles y la pared para captar el sonido a mayor velocidad y potencialmente aumentar la absorción del mismo.

Materiales y procesos de manufactura
Los materiales necesarios para la fabricación del producto son los siguientes:
MDF de 6 mm, relleno acústico Kinnarps de 20 mm, fieltro de lana de 20 mm, tela de poliéster, imanes neodinios y piezas comerciales para anclaje a muros.
Los procesos necesarios para la fabricación del producto son los siguientes:
corte con router CNC, moldeado y prensado con calor, corte y ensamble manual por un operador.

Factores humanos considerados
Se consideraron los datos obtenidos de la investigación documental donde se recabaron las frecuencias de sonido que el producto debería de absorber dependiendo de cada espacio, factores ergonómicos de los montadores, además de los resultados obtenidos de una investigación de campo, que incluyó entre otras cosas, estudios de usuario y entrevistas con clientes, reflejados en *personas* descritas en este documento.

Estética del producto
El estilo viene principalmente de un estudio de palabras clave que describen a la marca escandinava Kinnarps y en *moodboards* de espacios interiores diseñados por la misma empresa. La estética de los paneles se basa en formas regulares simples, y en siluetas que asimilan la hoja de un árbol, que al ser montadas en las bases, pueden crear distintas composiciones y un contraste llamativo entre las chapas de madera y la gran variedad de textiles que la marca ofrece.

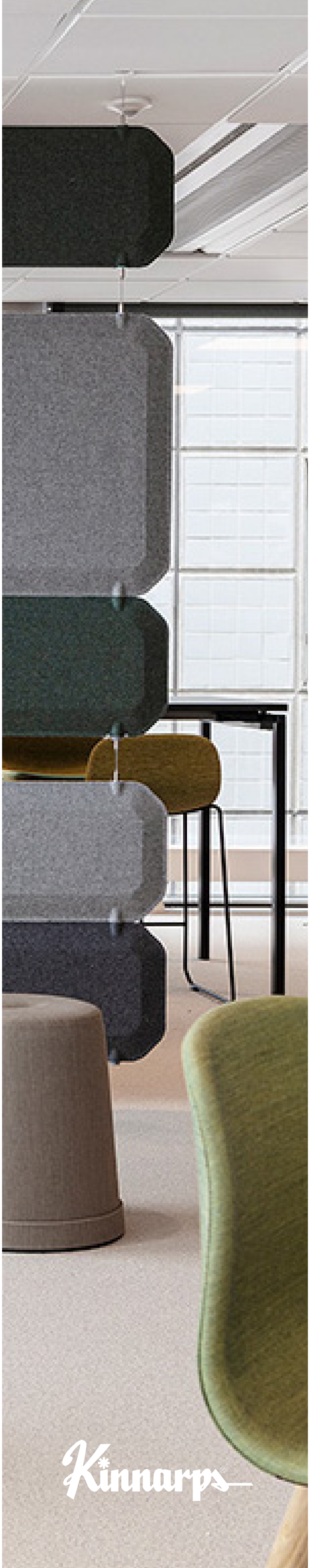
A mis padres Marta y Gerardo, a mis hermanos Gerardo y Luis, porque sin ellos, no sería la persona que soy hoy.

ÍNDICE

PRIMERA SECCIÓN

SEGUNDA SECCIÓN

TERCERA SECCIÓN



PRIMERA SECCIÓN

Introducción

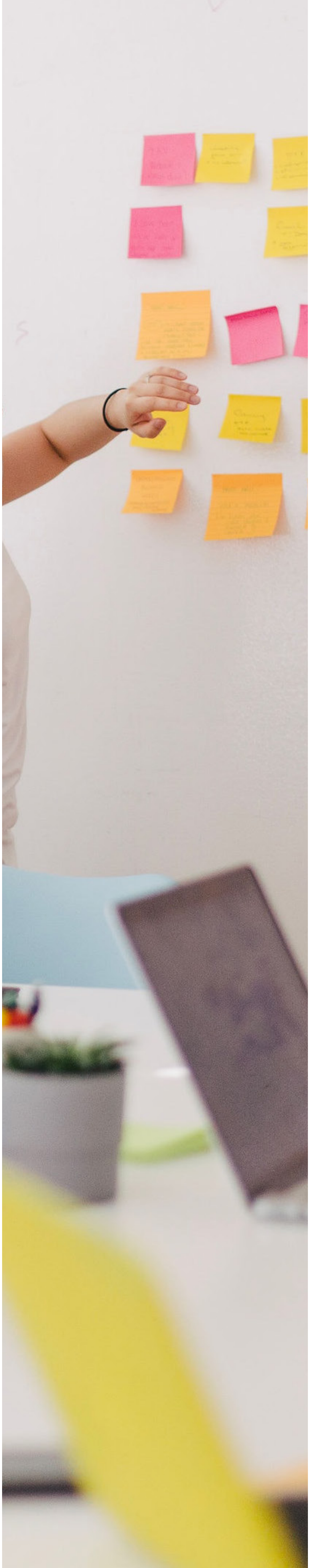
El proyecto presentado aquí fue elaborado en colaboración con mi compañero Julián Soria de la Torre durante el semestre de primavera 2019 en la Universidad de Skövde en Suecia, como parte del Programa de Movilidad Estudiantil Internacional de la Facultad de Arquitectura de la UNAM. Dicho proyecto fue desarrollado en la materia *Bachelor Degree Project in Product Design Engineering*, bajo la supervisión de Ulrica Bohné, Aitor Irondo Pascual y la examinación de Ari Kolbeinsson. El proyecto surgió a partir de una ardua búsqueda de distintas empresas que tuvieran interés en realizar un proyecto relacionado con el diseño de producto en colaboración con nosotros, estudiantes del último año de licenciatura. La empresa con la que se llegó a un acuerdo final fue la compañía *Kinnarps AB*, una destacada empresa sueca que ofrece soluciones de espacio interior para oficinas y entornos públicos, que es distinguida por su alta calidad y el bajo impacto ambiental que tienen sus productos. Trabaja bajo un esquema muy similar al concepto *cradle-to-cradle* (Haggar, 2007), ya que sigue un ciclo donde los materiales de los productos finales pueden reciclarse o reutilizarse, donde se utiliza el desperdicio de los procesos de fabricación para generar energía o para crear nuevos materiales, tratando de minimizar el desperdicio, la contaminación y el agotamiento de los recursos naturales.

El proyecto que la empresa nos otorgó, consistió en el desarrollo de una familia de paneles acústicos que siguiera las pautas de su marca. Los paneles acústicos tienen como función principal reducir el ruido y mejorar la acústica de las habitaciones por medio de la difusión y absorción del sonido, y como función secundaria, ser elementos decorativos. La compañía está muy interesada en el desarrollo de este tipo de productos y en general en la acústica de las habitaciones, debido al crecimiento de este mercado en Europa, es por esto que la marca quiere lanzar una nueva familia de paneles (absorbentes de sonido en específico) que sean más aceptados por sus clientes en comparación con los que venden actualmente. Los clientes principales para este producto son empresas, escuelas, bibliotecas y hospitales, que comúnmente utilizan este tipo de productos en oficinas, salas de juntas, salas de espera y salones de clase.

Desde el inicio, se acordaron los lineamientos principales del proyecto y las responsabilidades de ambas partes, la empresa *Kinnarps* se comprometió con el financiamiento y acompañamiento del proyecto y nombró como asesor principal a

Marcus Söderström, gerente del área de diseño y desarrollo de producto. Mientras que nosotros nos comprometimos a concluir el proyecto en 5 meses y a entregar prototipos 1:1, visualizaciones digitales del o los conceptos y el documento de investigación (Documento extenso en inglés aquí expuesto).

Para facilitar la lectura del documento es importante mencionar que éste se divide en tres secciones, como primera, un resumen en idioma español, donde se describen los elementos principales del desarrollo de cada etapa del proyecto para dar un entendimiento general del mismo, como segunda, el documento extenso en idioma inglés, que describe a detalle cada etapa y decisión del proyecto y muestra el resultado de la propuesta final de diseño con sus especificaciones, cabe destacar que dicho documento fue entregado también como resultado final a la Universidad de Skövde y como tercera, los planos técnicos de la propuesta final. A lo largo de las distintas secciones el lector podrá conocer el proceso de diseño y desarrollo del producto mencionado anteriormente, siguiendo los pasos sugeridos por el *Design Thinking*, que fue la metodología principal seguida: empatizar, definir, idear, prototipar y evaluar. Los resultados de cada etapa se presentan y se discuten con una perspectiva crítica. Así mismo se muestra un estudio de distintas fuentes documentales sobre absorción acústica que brinda un conocimiento base para poder proponer soluciones factibles, seguidos de otras herramientas que forman parte del programa de Ingeniería de Diseño de Producto de la Universidad de Skövde, tales como investigación de mercado, estudios de usuarios, lista de requerimientos, descomposición de problemas, lluvia de ideas, etc., que pueden ser aplicadas en el diseño de casi cualquier otro objeto producto.



Objetivo y metodología

El objetivo principal de éste proyecto fue generar uno o dos conceptos factibles, que alcancen una absorción acústica efectiva, una propuesta de materiales y procesos de fabricación viables, una instalación sencilla, estable y una apariencia estética atractiva para el mercado al que se dirige el producto.

Para lograr el objetivo anterior, se utilizó como metodología principal el *Design Thinking*, con un enfoque de diseño centrado en el usuario. Las 5 etapas principales del *Design Thinking* que siguió este proyecto son: empatizar con los usuarios, definir el problema, idear posibles soluciones, prototipar las soluciones y evaluarlas (Doorley et al., 2018). Esta metodología se distingue por el uso del pensamiento divergente y convergente y por alentar el "aprendizaje creativo mientras se hace" con bocetos y prototipos rápidos, sugiriendo iteraciones entre sus diferentes etapas y proponiendo resolver el problema principal mientras se buscan e intentan diferentes soluciones posibles (IDEO, 2003). Un ejemplo gráfico de la estructura de la metodología se muestra en la *Figura 1*. El enfoque de diseño centrado en el usuario nos sugiere considerar a los usuarios como el elemento central del proyecto, estudiando e involucrando a éstos durante todas las etapas del diseño (Zoltowski et al., 2012). Este enfoque busca encontrar innovación por medio de una comprensión profunda de los usuarios, de sus necesidades y de sus gustos y disgustos con respecto a productos existentes (Brown, 2008).

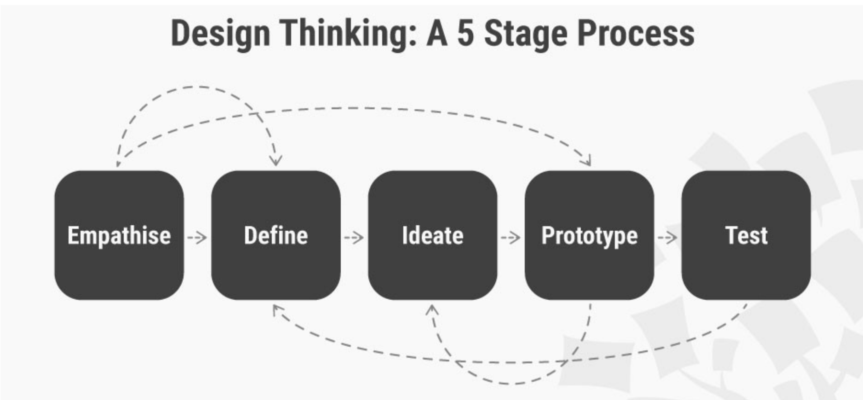


Figura 1. Diagrama del *Design Thinking* (Interaction Design Foundation, n.d.)

Esta metodología fue elegida debido a la estructura que sugiere, que se usa comúnmente para proyectos que buscan innovación, al involucrar la creatividad como una estrategia clave para resolver problemas complejos o en inglés *ill-defined* / wicked problems (problemas que no tienen toda la información disponible, que pueden tener más de una sola solución perfecta y correcta) (Cross, 2006).

El proyecto además sigue una "estrategia centrada en la solución", lo que significa que el proceso se enfoca más en trabajar con las posibles soluciones antes que con el análisis del problema en sí. Los problemas de diseño normalmente no se resuelven simplemente sintetizando la información recopilada. En cambio, se exploran varias direcciones al momento de tratar de resolver y eso es lo que puede ayudar a aclarar el problema y a aportar información valiosa que ayude a desarrollar la solución más adecuada (Cross, 2006).

Algunas de las etapas del proceso de desarrollo de producto establecidas en el libro *Product Design and Development* (Ulrich y Eppinger, 2008) también complementaron e influyeron en la metodología principal que guía todo el proyecto.

Las etapas son: planificación, desarrollo de conceptos, diseño a nivel sitémico, diseño detallado, pruebas-refinamiento, y producción. Destacando los primeros cinco, que se consideraron más convenientes para este proyecto. (Ulrich y Eppinger, 2008).

Además se buscaron herramientas adicionales para explorar diferentes enfoques que podrían aplicarse a varias etapas del proyecto, y se encontraron las tarjetas de métodos IDEO, 51 tarjetas que explican algunos de los métodos que la empresa estadounidense IDEO ha utilizado para explorar, obtener nuevas perspectivas e inspirarse. Funcionan como una guía, dan ejemplos y sugerencias para trabajar con un enfoque centrado en el usuario (IDEO, 2003). Después de un análisis de éstas, solo se eligieron 5 para trabajar con observación de usuarios (*shadowing*), escenarios, encuestas sobre los productos de la competencia, modelado a escala y prototipo de experiencia.

En términos generales, la metodología para el desarrollo de los conceptos para la familia de paneles acústicos se basa principalmente en la guía de cinco pasos del *Design Thinking*, y está influenciada secundariamente por el proceso de desarrollo del producto de Ulrich & Eppinger (2008) y algunas tarjetas de métodos IDEO.

Investigación documental

La investigación documental se centra en generar un entendimiento general del sonido, en cómo se da la absorción del mismo y en la acústica de los espacios interiores. Se describen conceptos como la reverberación, el ruido en espacios de trabajo, y propiedades de distintos materiales acústicos, que potencialmente podrían ser utilizados en el proyecto. Se hace un énfasis en cómo funciona la absorción del sonido, cómo se mide y los diferentes mecanismos que logran alcanzar un alto nivel de absorción.

También se estudiaron algunos otros factores que podrían influir en la dirección del diseño, como lo son: patentes existentes, la experiencia del usuario, la ergonomía sensorial de los usuarios, la ergonomía del montador y la sustentabilidad de la empresa. De esta sección se concluyeron datos importantes que influenciaron las siguientes etapas del desarrollo del producto, entre los que destacan:

- El rango de frecuencia audible para los humanos va de 20 a 20,000 Hz (Parkin, 2015).

- La absorción ocurre cuando las ondas sonoras interactúan con objetos físicos al ser reflejadas, transmitidas y/o absorbidas por el material, todos los materiales se comportan diferente ante este fenómeno, por lo que tienen diferentes porcentajes de absorción , reflexión y transmisión (Long, 2005). Ésto se puede observar en los esquemas de la Figura 2.

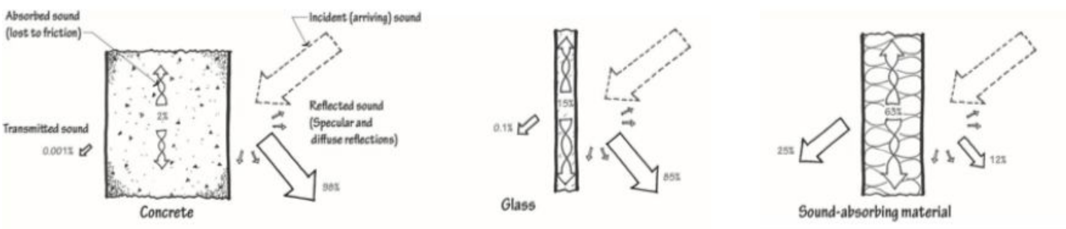


Figure 2. Absorción del sonido en 3 distintos materiales (Ermann, 2015).

- La reverberación es uno de los fenómenos más comunes que afecta los espacios de trabajo, es el proceso de reflexión y atenuación de un sonido (Hall, 1993). El tiempo de reverberación expresa el tiempo que estos sonidos reflejados tardan en caer por debajo del umbral de la audición humana y ser inaudibles para los humanos. Cuanto más corto sea el tiempo de reverberación, mejor será la acústica de una habitación en términos de inteligibilidad del habla (Parkin, 2015).

- La difusión es muy útil para reducir los problemas de eco y mejorar la acústica de una habitación. Existen ciertos tipos de geometrías, como curvas convexas, pirámides, superficies en ángulo, pilastras sobresalientes o superficies escarpadas que generan una reflexión difusa debido a que las ondas impactan sobre ellas y se reflejan de forma aleatoria. (Ermann, 2015). Se puede observar como se reflejan las ondas de distinta manera, dependiendo de la geometría de la superficie, en la Figura 3.

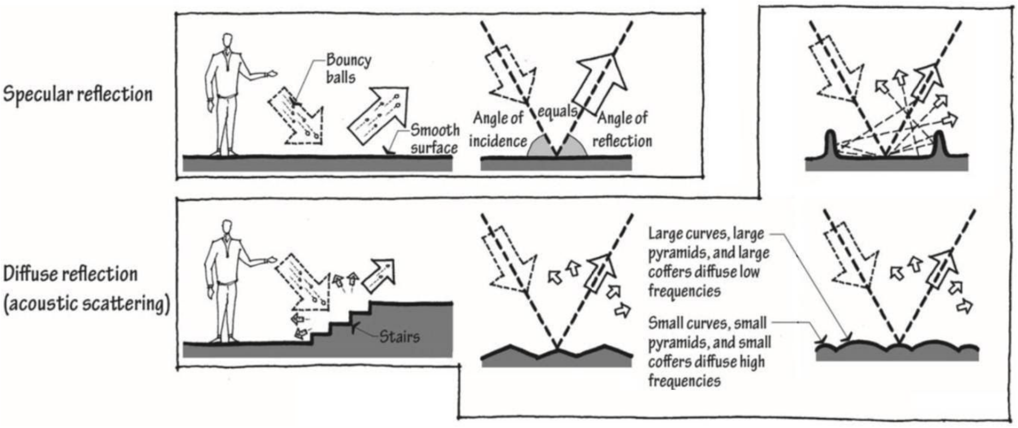


Figura 3. Reflexión difusa y especular (Adaptada de Ermann, 2015).

- Los materiales porosos son buenos absorbentes acústicos ya que funcionan gracias a un mecanismo llamado "arrastre viscoso" que básicamente se da cuando las ondas de sonido provocan un movimiento de aire en los espacios que existen entre las fibras del material en diferentes direcciones, produciendo fricción, pérdidas de impulso y calor (Long, 2005).

- Al perforar paneles de ciertos materiales se puede observar un aumento en sus niveles de absorción. (Parkin, 2015)

- Un material que tiene baja densidad funcionará mejor con frecuencias bajas (<500 Hz), mientras que uno con alta densidad absorberá frecuencias más altas(> 2000 Hz) (Seddeq, 2009).

- El tener un espacio de aire detrás de una capa de material absorbente aumentará sus valores de coeficiente de absorción (Seddeq, 2009).

- Para bajas frecuencias, la mejor absorción se logrará al aumentar el grosor de los materiales absorbentes (Seddeq, 2009).Existen materiales naturales y biodegradables que tienen propiedades absorbentes, de los cuales, sobresale el Kenaf y la lana de oveja. (Berardi e Iannace, 2015).

- La experiencia del usuario se refiere a cómo un producto puede causar efectos en los usuarios gracias a su interacción con él. Está influenciado por algunos factores, como la usabilidad, la utilidad, la funcionalidad y el impacto emocional (Hartson y Pyla, 2012).

- Dentro de la ergonomía sensorial, la buena acústica en habitaciones se considera muy importante para la concentración según los trabajadores de oficina (Lesman citado en Tietema, 2017). Las personas comúnmente relacionan el ruido con la insatisfacción en los espacios de trabajo. (Parkin, 2015).

- Existen trastornos musculoesqueléticos de las extremidades superiores relacionados con el trabajo, como el síndrome de DeQuervain, el segundo trastorno más común en la población activa (Violante et al., 2000) ganglios y tenosinovitis causada por acciones cómo insertar tornillos en los agujeros repetidamente, o epicondilitis ("codo de tenista") causada por acciones como girar tornillos y ensamblar piezas pequeñas. (Salvendy, 2012).

- Es posible observar similitudes entre la cadena de valor de Kinnarps, *Figura 4*, con las bases del concepto *Cradle to Cradle, Figura 5* (Haggar, 2007). Ambos siguen un ciclo donde los materiales de los productos finales pueden reciclarse o reutilizarse, minimizando el desperdicio, la contaminación y el agotamiento de los recursos naturales, y de esta manera reduciendo el impacto ambiental. Los objetivos principales son tener más de una reutilización del producto final, reutilizar el desperdicio de los procesos de fabricación, tratando de asegurar un ciclo de vida del producto sostenible (Haggar, 2007).

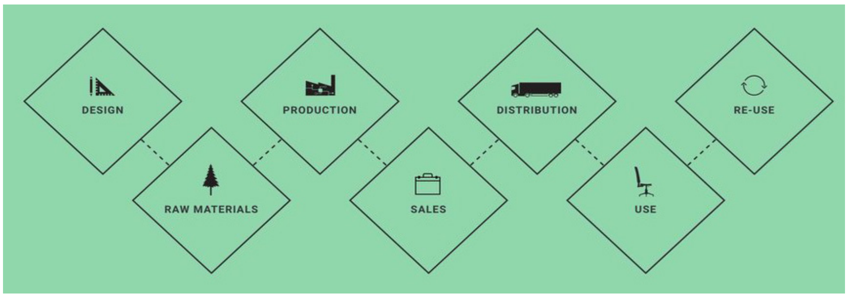


Figura 4. Cadena de valor de Kinnarps (Kinnarps Group, 2018).

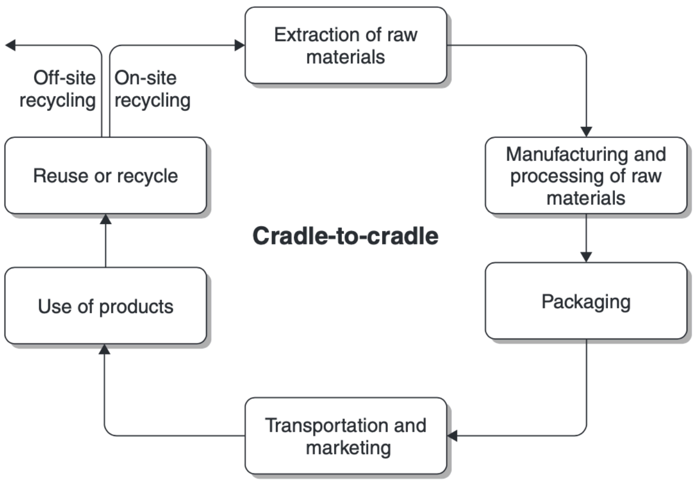


Figura 5. Análisis del ciclo de vida basado en el concepto *Cradle-to-cradle* (Haggar, 2007).

- Kinnarps Group ha desarrollado su propia medición de sostenibilidad llamada *The Better Effect Index*, el cual consiste en evaluar cada producto en seis áreas diferentes: materias primas y recursos, clima, materiales puros, responsabilidad social, reutilización y ergonomía. Estos se califican del 1 al 3 logrando un resultado final que es el promedio de ellos (Kinnarps, 2019).

Después de analizar la información investigada, se definieron las oportunidades de diseño y los datos clave encontrados, que posteriormente se usaron como punto de partida para la etapa de ideación, influenciando directamente los conceptos que se fueron trabajando hasta llegar al diseño de la propuesta final. Estas oportunidades van desde la opción de implementar algún mecanismo de absorción en la configuración del producto, utilizar posibles geometrías que ayudan a la difusión del sonido en el diseño del panel, buscar nuevos materiales absorbentes (considerando sus propiedades y evaluaciones oficiales), hasta buscar distintas maneras de reducir el riesgo de lesiones musculoesqueléticas en los montadores.

Análisis de mercado

El análisis del mercado se realizó para tener un conocimiento general de los estilos estéticos de ese año, 2019, para conocer más sobre los productos de los principales competidores en este campo y para evitar cualquier tipo de plagio. Se dividió en dos etapas: la primera consistió en una búsqueda en internet, consultando sitios web de empresas suecas e internacionales para tener un primer acercamiento a ellas y la segunda en visitas a algunas de las ferias de muebles más importantes del mundo: la Feria del Mueble de Estocolmo y el Salone del Mobile durante la Semana del diseño de Milán.

En estas visitas además de observar y detectar ciertas tendencias también fue posible hablar con diferentes vendedores sobre las propiedades de sus productos. Entre otras cosas se encontraron datos interesantes, como el uso de tres materiales diferentes dentro de un solo panel de la marca Decibel, las propiedades acústicas de los paneles de Nordgröna hechos de musgo de reno que usan la humedad del aire para sobrevivir sin necesidad de regarlo, el corcho reciclado utilizado en los paneles acústicos de Abstracta, la pulpa y lana de madera de Baux, las alfombras absorbentes de la compañía Ogeborg y las formas cilíndricas de los absorbedores colgantes de la compañía Offect.

Se realizaron *moodboards* con las imágenes colectadas (*Figura 6* y *Figura 7)*, se analizaron y se hicieron anotaciones de datos relevantes encontrados como lo fue un material absorbente que destaca por su grosor y un alto nivel de absorción (fieltro textil de 10 mm) de la empresa danesa *Really*.

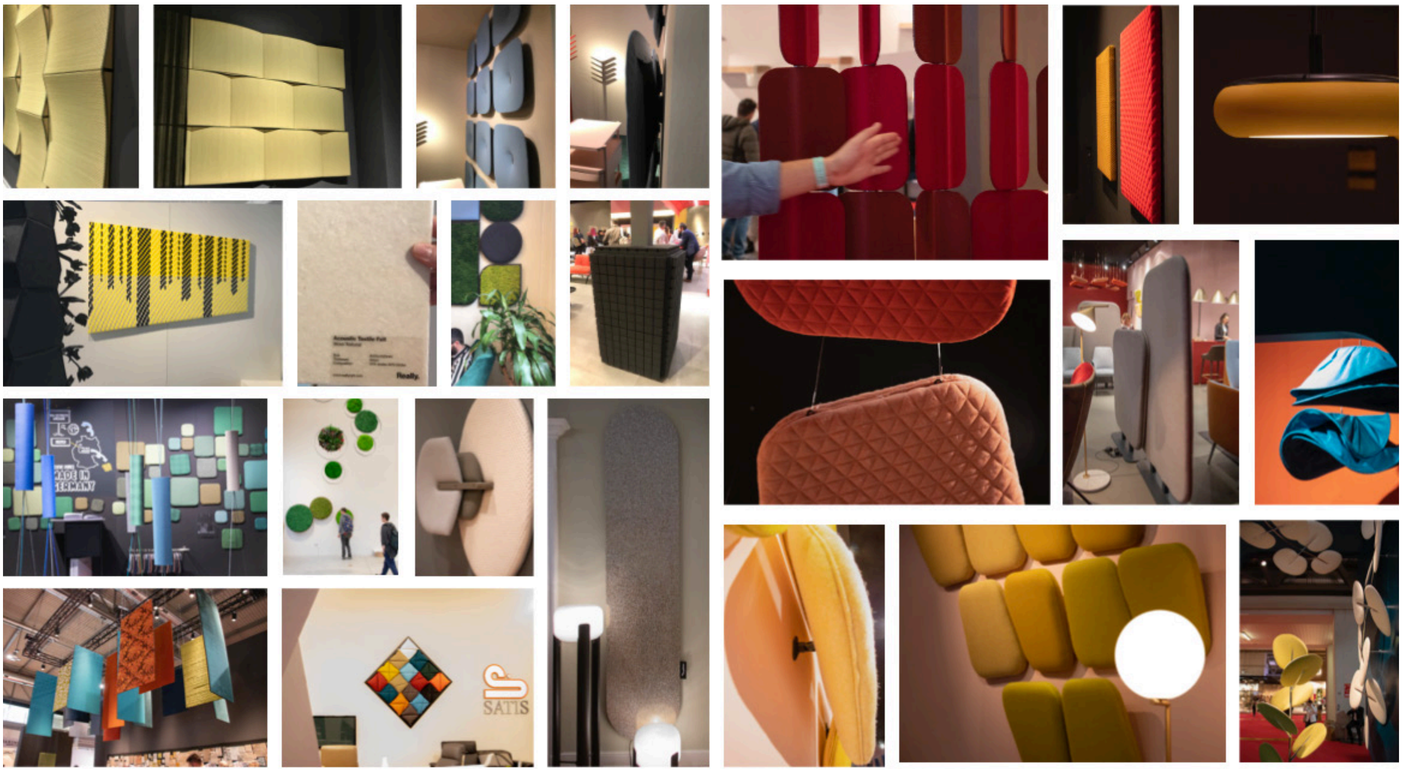


Figura 6. Milan Design Week 2019 Investigación de mercado.

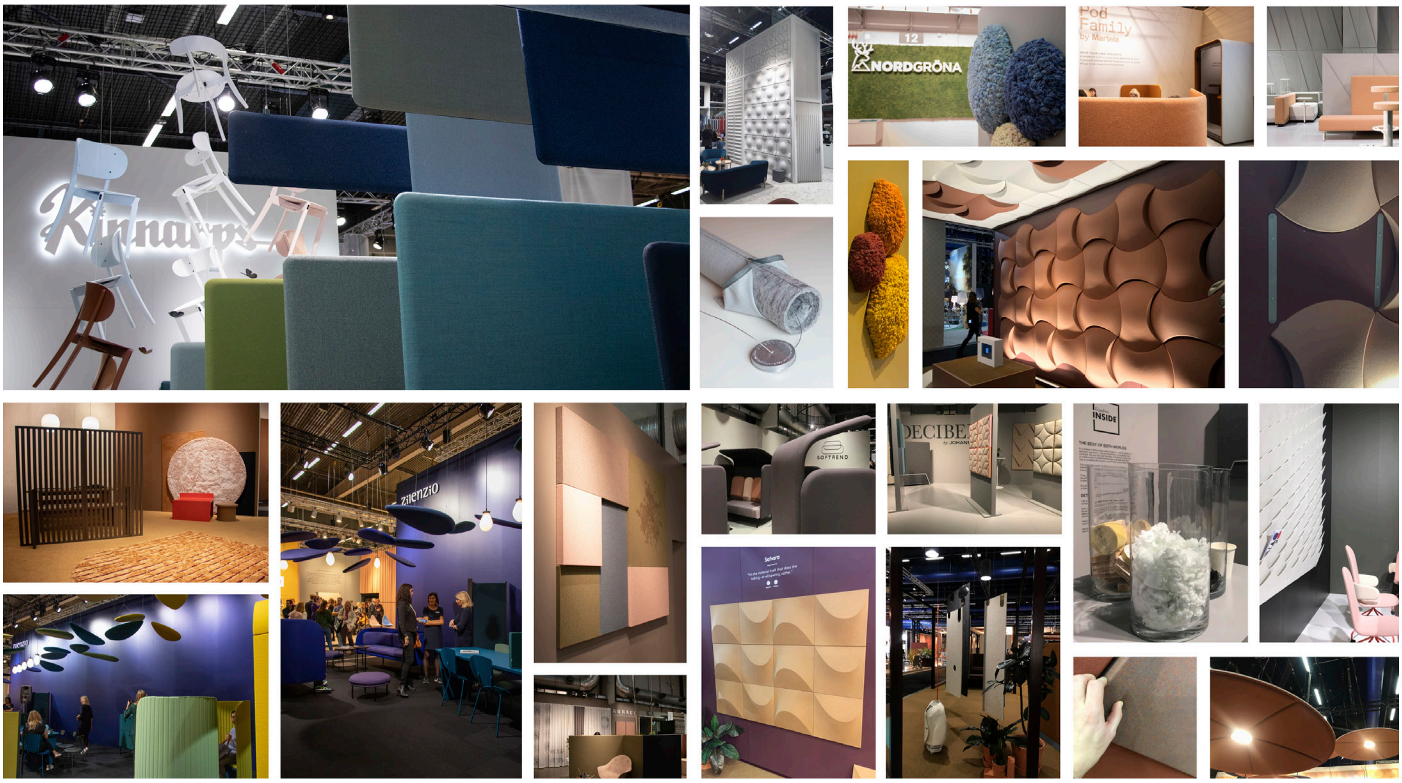
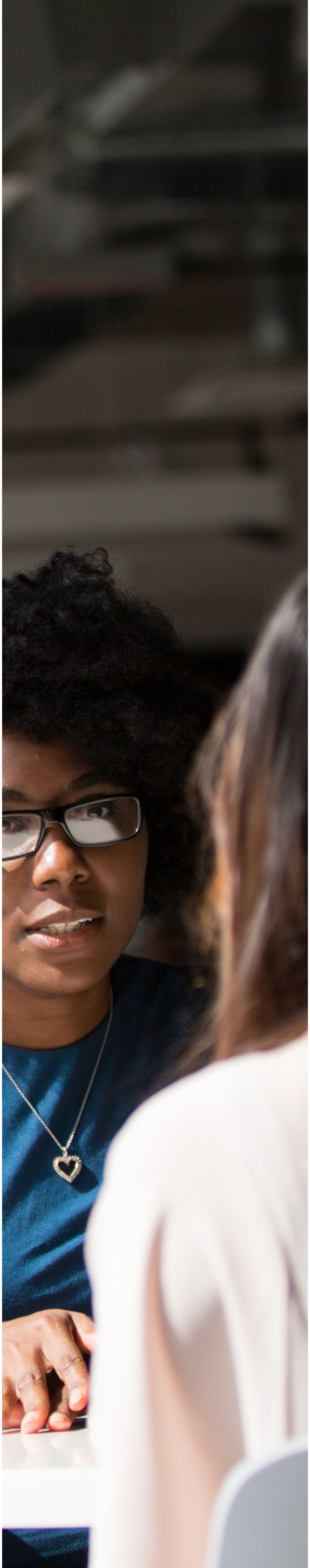


Figura 7. Milan Design Week 2019 Investigación de mercado.



Estudios de usuario

Los estudios de usuario se realizaron para obtener información útil del grupo objetivo y oportunidades de diseño para trabajar en el proceso de ideación. Se utilizaron distintas herramientas con diferentes niveles de interacción como cuestionarios en línea, entrevistas 1:1, y observación de usuarios en sus ambientes (salones de clase, oficinas, salas de espera)

Para obtener una perspectiva general sobre la percepción, las preferencias y las características particulares de un mayor número de personas con respecto a los paneles acústicos, se creó una encuesta en línea. Las principales conclusiones de este cuestionario fueron que el 100% consideró que estos productos afectan de manera positiva los entornos de trabajo, se prefieren paneles de pared (76.7%) contra paneles colgantes o de pie y que al momento de seleccionar entre paneles acústicos de diferentes marcas (incluidos los productos Kinnarps), existía una clara preferencia por los paneles con un estilo moderno de empresas como Abstracta y Offect. Los encuestados mencionaron que su elección entre diferentes paneles se basó en aspectos como la modularidad, una apariencia decorativa, un gusto por formas orgánicas o simples, la combinación de colores, y la facilidad de integración con otros muebles. También es importante mencionar que el 96.7% consideró que es importante la personalización de los colores y la posición de los paneles.

Las entrevistas ofrecieron un contacto más directo y profundo con el grupo objetivo y dieron la oportunidad de saber más sobre ellos. Los aspectos principales en los que se centraron las entrevistas fueron: sus personalidades, gustos, las características principales que consideran cuando eligen paneles acústicos, preferencias del tipo de panel y saber si estaban interesados en factores personalizables para estos productos, ya que esa fue una primera idea que se quería evaluar en esta etapa. Los compradores potenciales elegidos para ser entrevistados fueron arquitectos, gerentes de escuelas/guarderías y vendedores que se encargan de elegir los paneles acústicos para diferentes proyectos, entre los que se incluyen: bibliotecas, salas de espera, salones de clase, etc. A partir de estas entrevistas, se hicieron algunas conclusiones como:

- Varios entrevistados mencionaron que respecto al factor estético de los paneles, prefieren formas geométricas sencillas, con pocos elementos visuales, aunque otro tipo de formas también pueden ser adecuadas dependiendo del tipo de proyecto en el que están trabajando.

- El precio del producto influye en su elección, no debe ser excesivamente alto.

- Un factor importante es dar a los clientes la posibilidad de personalizar la composición, el tamaño y los colores.

- La funcionalidad es muy importante.

- El tipo de absorbentes que usan principalmente son paneles de pared o de pie, aunque también usan muebles y alfombras para trabajar con la acústica.

- El factor estético de los paneles es un punto realmente clave al momento de elegir entre varias opciones.

En la etapa de observación *shadowing* (IDEO, 2003), se observó a niños, estudiantes, maestros y trabajadores en los distintos ambientes en que se desenvuelven, para conocer más a detalle dichos espacios, dónde colocan los paneles y de qué tipo utilizan. Esta estrategia nos ayudó además a empatizar particularmente usando nuestros sentidos, ya que pudimos escuchar los sonidos que se producen continuamente ahí, destacando llamadas telefónicas, varias personas hablando, y niños jugando, dependiendo claramente del lugar que se visitaba. Por otra parte, se buscó notar si había algún tipo de interacción entre los usuarios y los paneles, sin embargo, se encontró una muy baja interacción entre ellos. Lo único particular que se destacó de esa observación fueron estudiantes jóvenes que se recargaban en los paneles y que los niños fijaban con tachuelas sus dibujos sobre los paneles.

Para tener una idea general sobre lo que las personas relacionan con la marca Kinnarps, se realizó una encuesta de palabras clave a 6 participantes que conocieran sobre la marca. Las palabras más votadas que describen mejor a la empresa fueron “escandinavo” y “oficinas”. Otras palabras repetidas fueron “ergonomía”, “moderno”, “cómodo”, “alta calidad” y “funcional”. Al considerar estas palabras como una guía de diseño en la etapa de ideación se genera una estrategia para garantizar que se mantenga el estilo y la percepción de la marca en los conceptos.

Inspirados en los perfiles de las personas entrevistadas, se crearon personajes ficticios típicos basados principalmente en los encargados de elegir los paneles acústicos (arquitectos, diseñadores de interiores, vendedores de mobiliario y gerentes de escuelas). La información colectada se sintetizó y visualizó en una plantilla que muestra con datos concretos su información general, objetivos, necesidades, personalidad y preferencias de marcas existentes, representado en la *Figura 8*. De igual manera se desarrollaron “escenarios” con el fin de ilustrar el contexto de uso del producto y tener una idea de las posibles situaciones en las que el usuario y el producto podrían estar involucrados. Esto es útil para comprender la experiencia del usuario y saber cómo podrían beneficiarse los usuarios del producto en un posible entorno de uso (IDEO, 2003).

Hans

Edad: 58
Trabajo: Arquitecto
Familia: Trabajo
Ubicación: Skövde, Suecia

Personalidad

Introvertido — Extrovertido
Racional — Emocional
Conservador — Liberal
Analítico — Creativo

Objetivos

- Alcanzar un proyecto de alta calidad
- Escoger los elementos adecuados para cada proyecto
- Apredender sobre nuevas tendencias dentro de la arquitectura

Frustraciones

- No encontrar los productos necesarios para cada necesidad del proyecto
- Ser lo suficientemente claro en las especificaciones del proyecto para evitar errores de construcción
- No encontrar algunas dimensiones específicas de paneles acústicos.

Bio

Hans es un arquitecto con más de 30 años de experiencia, que trabaja en su estudio ubicado en Skövde. Él se encarga de dirigir todos los proyectos que el despacho maneja, sin embargo su mayor interés está en el diseño de interiores. Su principal colega es su esposa Hannah, quien le ayuda a mantenerse tranquilo en momentos estresantes mientras trabajan con varios proyectos a la vez.

Motivación de compra

Estética
Funcionalidad
Diseño escandinavo
Acústica
Ergonomía

Preferencia de marcas

Kinnarps WORKSPACE SOLUTIONS
OFFECCT
zilenzio Selling silence

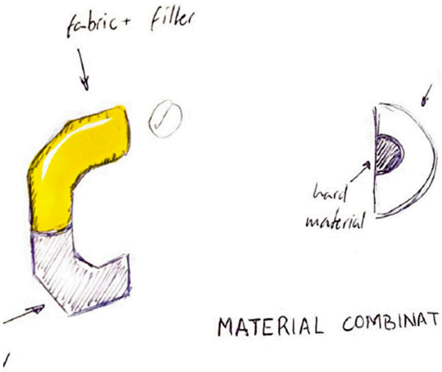
Figura 8. Persona 1 (Xtensio, n.d.)

Especificaciones

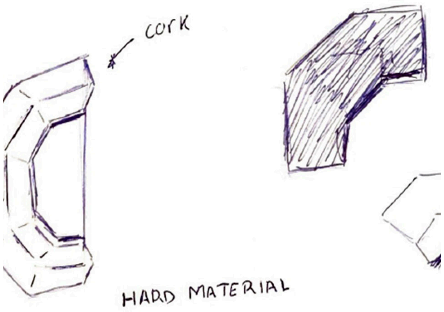
En la etapa de especificaciones, se definieron varios requisitos para los conceptos finales de la familia de paneles acústicos. Los requisitos se dividieron en diferentes campos, se marcaron como deseos o exigencias y se establecieron métodos de evaluación para cada uno en una lista de requerimientos, *Tabla 1*. Este proceso se realizó junto con el gerente del área de diseño de la empresa y tiene como objetivo guiar y evaluar las posibles soluciones. Se especificaron grosores, peso máximo (1 kg), niveles de absorción deseados (N_{10}<6) y otras características más que se esperan del producto final.

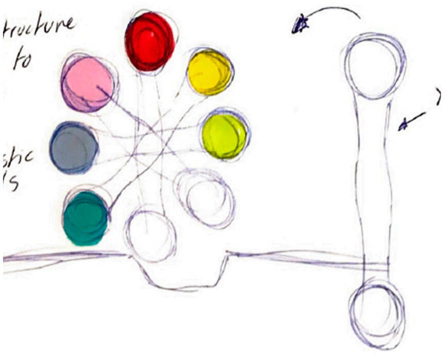
Högskolan i Skövde - Kinnarps	Lista de requerimientos Proyecto: Diseño de una familia de paneles acústicos			Elaborado el día: 02/27/19 Responsables: Julián Soria de la Torre Gabriel Juárez Mejía
Cambios	D/E	Requerimientos		Método de evaluación
02/13/19 02/27/19	E	Geometría:	Grosor panel 35-80 mm	Medición manual
	E		Distancia del muro al panel > 90mm	Medición manual
	E	Cinemática:	Fácil de montar	Prueba con usuario
	D		Instalación rápida	Tiempo
	D		Posición ajustable	Sí/No
	D		Módulos conectables	Sí/No
	E	Fuerza:	Peso <1 kg + elementos de fijación	Medición en báscula
	E	Función: (Abs sonido)	N_{10} ≤ 6 (6 paneles de pared o 1 panel de pie)	SS-EN ISO 354 y SS 25269
	D		Alentar la concentración	Test con usuario
	D		Mejora la atmósfera del espacio de trabajo.	Test con usuario
	E	Material:	Textiles *KCS* (Si se usa textil)	Sí/No
	D		Relleno de poliéster reciclado de Kinnarps.	Sí/No
	D		Parcialmente reciclado	Sí/No
	E		Valor sustentable >2	*The Better Effect Index* de Kinnarps
	E	Seguridad:	Seguridad del operador	Leyes suecas del entorno laboral
	E		Seguridad del montador	Leyes suecas del entorno laboral
	E		Seguridad del usuario	Sí/No
	E	Manufactura:	De acuerdo con los estándares de la industria.	Sí/No
	D		Usar instalaciones existentes	Sí/No
	D		10.000-25.000 piezas por año	Sí/No
	E	Factor estético:	Colores de la marca	Sí/No
	E		Seguir la estética de la marca	Análisis estético (Palabras clave de la marca Kinnarps)
	D		Atractivo para usuarios y clientes.	Prueba con usuarios
	D	UX:	Considerar los estudios de usuarios	Sí/No
	E	Tiempo:	5 meses en desarrollo	Sí/No
	D	Precio:	750 SEK	Sí/No
	D	Mantenimiento:	Fácil de limpiar	Prueba con usuarios

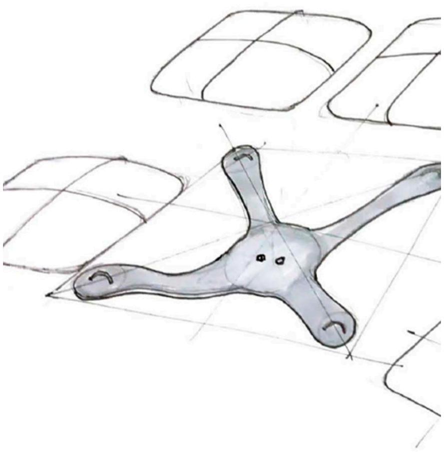
Tabla 1. Lista de requerimientos

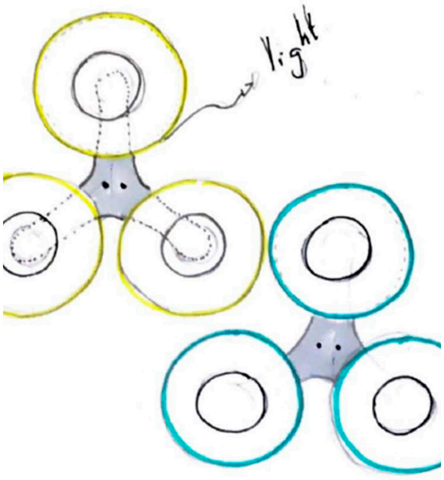


Conceptualización









Para la conceptualización, se utilizó como punto de inicio la información recopilada de la investigación documental, principalmente con respecto a la absorción del sonido y los datos recopilados de los estudios preliminares, haciendo énfasis en los estudios de los usuarios y en las palabras clave de la marca. El proceso comenzó con el método de diseño a nivel sistémico (Ulrich & Eppinger, 2008) que consistió en dividir el problema en categorías o subsistemas y abordar cada uno por separado, ejemplificado en la *Figura 9*, seguido de una lluvia de ideas de posibles soluciones para estos subsistemas, una exploración con bocetos de diferentes formas y con modelos a escala.

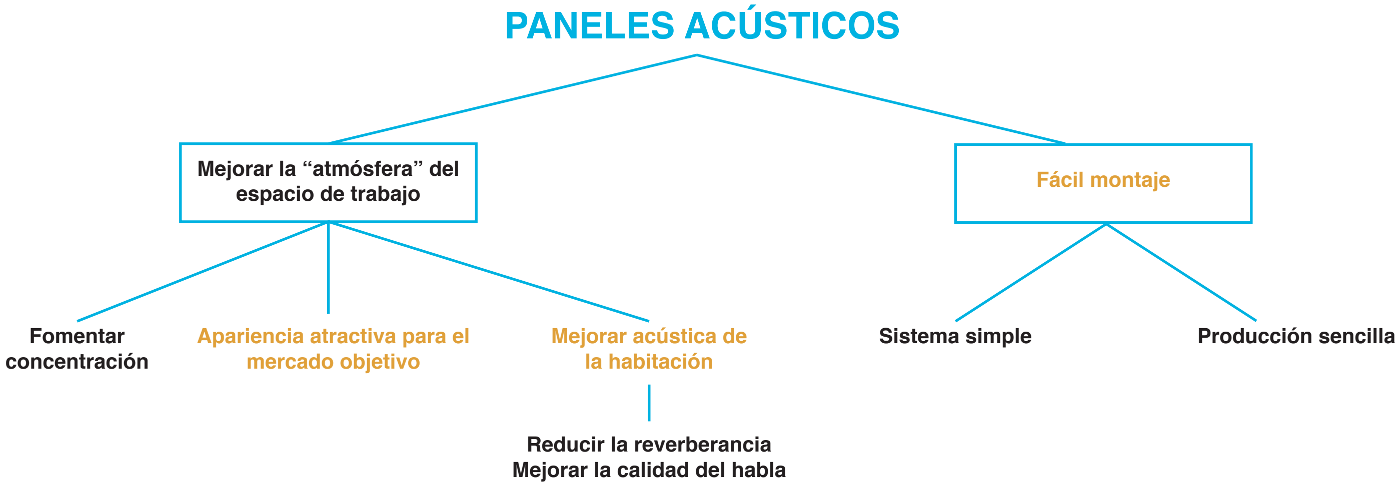


Figura 9. *Diseño a nivel sistémico*

En la lluvia de ideas (*Figura 10)*, se buscaron diferentes soluciones, alentando el pensamiento divergente y las ideas "fuera de la caja". Entre las soluciones exploradas en la lluvia de ideas, algunas pueden destacarse como el uso de imanes para montar los paneles, el uso de paneles perforados como alternativa para los materiales porosos, combinar diferentes capas de materiales para el interior de los paneles, unos de baja y otros de alta densidad, basar las geometrías de los paneles en formas básicas (cuadrado, círculo), con pocos elementos visuales, y paneles que pueden ser personalizados.

Figura 10. Lluvia de ideas-Posibles soluciones

La realización de bocetos mostrados en la *Figura 11* comenzó al mismo tiempo que la investigación documental, el estudio de mercado y de los usuarios para evitar perder ideas que se iban generando al leer u observar, sin embargo el mayor desarrollo de esta etapa se llevó a cabo después de finalizar la investigación inicial.

El objetivo principal de esta etapa divergente fue crear rápidamente conceptos diferentes, tratando de generar tantas ideas como fuera posible, que pudieran combinarse y madurarse en las siguientes etapas.

Varios *moodboards* adicionales a los efectuados en el análisis de mercado se desarrollaron como una herramienta inspiradora en esta etapa, usando el "pensamiento analógico" (Rodgers y Milton, 2011) que básicamente sugiere tener un aporte adicional e influencia de productos de otro contexto. Otros *moodboards* se hicieron con diseños de interiores realizados por Kinnarps para tener en cuenta la estética de la marca todo el tiempo.

Algunos de los conceptos explorados por medio del bocetaje como "modular" y otros más encontrados en el proceso como "estructuras base" fueron elegidos para ser desarrollados en plastilina, cartón y papel, como los muestra la *Figura 12*. Este método facilitó la representación de las ideas en 3D y proporcionó más información para seguir trabajando en la conceptualización. Después la compañía revisó estas ideas generadas y eligió tres ideas potenciales que definirían las direcciones a seguir. Estas guías se muestran en la *Figura 13.*

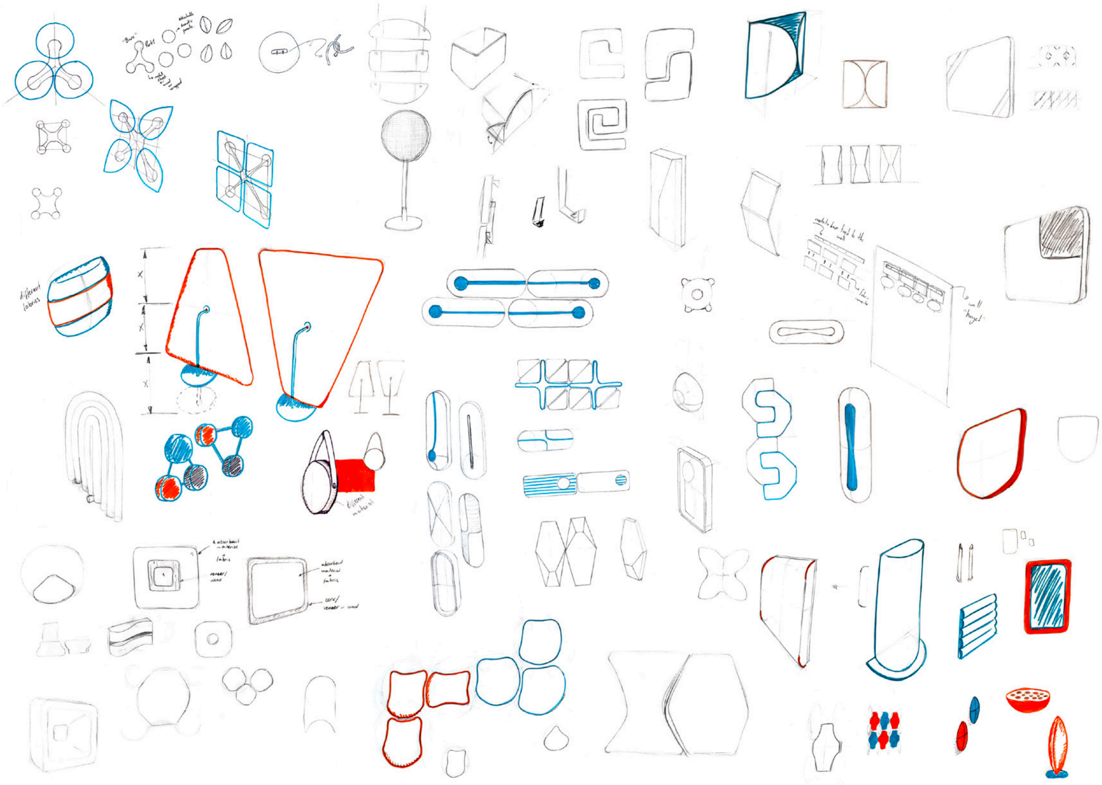


Figura 11. Bocetos de ideación

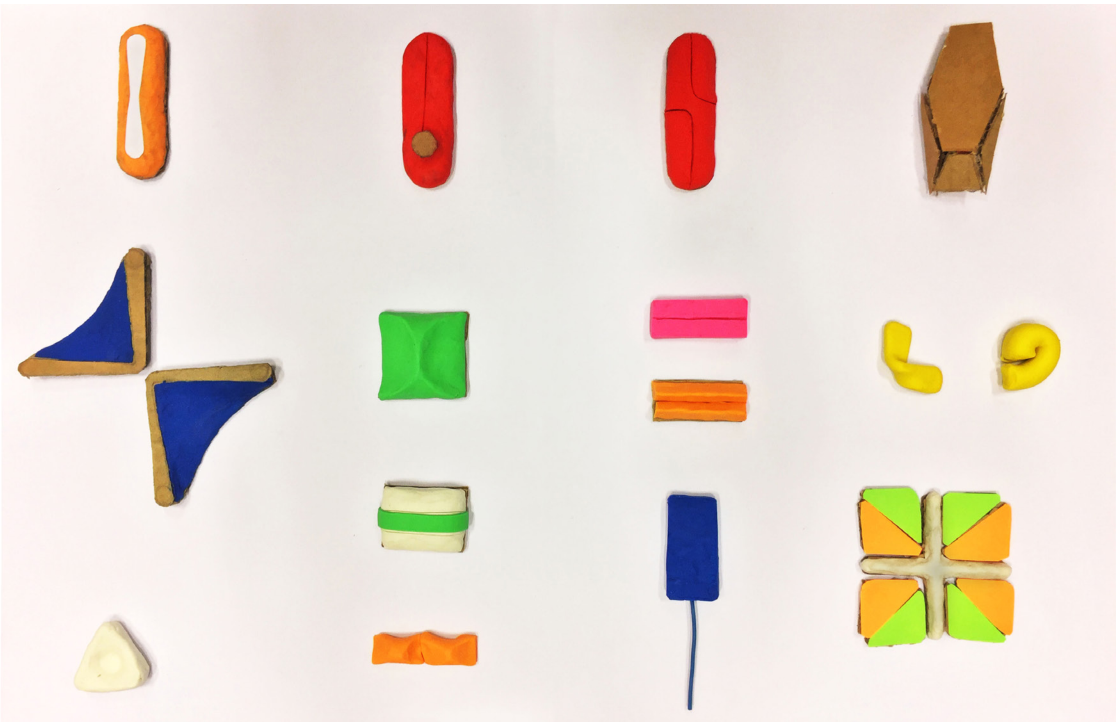


Figura 12. Modelos a escala para exploración formal

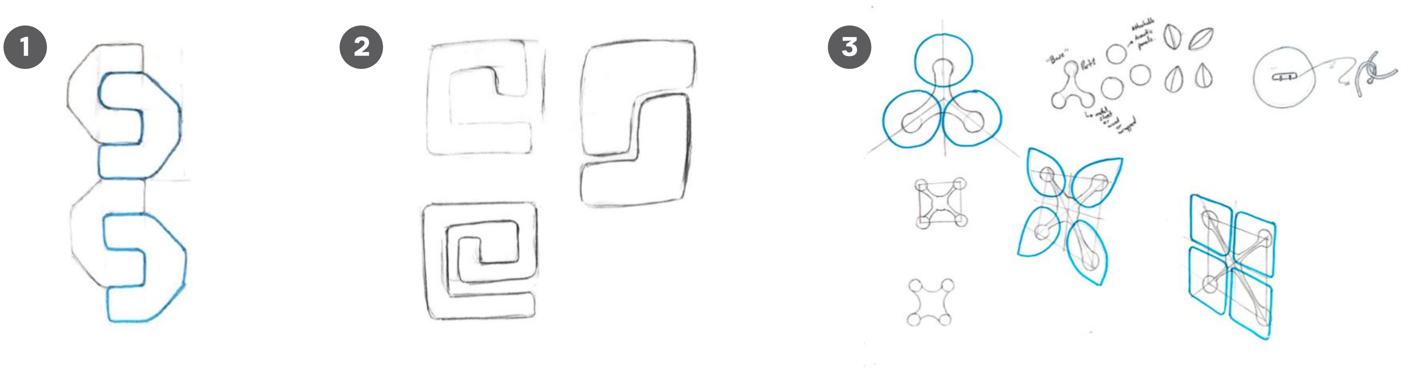


Figura 13. Selección de Kinnarps de guías potenciales

Se desarrollaron más bocetos de estudio con dos propósitos, trabajar en la definición de las geometrías de los paneles y generar aún más variantes de las mismas. Al mismo tiempo se exploraron distintas soluciones para el sistema de montaje *(Figura 14)*, buscando reducir el número de accesorios de fijación a la pared de cada panel para de esta manera proporcionar un sistema de instalación sencillo, como se establece en la lista de requisitos.

Es importante mencionar que el proceso de bocetaje se siguió utilizando en las siguientes etapas como iteraciones para volver a idear posibles soluciones a problemas que se iban presentando durante el proceso o para trabajar con partes más específicas del producto, por ejemplo para la exploración de ensambles entre piezas ya con los conceptos más definidos.

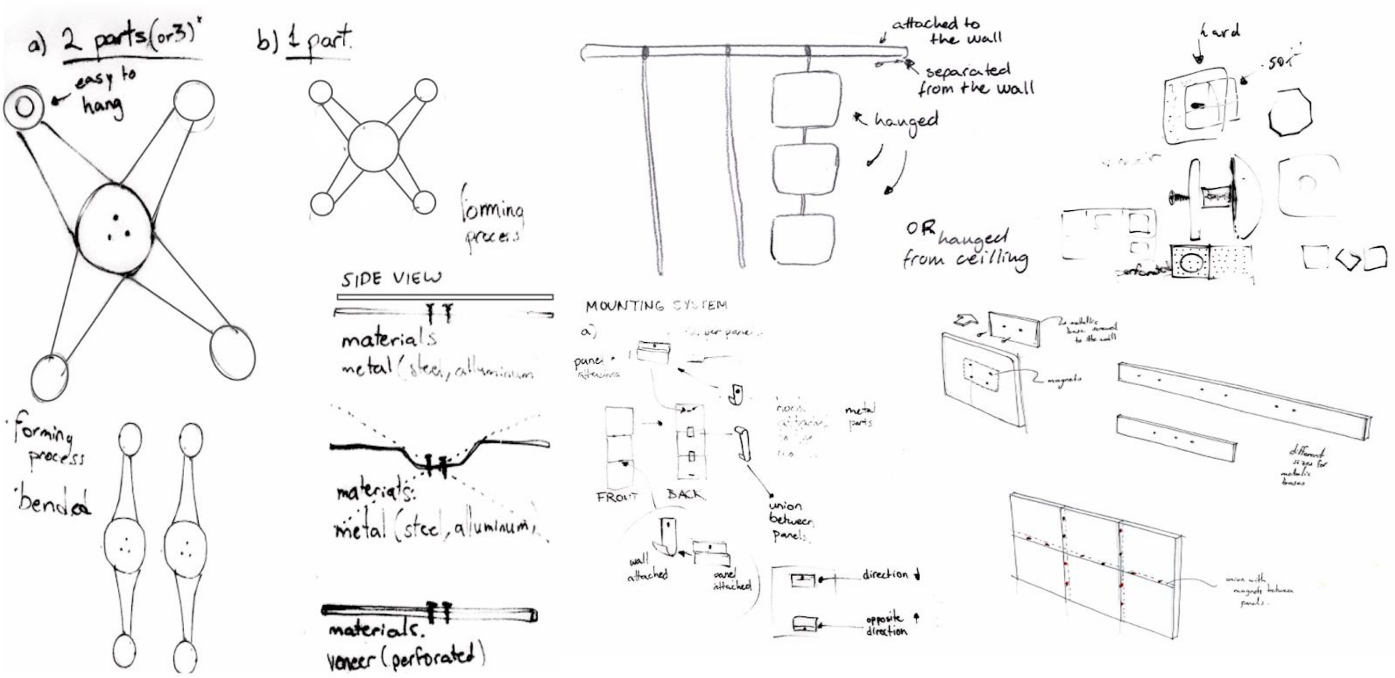


Figura 14. Bocetos de posibles soluciones para el sistema de montaje.

Selección de conceptos

Concept screening

Criterios de evaluación	Concepto										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**N (BASE)**
GEOMETRÍA											
Espesor dentro de los límites	1	0	1	1	1	1	0	1	1	1	0
ESTÉTICA											
Fomentar concentración	1	0	1	-1	0	0	1	-1	0	-1	0
Mejorar la atmósfera del espacio	1	0	0	0	1	0	1	1	0	-1	0
Apariencia atractiva para el grupo objetivo	0	1	0	0	0	-1	1	1	1	1	0
Potencial para ofrecer distintos materiales	1	0	1	-1	1	1	0	0	0	0	0
Potencial para ofrecer distintos colores	1	0	0	-1	0	0	0	0	0	0	0
Potencial para ofrecer varias formas	1	0	1	1	1	0	0	0	0	0	0
LIMPIEZA											
Sencillo de limpiar (materiales-geometría)	-1	1	-1	1	-1	0	-1	0	1	0	0
PRODUCCIÓN											
Sencillo de producir (número de procesos)	-1	0	-1	0	-1	-1	-1	0	-1	-1	0
SOSTENIBILIDAD											
Materiales con bajo impacto ambiental	0	1	1	1	1	1	1	1	0	1	0
PUNTUACIÓN FINAL	4	3	3	1	3	1	2	3	2	0	0
Ranking	**1**	**2**	**2**	**4**	**2**	**3**	**3**	**2**	**3**	**5**	
Continúa?	SÍ	SÍ	SÍ	NO	SÍ	NO	NO	SÍ	NO	NO	

Tabla 2. *Concept screening*

Basado en la intuición de los diseñadores, hubo una selección preliminar de las 10 ideas principales que tuvieran una apariencia interesante y potencial para cumplir con los requisitos iniciales del proyecto. Después se utilizó el método *Concept Screening* (Ulrich & Eppinger, 2008) para hacer una selección de los 5 conceptos con mayor potencial para continuar siendo desarrollados. Se tomaron como criterios de evaluación algunos puntos principales de la lista de requerimientos como: geometría, estética, mantenimiento, fabricación y sostenibilidad. Se usó un producto exitoso de la competencia como elemento de comparación, al que se le denomina línea base y con el cual se evaluaron todos los conceptos. Si el concepto evaluado se consideraba mejor que el de línea base, recibía un punto positivo, si se consideraba igual no recibía puntos, y si se consideraba peor, recibía un punto negativo. Los puntos se sumaron y los resultados mostraron los conceptos que deberían desarrollarse más a fondo. Este método es representado en la *Tabla 2.*

En esta parte del proceso es posible ver cómo convergieron, evolucionaron y evaluaron las ideas. Se siguió trabajando con los cinco conceptos con las puntuaciones más altas y se realizaron algunos bocetos e impresiones 3D, mostrados en la *Figura 15,* cada concepto se explicó con más detalle, considerando su sistema de montaje y funcionalidad.

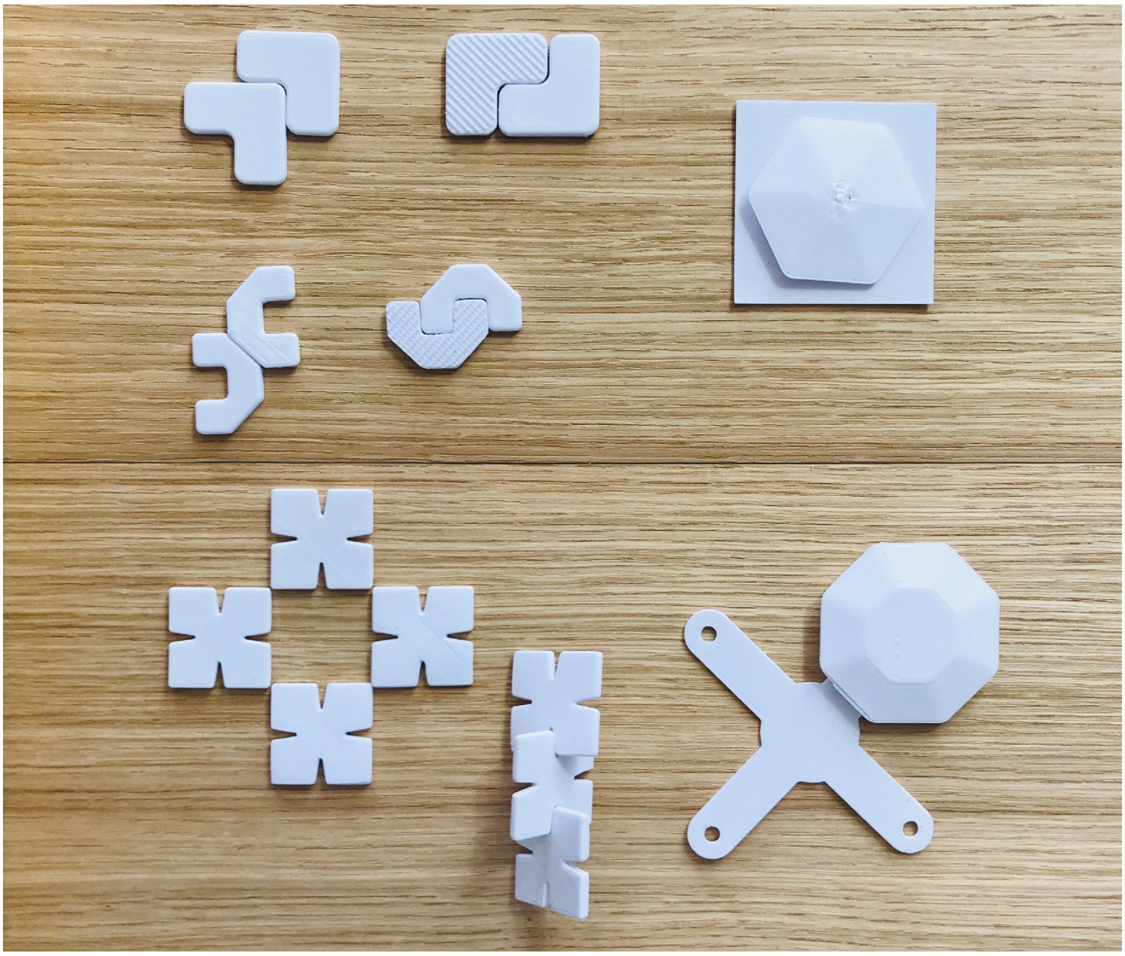


Figura 15. Modelos a escala impresos en 3D.

Estos conceptos se presentaron a la empresa y según sus preferencias, se seleccionaron tres como los conceptos finales que se desarrollarían con prototipos y posteriormente se evaluarían funcionalmente.

Los tres conceptos finales son los siguientes:

El concepto uno consiste en diferentes tipos de estructuras de MDF que funcionan como una base para montar paneles acústicos con distintas apariencias de una manera sencilla por medio de herrajes o imanes. Este concepto busca reducir el número de agujeros en la pared por panel en comparación con el que la compañía tiene actualmente y generar un espacio de aire entre los paneles y la pared, que de acuerdo con la investigación literaria aumenta la absorción del sonido. Este concepto también le brinda al cliente la posibilidad de elegir y combinar diferentes tipos de paneles en diferentes posiciones. Gráficos del concepto se muestran en la *Figura 16.*

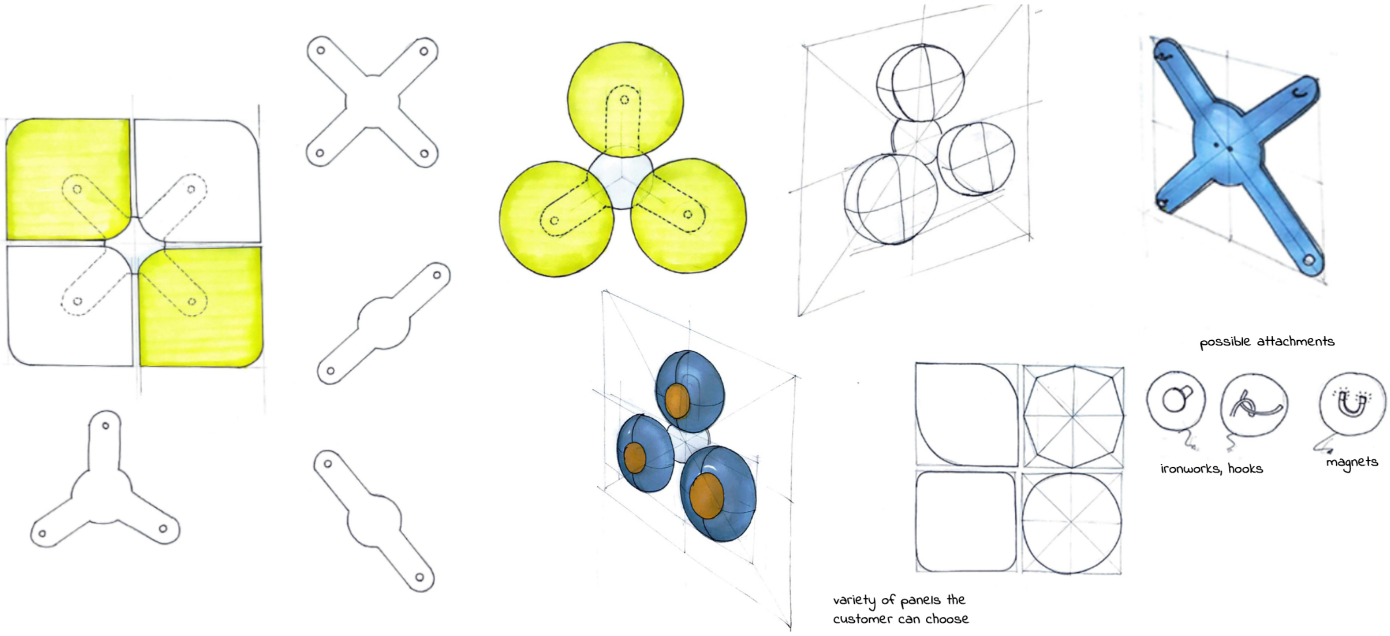


Figura 16. Concepto uno.

El concepto dos consiste en paneles "plegados" de distintos tamaños que permiten varias composiciones en las paredes. El material absorbente se moldearía en esta forma y se cubriría con las telas de Kinnarps. La apariencia de este panel acústico intenta diferenciarse de lo que se encontró en la investigación de mercado. Esta forma doblada además se cree que proporciona un espacio de aire entre las superficies por donde pasa el sonido por lo que se espera de igual manera que esto aumente el nivel de absorción. Gráficos del concepto se muestran en la *Figura 17.*

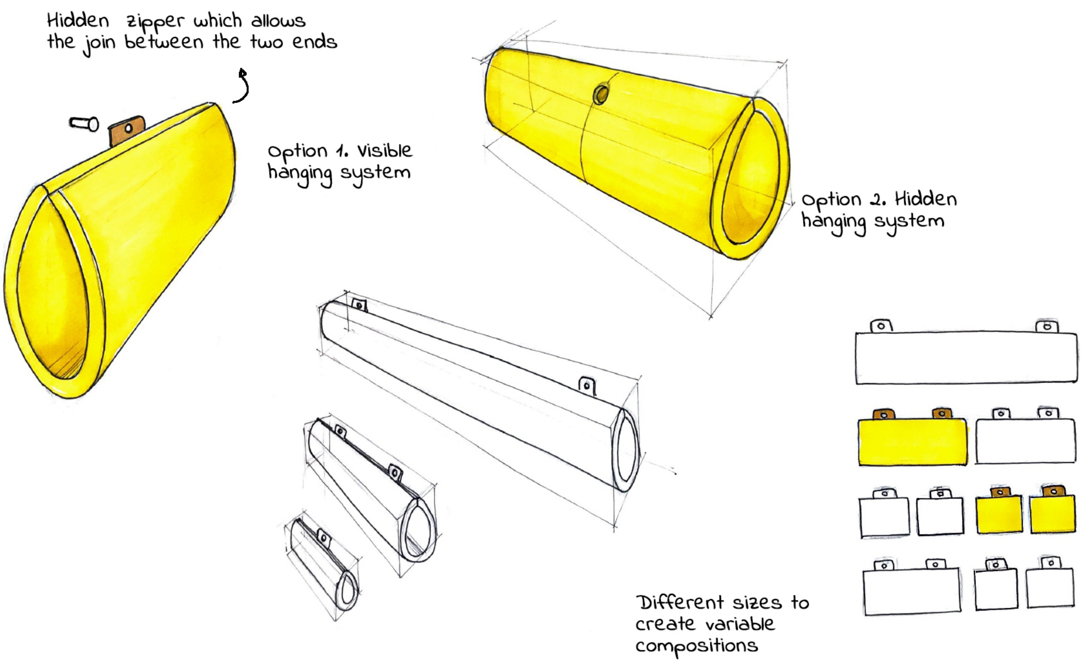


Figura 17. Concepto dos.

El concepto tres tiene como objetivo principal combinar diferentes tipos de paneles acústicos de forma modular. El cliente tiene la opción de escoger entre diferentes materiales, colores y acabados del mismo panel para generar diversas composiciones que se adapten al espacio con el que está trabajando. Gráficos del concepto se muestran en la *Figura 18.*

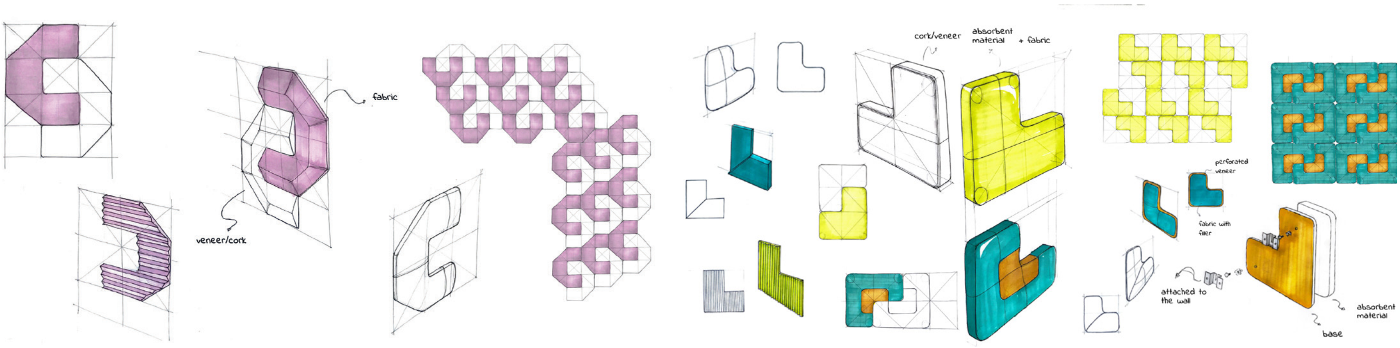
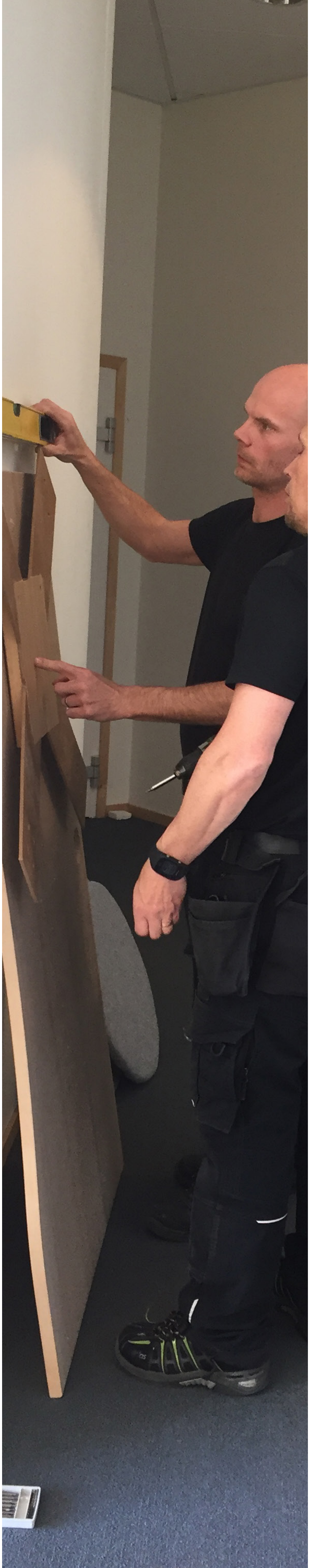


Figura 18. Concepto tres.

Prototipado y evaluación



El proceso de prototipado comenzó con prototipos "rápidos" que ayudaron a tener una mejor percepción de su tamaño, su proceso de fabricación, su viabilidad y su apariencia. (IDEO, 2003).

Los prototipos para el concepto uno y tres se hicieron cortando una estructura de MDF escala 1:1 y utilizando el material absorbente que la compañía maneja actualmente. La retroalimentación del supervisor de la compañía fue positiva para el concepto uno, sin embargo respecto al prototipo del concepto tres, se sugirió que se detuviera su desarrollo para enfocarse en los conceptos uno y dos, que se consideraban más atractivos para la empresa.

Los prototipos "rápidos" del concepto dos fueron manufacturados por la empresa. El personal de *Kinnarps* realizó una prueba de absorción de estos prototipos, visible en la *Figura 19*, aprovechando la oportunidad de que habían alquilado un laboratorio acústico para la evaluación de otros productos de su portafolio. La prueba consiste en hacer una comparación entre el tiempo de reverberación de la habitación sin productos y el tiempo de reverberación cuando los productos se colocan dentro. Calcula la cantidad de ruido que se absorbe gracias al coeficiente de absorción en relación con el área del producto. Después de reproducir diferentes sonidos de frecuencia a un nivel constante, se mide el tiempo hasta que la reverberación se reduce en 60 dB (AcousticFacts, 2017).

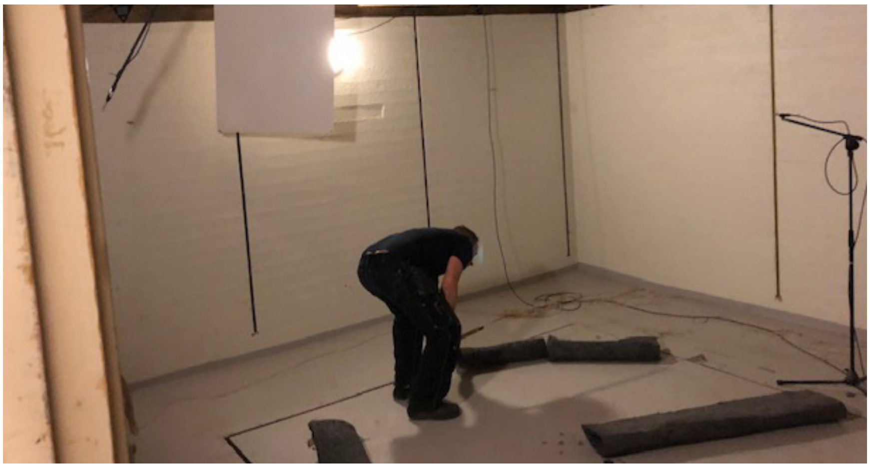


Figura 19. Prueba en laboratorio acústico de prototipos del concepto dos.

Es imporante mencionar que para la prueba acústica se consideró el sonido a una temperatura de 20ºC y en un rango de humedad del 50-70%, porque son los valores considerados comunes para ambientes interiores (AcousticFacts, 2017).

Los resultados obtenidos de la prueba no fueron tan buenos como se esperaba, sin embargo fue posible obtener algunas conclusiones de esta prueba para lograr mejores resultados con los siguientes prototipos:

- El grosor del prototipo (20 mm) no fue el apropiado, debe ser más grueso (40 mm).
- El número de paneles probados no fue suficiente para lograr resultados 100% adecuados (según el ingeniero del laboratorio).
- El espacio interior del panel debería ser mayor en todo el producto.
- El prototipo debe estar cubierto por tela, que también es un material absorbente.
- Debe evaluarse con un espacio entre el panel y la superficie detrás.

Después de esa evaluación se desarrollaron prototipos con más detalle (*Figura 20*), tomando en cuenta las conclusiones mencionadas anteriormente para así poder tener una similitud más cercana con un producto comercial y seleccionar el concepto final. Estos prototipos finales ayudaron a hacer una evaluación ergonómica y otra estética y además a continuar evolucionando características específicas para cada concepto, como el montaje, su manufactura, selección de materiales, etc.

Figura 20. Prototipos del Concepto uno y dos.

Con el prototipo del concepto 1 se probaron dos sistemas de montaje con montadores de la compañía, imágenes de dicha prueba se muestran en la *Figura 21.* El primer sistema consistió en dos ganchos de pared donde se colgaría la estructura, los ganchos se fijaron a la pared usando un tornillo para cada uno. El segundo sistema consistió en dos perforaciones en la estructura donde se colocarían dos tornillos directamente en la pared. El sistema de imanes para unir los paneles a la estructura también se probó para conocer su efectividad. La prueba de montaje permitió corroborar si el proceso de montaje era intuitivo y rápido para el montador en comparación con los paneles acústicos anteriores de la compañía.

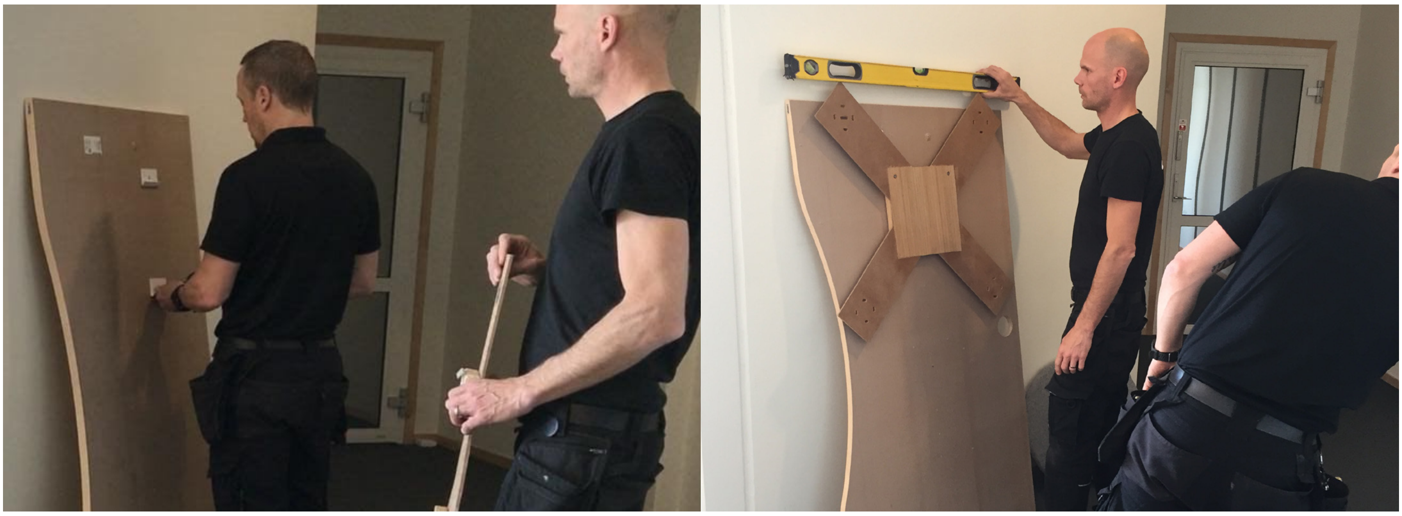


Figura 21. Evaluación con Montadores

Los principales comentarios recibidos por los usuarios fueron:

- El sistema de los dos ganchos metálicos necesitaría un tornillo adicional en cada uno para ser más estable.

- Se prefiere el sistema de tornillos directos en la estructura porque es una instalación más estable.

- La combinación de la estructura y el sistema magnético se consideró una gran mejora para ellos en el sistema de montaje de los paneles actuales. Consideran que este sistema combinado haría más rápido el montaje de una gran cantidad de paneles.

Paralelamente se realizaron modelos CAD, para explorar ciertas variaciones en las geometrías de los paneles y con las cuales se definió una configuración final. Con estos modelados virtuales, fue posible desarrollar algunos renderizados realistas con el software Cinema 4D, utilizando la biblioteca de materiales de la compañía para configurar una visualización óptima.

También se realizaron composiciones en ambientes diseñados por Kinnarps para mostrar las distintas posibilidades de los conceptos en un contexto real y éstas fueron utilizadas para la evaluación estética o de apariencia. Ejemplos de estas composiciones se muestran en la *Figura 22*.

Las personas evaluadas fueron los trabajadores de ventas encargados de elegir los paneles acústicos para los diseños de interiores de varias empresas. Y éstos eligieron al Concepto 1 como el concepto con mayores ventajas, entre las que destacan:

- "Diseño atractivo".
- Se considera como un producto fácil de vender.
- Sistema de montaje sencillo.
- La combinación de tela y chapa de madera es una buena idea porque los clientes pueden jugar con los colores y combinarlos con el resto de los muebles de los espacios de trabajo. Además de que da una percepción de un objeto de alta calidad.

Figura 22. Paneles integrados en espacios diseñados por *Kinnarps* para evaluación estética

Resultados

La selección final de la propuesta que se presenta se realizó en base a la prueba de apariencia con los usuarios objetivos, la opinión de los gerentes de Kinnarps, un análisis de la lista de requerimientos inicial y la intuición de los diseñadores. El concepto final (*Figura 23)* que se propone como familia de paneles acústicos consiste en tres tipos diferentes de estructuras de MDF, que funcionan como bases donde dos, tres o cuatro paneles acústicos se pueden montar fácilmente con imanes.
Este concepto tiene como características principales:

- Ofrecer al cliente la posibilidad de elegir y combinar diferentes tipos de paneles en diferentes posiciones, según el tipo de espacio que tengan.

- Reducir el número de tornillos por panel en comparación con el que la compañía tiene actualmente (cuatro por panel).

- Generar un espacio de aire entre los paneles y la pared para captar el sonido a mayor velocidad y aumentar la absorción del mismo.

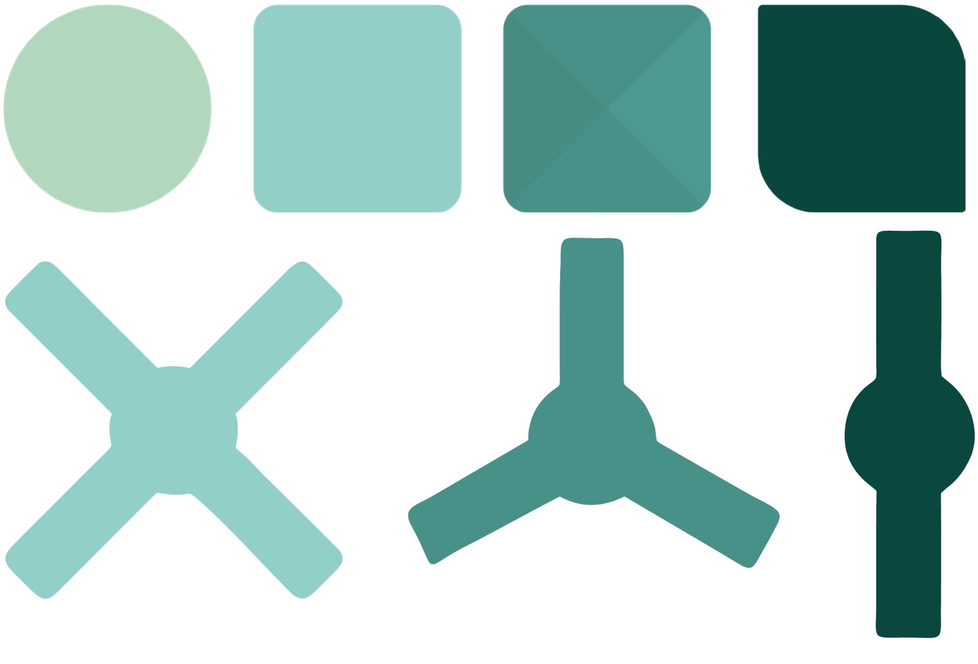


Figura 23. Geometrías de las estructuras y paneles del concepto final

Para el montaje se necesitan dos tacos de pared, dos rondanas y dos tornillos M6 (60 mm de largo). Se realizó un manual gráfico (Evans et al., 2010) para explicar cómo interactúa el montador con el producto. Ver *Figura 24.*

1. El montador mide y marca la distancia entre los tornillos en la pared.
2. El montador hace los agujeros en la pared con un taladro manual.
3. El montador inserta los tacos de pared.
4. El montador coloca las rondanas y los tornillos en los orificios de la estructura.
5. El montador atornilla la estructura a la pared.
6. El montador une los paneles en la posición deseada alineando los imanes a los bajo relieves de la estructura.

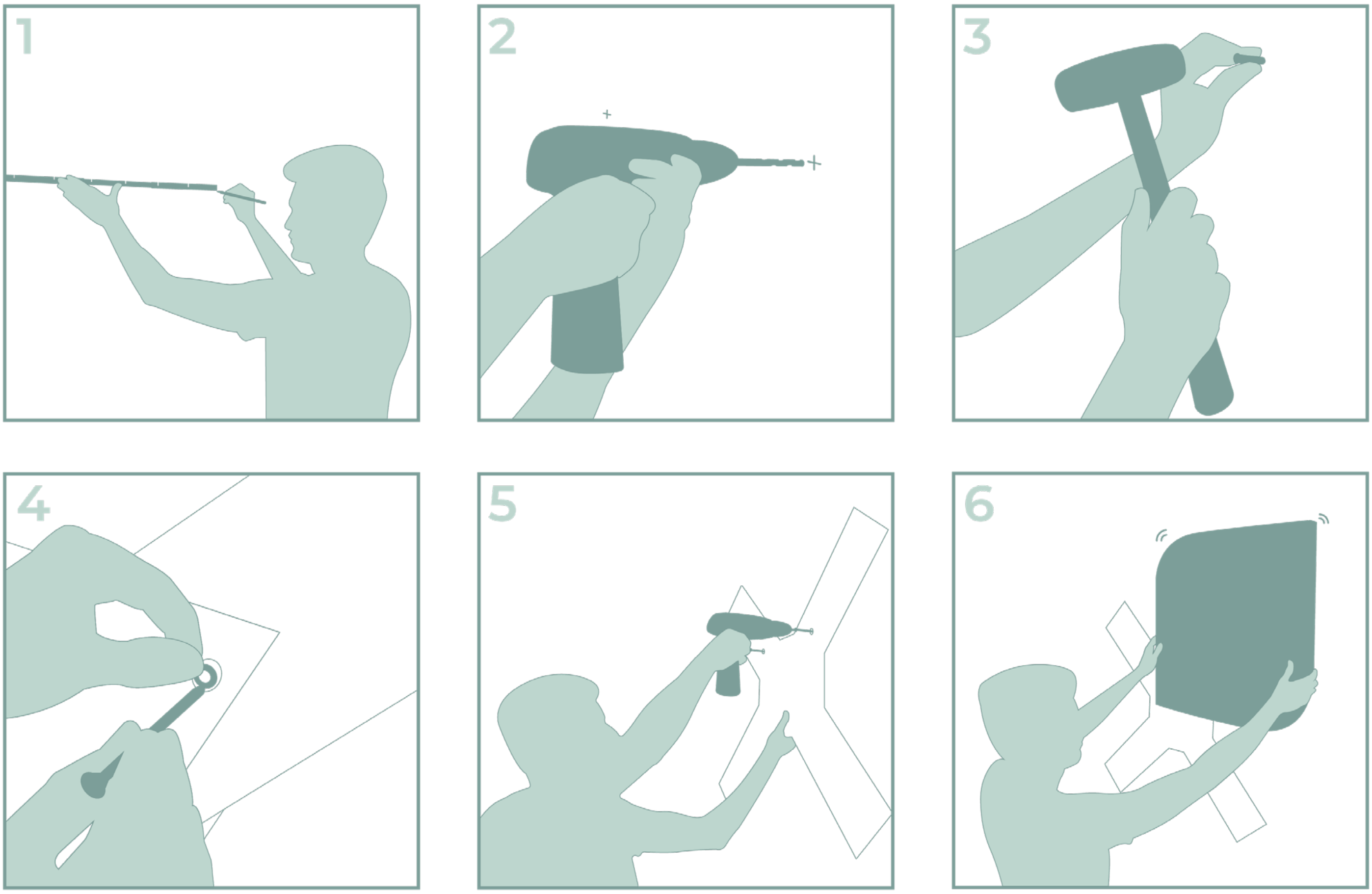


Figura 24. Manual gráfico de montaje.

La estética de los paneles se basa en formas regulares y simples, círculos, cuadrados, pirámides y siluetas que asimilan la hoja de un árbol, que al ser montadas en las bases pueden crear composiciones interesantes. Todos los paneles tienen los bordes redondeados y son simétricos en una dirección. El estilo se basa principalmente en las palabras clave de la marca, en el pensamiento analógico y en los moodboards de los entornos diseñados por la empresa. Una visualización del diseño final de los paneles se muestra en un espacio diseñado por Kinnarps en la *Figura 25.*

Figura 25. Visualización del diseño final en entorno *Kinnarps.*

Se propone tener dos capas de diferentes materiales absorbentes, combinando 20 mm de relleno acústico Kinnarps hecho de sus fibras de poliéster recicladas que ha mostrado propiedades acústicas eficientes en sus productos actuales, en conjunto con fieltro de lana (20 mm), que es la fibra natural con uno de los coeficientes de absorción más altos (NRC = 0.70). Esta combinación propuesta y el espacio de aire generado por la estructura podrían mejorar los resultados de absorción para los paneles. Aun así, para verificarlo, sería necesario probarlos en un laboratorio acústico. Desafortunadamente, no fue posible probar la propuesta antes de que este proyecto hubiera finalizado, ya que era demasiado costoso alquilar el laboratorio solo para evaluar los prototipos que elaboramos.

Respecto a la producción, se buscaron dos objetivos principales: lograr una buena valoración en la evaluación de sostenibilidad que maneja la empresa (Kinnarps Group, 2018) y garantizar la seguridad de los operadores. Para cumplirlos, se propuso continuar con los materiales y los procesos que utilizan actualmente.

Los procesos necesarios para la fabricación del producto son los siguientes:
Para las estructuras (bases):

- Corte con router CNC, es necesario para crear las piezas de cada estructura. (La estructura se dividió en 4 partes que se unen con una pieza central para evitar grandes áreas de desperdicio en los tableros de MDF).

- Ensamble manual con un operador, es necesario para pegar las partes que componen a la estructura, para enchapar la pieza central y fijar los separadores de goma en la parte posterior.

Para los paneles:

- Moldeado y prensado con calor, la tela y los materiales absorbentes se presionan en un molde a altas temperaturas, dando la forma deseada de cada panel.

- Ensamble manual con 1 operador, se deberán cortar los sobrantes del panel y unir las piezas las piezas centrales de MDF con los imanes en la parte posterior de éstos.

Una ilustración del despiece del producto es visible en la *Figura 26*.

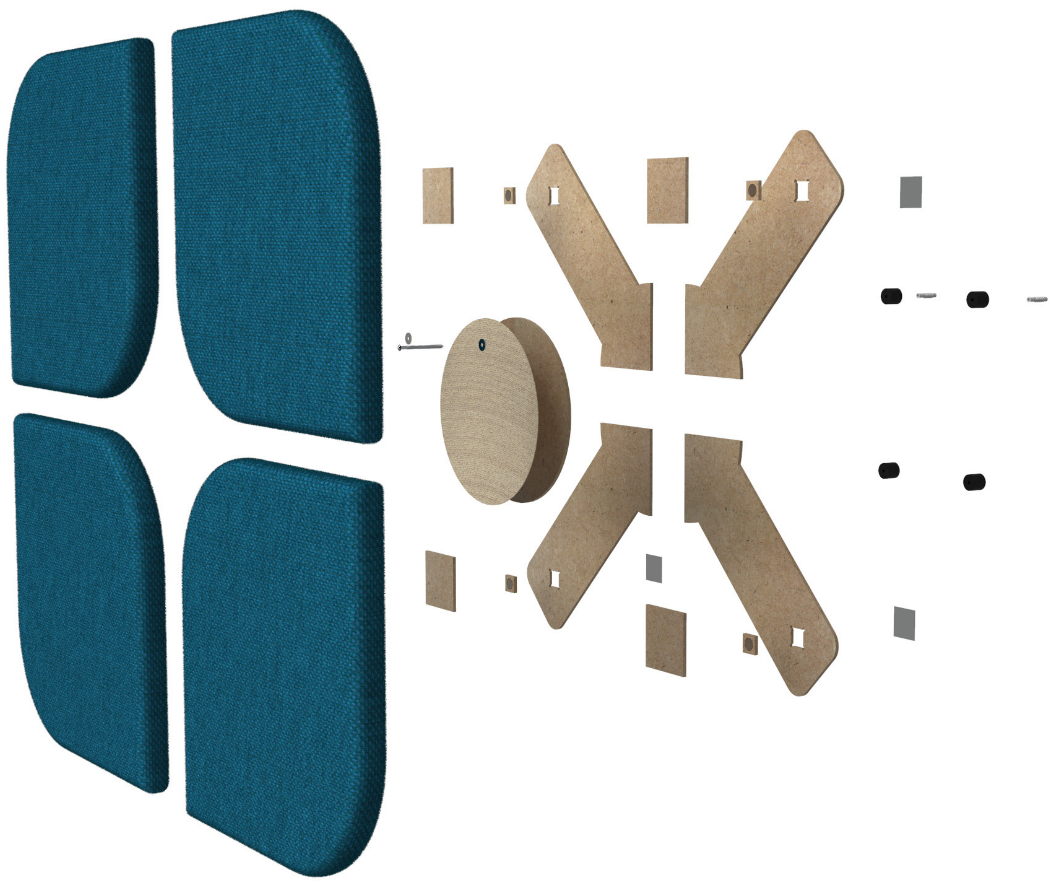
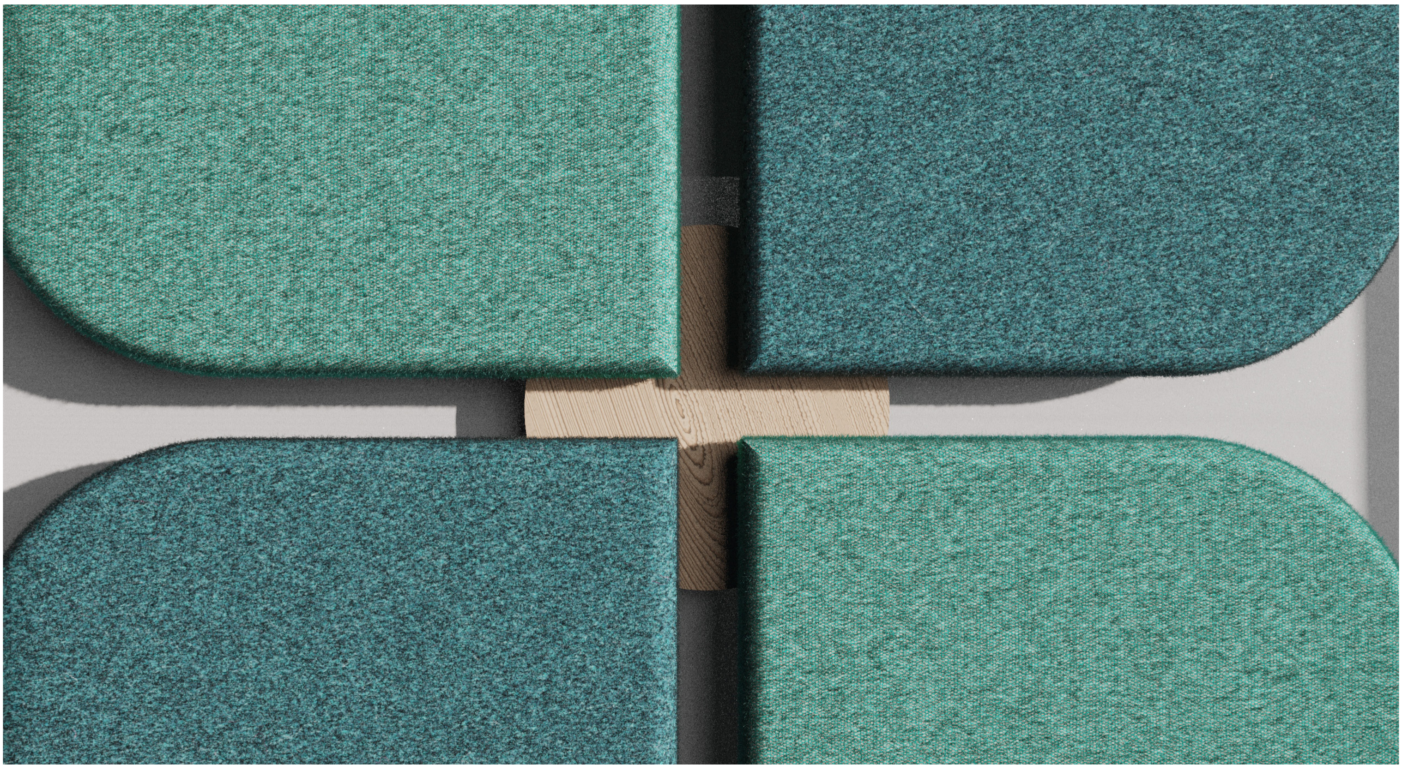


Figura 26. Despiece de Panel con 4 brazos

Visualizaciones del producto final



Conclusiones

Al término del proyecto se discutieron los resultados y se hicieron conclusiones con una perspectiva autocrítica sobre el proyecto. Se tomaron en consideración todas las etapas y se hizo un énfasis en el cumplimiento de las especificaciones iniciales del producto, en la colaboración con la empresa, las metodologías utilizadas y su influencia en el proyecto y en el aprendizaje en general de todo el proceso de diseño.

Respecto a los resultados, se concluyó que se cumplieron con todos los requisitos establecidos en las especificaciones del producto inicial que fueron marcados como exigencias por parte de la empresa, sin embargo hay algunos puntos que se pueden poner a discusión. En el caso de la funcionalidad, como ya se mencionó, aún se necesitan pruebas formales con el equipo adecuado para corroborar esta característica con las dimensiones, formas y materiales propuestos, aunque se espera un N_{10} <4 como resultado debido a que los materiales utilizados muestran buenos niveles de absorción con resultados oficiales que siguen el SS-EN ISO 354. Con respecto a la sostenibilidad, se buscó evitar el desperdicio de material en la fabricación de la base de los paneles mediante el diseño de módulos más pequeños que optimizaran los tableros de MDF, y en el caso de los materiales, el principal material absorbente propuesto no tiene un alto impacto negativo en el medio ambiente ya que está hecho a base de materiales reciclados de la propia empresa, por otro lado se considera que se debe realizar un estudio más profundo que tenga en cuenta el ciclo de vida completo del producto y las diferentes áreas del *The Better Effect Index* de la empresa. Proporcionar un sistema de montaje más fácil y rápido fue uno de los requisitos principales del proyecto, y gracias a las estructuras propuestas, este requisito se cumplió al reducir el número de agujeros en la pared a solo dos de ellos para cada tipo de estructura en lugar de cuatro por panel, como el modelo anterior de la marca. El uso de una cantidad menor de tornillos también reduce el riesgo de tener diferentes trastornos musculoesqueléticos para el montador.

La investigación y los estudios preliminares fueron de suma importancia para el desarrollo del proyecto ya que dieron las bases principales para la toma de decisiones a lo largo de todo el proceso y concluyeron en el concepto final propuesto. La revisión de la literatura sobre la absorción del sonido y los materiales influyó en la elección de los materiales propuestos, el uso de un espacio de aire detrás de los paneles para aumentar la absorción y la geometría piramidal de uno de los paneles para difundir las ondas de sonido reflejadas. Los estudios de usuario guiaron la elección del tipo de panel a desarrollar (panel de pared), la apariencia estética y la característica “personalizable”, que le da la opción al cliente de escoger entre varias opciones de paneles, para que escoja el que se adapte mejor a su espacio.

Respecto a la metodología, se concluye que el *Design Thinking* con un enfoque centrado en el usuario es una buena herramienta para trabajar con proyectos de diseño de producto que buscan un resultado innovador, debido a la combinación de pensamiento divergente y convergente que sugiere, que proporciona una combinación adecuada de exploración y selección de ideas, y que además al enfocarse en el usuario desde un inicio genera un rápido encuentro de oportunidades de diseño y mejora del producto, y una retroalimentación muy relevante en la evaluación de los conceptos generados en etapas posteriores. Respecto a las iteraciones, en general, fueron muy útiles para evolucionar los conceptos y volver a desarrollar partes específicas que se iban descubriendo que tenían que mejorarse, las principales iteraciones que se hicieron en el proyecto y que más ayudaron a la evolución del diseño fueron por medio de lluvia de ideas, proceso de bocetaje y prototipado, por ejemplo, después de que la empresa nos seleccionara tres direcciones en la etapa de conceptualización, se volvió a bocetar con esta guía, tratando de encontrar nuevos conceptos alternativos y/o definir más los tres conceptos "guía", lo que nos dirigió al desarrollo del concepto final, otro ejemplo fue cuando no resultaban completamente satisfactorias las soluciones de montaje propuestas en el prototipado, por lo que se volvía a hacer una lluvia de ideas de posibles soluciones alternativas, se bocetaban y se prototipaban para su evaluación, hasta que se llegó al sistema de montaje final. Sin embargo, se descubrió que las iteraciones tienen algunos aspectos negativos, se observó que éste proceso continuo puede llegar a convertirse en un riesgo si no hay un límite, ya que en ocasiones parecen ser infinitas las veces que se puede iterar, y cada iteración implica mucho tiempo que puede retrasar el proceso de desarrollo.

Por otra parte, la combinación de diferentes metodologías se consideró una manera adecuada de acercarse al problema en éste proyecto porque sus diferentes enfoques se complementaron entre sí. Por ejemplo, el enfoque de ingeniería de Ulrich & Eppinger sugirió indicar datos más concretos y técnicos, que funcionaron como limitantes y restricciones, mientras que las tarjetas de método IDEO y el *Design Thinking* sugirieron herramientas centradas en generar un gran número de ideas, fomentando la creatividad de los diseñadores en busca de encontrar un valor agregado para los usuarios.

El colaborar en un proyecto real de este nivel, llevó a entender y a practicar el cómo es trabajar con el desarrollo de nuevos productos para un mercado específico, se ejercitó la habilidad de trabajar con proyectos complejos, donde se involucran múltiples variables y donde no hay una solución única, se tuvo que tomar en cuenta las características del mercado objetivo, la experiencia de los usuarios, la ergonomía, la funcionalidad, producción, estética, viabilidad y ciclo de vida del producto durante todo el proceso, para poder encontrar un equilibrio y conjuntar esta información en una propuesta conceptual de un objeto producto, un proceso con el que comúnmente trabaja el diseñador industrial y que hace distinguir a nuestra profesión de otras.

Éste proyecto tuvo un énfasis importante en un estudio de la acústica y el sonido, por lo que es importante destacar que como diseñador, hay ocasiones en las que se debe de trabajar con temas dónde no somos expertos, pero que con asesoría de personas capacitadas y con investigación de distintas fuentes se puede generar un conocimiento base para poder proponer soluciones viables a través de nuestras propuestas de diseño.

Durante el proceso se aprendió el cómo aplicar al desarrollo del producto de una empresa real, algunos de los métodos y estrategias obtenidos de la educación de los ingenieros de diseño de producto. También se entendió que la planificación del proyecto es tan esencial como cualquier otra etapa del proceso porque crea una estructura a seguir, marca un ritmo de trabajo, con objetivos establecidos que deben lograrse cada cierto tiempo. Y como en todos los proyectos, se encontraron ciertas dificultades, en el caso de la investigación documental, se considera que tomó mucho tiempo debido a una planificación no bien estructurada, ya que primero se recopiló información en exceso de los campos principales, que eran aún áreas de investigación muy amplias, luego se filtró dicha información y finalmente se estructuró. Además, también hubo complicaciones en la construcción de los prototipos, ya que fue difícil lidiar con algunos proveedores de materiales o con los encargados de los laboratorios acústicos, debido a limitantes como el idioma o el transporte.

Cabe mencionar que la propuesta de diseño final presentado aquí es la propuesta que fue posible desarrollar dentro del límite de tiempo establecido por la empresa y la Universidad de Skövde, que fue de aproximadamente 5 meses. Por lo tanto, si el proyecto tuviera más tiempo para ser desarrollado, aún se podría trabajar con más profundidad para acercarse a la fase de producción. Se tendrían que realizar más evaluaciones y refinamientos a detalle del producto, por ejemplo, la evaluación de la funcionalidad, un enfoque en la fabricación de todas las piezas, considerando especialmente la combinación de los materiales acústicos en el molde, la viabilidad de estos procesos de fabricación, un análisis para examinar posibles fallas (Ginn et al., 2004) y un análisis de todos los costos involucrados.

Gracias a la colaboración con la empresa, fue posible tener una visión general de la gestión de una compañía de gran tamaño como lo es *Kinnarps*, desde la fabricación de sus productos, hasta la logística de su distribución. Entre otras cosas se dió la oportunidad de conocer cómo funciona el Departamento de Desarrollo de Productos, algunas de las consideraciones que toman en cuenta antes de lanzar un nuevo producto y los procesos de producción que utilizan en su fábrica. De los comentarios de los asesores de *Kinnarps*, destaca la recomendación que dieron de no restringir demasiado el proyecto desde el principio para dejar libertad, e incentivar creatividad e innovación durante todo el proceso. La comunicación con las personas de la empresa involucradas en el proyecto se consideró clave en el desarrollo de este proyecto. La retroalimentación constante, una reunión semanal, fue una muy buena estrategia para corroborar la dirección del proyecto y no olvidar los objetivos principales durante su ejecución, además de que ayudó a corregir a tiempo errores y a planear acciones futuras en conjunto. Esta estrategia nos ayudó a generar disciplina en nuestro equipo, ya que al tener fechas de entrega preestablecidas, se debía organizar cada día de trabajo para poder lograr un avance considerable para cada reunión y es por esto que se concluye que el tener entregables preestablecidos continuamente con tu equipo de trabajo es muy útil y eficiente para alcanzar los objetivos marcados. Esta estrategia se puede aplicar a otros proyectos con los que se tenga que trabajar en un futuro.

Trabajar con otro compañero fue una gran ventaja para el proyecto desde mi punto de vista porque ambos estábamos involucrados de manera equitativa, pensando con una mente abierta, siendo críticos, ayudándonos mutuamente y buscando alcanzar el mejor resultado posible. El venir de distintas universidades y de distintas culturas se consideró algo muy enriquecedor y útil ya que al tener otro punto de vista durante todo el proceso ayudó a cubrir el problema principal desde una perspectiva más amplia, a generar una discusión y complementar el conocimiento y las habilidades del otro.

El participar en el programa de movilidad académica en la Universidad de Skövde, resultó una experiencia completamente enriquecedora para mi desarrollo como diseñador industrial y como persona en general. Gracias a este programa tuve la oportunidad de conocer desde distintas culturas, lugares, personas, hasta distintos enfoques y formas de trabajo, además de que me abrió las puertas para poder colaborar con la empresa *Kinnarps* y me dió nuevas herramientas para poder seguir construyendo mi carrera profesional.

Como consejo final para futuros estudiantes que tengan la oportunidad de tener una experiencia similar, quiero compartir que mantengan actualizados sus portafolios, y que estén completamente traducidos al idioma inglés, ya que estos fueron nuestras tarjetas de presentación con todas las compañías que contactamos para poder generar una colaboración. Es importante ser muy claros con la compañía desde un inicio, explicar los alcances del proyecto estipulados por la universidad, y las limitantes que se tendrán debido a diferentes circunstancias tanto de la compañía como de ustedes al ser estudiantes universitarios extranjeros. Si es la primera experiencia con una empresa, no se intimiden, solo recuerden que ya tienen las herramientas necesarias para alcanzar un resultado de alto nivel y que la experiencia y el conocimiento adquirido del proyecto serán inigualables, trabajen duro y constante.

Referencias

Berardi, U., & Iannace, G. (2015). Acoustic characterization of natural fibers for sound absorption applications. Building and Environment, 94, 840–852. Recuperado el 11 de febrero del 2019, de https://doi.org/10.1016/j.buildenv.2015.05.029

Brown, T. (2008). Design thinking. Harvard business review, 86(6), 84. Recuperado el 05 de febrero del 2019, de https://hbr.org

Cross, N. (2006). Designerly ways of knowing. Springer Verlag. Recuperado el 05 de febrero del 2019, de https://www.dawsonera.com/?li=true&dest=https%3A%2F%2Fwww.dawsonera.com%2Fabstract%2F9781846283017&modal=signIn

Ermann, M. A. (2015). Architectural Acoustics Illustrated. John Wiley & Sons, Inc. Recuperado el 26 de febrero de 2019, de https://bayanbox.ir/view/7749222788148188744/1118568494.pdf

Evans, M., Pei, E., & Campbell, I. (2010). ID Cards. Loughborough University.

IDEO. (2003). IDEO Method Cards: 51 Ways to Inspire Design. William Stout Architectural Books. Recuperado el 25 de enero del 2019, de https://www.ideo.com/post/method-cards

Kinnarps Group. (2018). The better effect: A sustainability report from the Kinnarps Group.

Long, M. (2005). Architectural Acoustics. Academic Press. Recuperado el 06 de febrero del 2019, de http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=205640&site=ehost-live

Parkin, A. (2015). Finishes and Interiors: A guide to office acoustics. Reino Unido: FIS.

Rodgers, P., & Milton, A. (2011). Product Design. Londres: Laurence King Publishing

Russo, K. M., & Russo, S. J. (2011). Magnet-based mounting systems for frames (United States Patent Núm. US20110042542A1). Recuperado el 11 de febrero del 2019, de https://patents.google.com/patent/US20110042542A1/en?q=magnets&q=hanging&q=system&q=walls&oq=magnets+hanging+system+walls

Seddeq, H. S. (2009). Factors influencing acoustic performance of sound absorptive materials. Australian Journal of Basic and Applied Sciences, 3, 4610–4617.

Sundstrom, E. D. (1986). Work places: The psychology of the physical environment in offices and factories. Nueva York: Cambridge University Press.

Ulrich, K. T., & Eppinger, S. D. (2012). Product design and development (5th ed.). Nueva York: McGraw-Hill/Irwin.

Violante, F., Kilbom, Å., & Armstrong, T. J. (2000). Occupational Ergonomics : Work Related Musculoskeletal Disorders of the Upper Limb and Back. CRC Press; nlebk. Recuperado el 26 de febrero de 2019, de http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=83305&site=ehost-live

Zoltowski, C. B., Oakes, W. C., & Cardella, M. E. (2012). Students' Ways of Experiencing Human-Centered Design. Journal of Engineering Education, 101(1), 28–59. Recuperado el 05 de febrero del 2019, de https://doi.org/10.1002/j.2168-9830.2012.tb00040.x

SEGUNDA SECCIÓN

Documento anexo

HÖGSKOLAN I SKÖVDE

Design of a family of acoustic panels that follows Kinnarps guidelines.

Bachelor degree project in Design Engineering
Level G2E 30 ECTS
Spring term Year

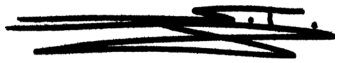
Gabriel Juárez Mejía
Julián Soria de la Torre

Supervisor: Ulrica Bohné
Assistant supervisor: Aitor Irondo Pascual
Examiner: Ari Kolbeinsson

ASSURANCE OF WORK

This project report has on (2019/07/04) been submitted by Gabriel Juárez Mejía and Julián Soria de la Torre to the University of Skövde as a part in obtaining credits on basic level G2E within Product Design Engineering.
We hereby confirm that for all the material included in this report which is not our own, we have reported a source and that we have not –for obtaining credits– included any material that we have earlier obtained credits within our academic studies.

Gabriel Juárez Mejía



Julián Soria de la Torre

ABSTRACT

Development of a conceptual proposal of acoustic panels for the Swedish company Kinnarps. The project uses as main methodology Design Thinking with an user centred approach. Secondarily is influenced by the product development process of Ulrich & Eppinger and some IDEO method cards. A literature review that mainly covers acoustics with an emphasis in absorption, a market research, and user studies were performed in order to have a based foundation to create feasible concepts. Along this report is possible to see how the development of the concepts has been done, how they were generated, evolved, and evaluated. As a final result it was proposed a family of three different types of structures with four variable absorbent panels. The mentioned structures generate an air backing space between the panels and the wall in order to catch the sound at a higher speed and increase the sound absorption. This solution also eases the way of mounting in comparison with the current panels of Kinnarps because it is only necessary to fix the bases to the wall using two or three screws for each one and then attach the absorbent panels to it with a magnetic system. The acoustic material proposed is a combination of layers of the current Kinnarps recycled filler, wool acoustic textile felt and polyester fabric. The variety of panels and the possible combinations with the different types of structures offer several compositions that the customers can choose depending on the type of atmosphere they want to generate on their workspace. It is considered that the final concept fulfils all the demands established in the initial specifications, although there are some debatable requirements like the functionality and sustainability that require further development. On the one hand several prototypes should be tested in a reverberation room with proper equipment to evaluate the efficiency of the absorption, and on the other a deeper sustainable analysis should be done considering the whole life cycle of the product. The methodology and the approach chosen were considered effective tools to work with product design projects that seek an innovative result because they give an appropriate mix of exploration and selection of ideas, suggest iterations that continuously evolve the emerging solutions and generate valuable input obtained from the involvement of the users during the whole process.

TABLE OF CONTENTS

1 INTRODUCTION

The project presented here aims to develop a family of acoustic panels for the company Kinnarps AB, a Swedish company that provides interior workspace solutions for offices and public environments, distinguished by the quality and the low environmental impact of their products. Kinnarps is part of Kinnarps Group which consists of six brands (Kinnarps, Materia, Skandiform, NC Nordic Care, Drabert and MartinStoll) being one of Europe's leading suppliers of interior design solutions (Kinnarps Group, 2018). The company is highly interested in the room acoustics, and in products for sound absorption, due to the recent growth of this market. They want to launch new families of acoustics panels, specifically sound absorbers, that are more accepted by their customers than the ones they currently sell. Therefore, the main goal of this project is to generate one or two feasible concepts, that reach an effective sound absorption, with feasible materials, manufacturing processes, a stable and easy way of mounting, and an attractive appearance for the target market.

To achieve this, "design thinking" was the main methodology chosen to be followed, with a user centred design approach. These concepts are described by different institutes and organizations as the Institute of Design at Stanford (The Interaction Design Foundation, n.d.), and the American company IDEO. This method is distinguished by the use of divergent and convergent thinking by encouraging "creative learning while doing" with sketching and fast prototyping, by suggesting iterations between its different stages and by analysing and understanding the main problem while you search and try different possible solutions (IDEO, 2003).

Along this document is shown a description of the whole design process and development of the product mentioned previously, following the principal steps suggested by the methodology chosen: Empathize, Define, Ideate, Prototype and Test. Also a literature review is shown regarding sound absorption that gives a foundation on the topic and bases for proposing different concepts, followed by other tools that are part of the Product Design Engineering programme, such as Market Research, User Studies, Requirement List, Decomposition of problems, Brainstorming, etc, that can be applied for the design of almost any other product.

2 METHODOLOGY

Design Thinking with a human-centred design approach is the principal methodology followed in this project. It was chosen due to the structure it suggests, that is commonly used for projects that seek innovation, by involving creativity as a key strategy to solve complex and "ill-defined" problems (problems that do not have all the information available, that may not have a single perfect and correct solution) (Cross, 2006). For instance, the American company IDEO has used this methodology for trying to find innovative solutions for design problems (Zoltowski et al., 2012).
Regarding the human-centred design approach, it consists basically in having the human beings as the central element of the project, by studying the stakeholders since the beginning and involving them during all the stages (Zoltowski et al., 2012). This approach is based on finding innovation with a thorough understanding of the people, of their needs, and likes and dislikes of the existing products (Brown, 2008).

The project in development also has a "Solution-focused strategy" that means the process should concentrate more in working with the solutions rather than with the analysis of the design problem itself. Design problems are not normally solved just by synthesizing the information collected. Instead, several directions followed while trying to solve them is what makes the problem clear and what influence and give input to find the most appropriate solution (Cross, 2006).

The method states to have a clear understanding of the two modes of thinking used during the development of the project, create and judge, converge and diverge. This separation of types of work will help to have a good flow in the search of innovation, by encouraging many ideas outside of the box in the divergent phase, and by having a critical judging in the selection of potential concepts, in the convergent one (Hartson & Pyla, 2012). *Figure 1* shows a graphic of how the divergent and convergent phases are represented in a double diamond structure during the design process.

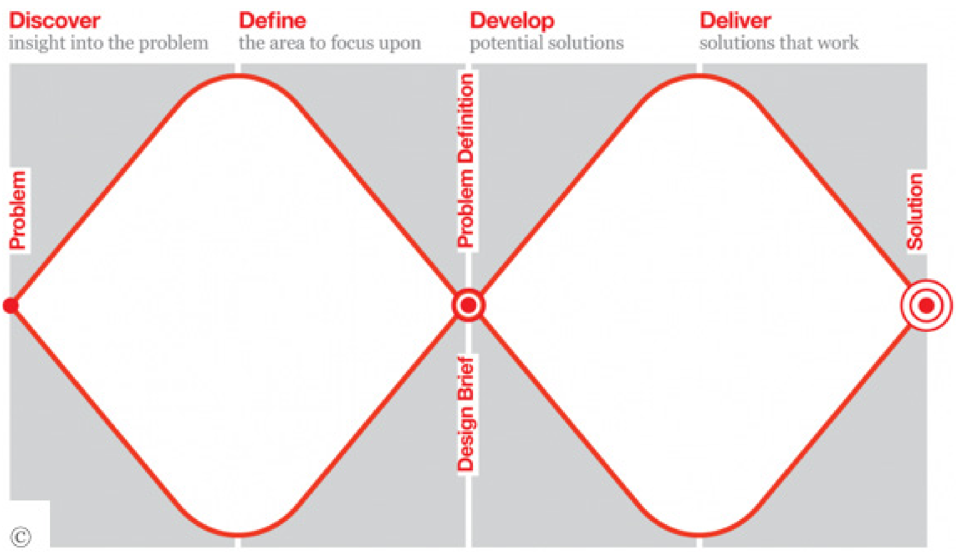


Figure 1. Double Diamond of the Design Council UK

The 5 main stages of Design Thinking that this project follows are: Empathize with the users, Define the problem, Ideate possible solutions, Prototype the potential solutions and Test them (Doorley et al., 2018).

1. Empathize with the users. Identify the users and try to understand their context, study their experience, their specific problems, their likes and needs, find design opportunities that help to create appropriate products for them. This stage is the most essential for a human centred design approach, even though the involvement of potential users and their insights should be considered through all the stages (Doorley et al., 2018).
Some research tools can be used to work with this kind of research, they are normally divided in 3 levels, low, medium and high, that state the level of user involvement, and depth of information. These tools go from questionnaires, web surveys, to workshops and evaluation meetings (Gheerawo et al., 2010).
The information collected from the interviews can be synthesized and shown by making "Personas" which are concrete descriptions of typical users, and "scenarios" which are stories of the users that help the designers to make products that completely satisfy a small percentage of the total user population (Hartson & Pyla, 2012).

2. Define the problem. Use the information previously collected, analyse and synthesize it to reframe the problem and identify the key points that are going to be tackled in the next stages (Doorley et al., 2018).

3. Ideate possible solutions. Generate different concepts that solve the problem or parts of it, trying to think "outside of the box", using different perspectives to approach it, and encouraging innovative ideas. It is suggested to have a mixed verbal and visual brainstorming (sketching) of different solutions for the design problem (Hartson & Pyla, 2012). For this stage, analogical and lateral thinking were found as tools that can be used to get extra input, by looking to other things not related with the context you are working on, searching similarities of function or potential existing ideas that can "solve" your problem if they are modified, and also by focusing in the deficiencies of existing solutions (Rodgers & Milton, 2011).

4. Prototype the potential solutions. Choose the ideas that are considered to have more potential and make prototypes, these can be scaled versions of it, full size, or only parts of the complete concept, depending on the type of input that the design team wants to get. These input can be gaining a better understanding of the users relation with the product, explore several configurations, test, refine solutions or take decisions (Doorley et al., 2018).
In this stage as in the whole creative process is common to use intuition as an important factor at the moment of taking decisions. Intuition can be seen as "abductive" reasoning, which is a type of thinking based in making suppositions (Cross, 2006).

5. Test the design. After prototyping the potential concepts, it is possible to make an evaluation of the proposed solutions in different areas like functionality, ergonomics or aesthetics. This stage may seem to be the last one but as it gives more input for the designer to redefine the concepts, or even the problem, the process does not stop here (Doorley et al., 2018).

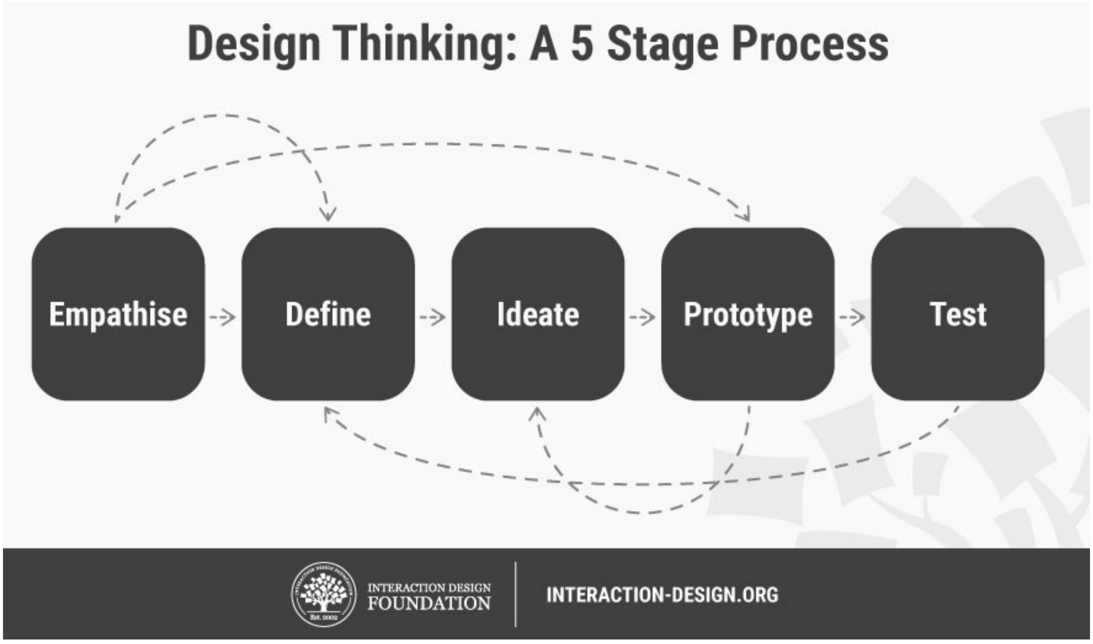


Figure 2. Design Thinking Diagram (Interaction Design Foundation, n.d.).

An essential characteristic of this method is that it is considered a non-linear process or iterative, that means it gives freedom for the designers to go back to any stage, whenever is necessary, either to develop further potential solutions or to test new alternatives that may appear in the process, and so on (Interaction Design Foundation, n.d.). A graphic example of this is shown in *Figure 2*.

Some of the stages of the product development process established in the Product Design and Development book complemented and influenced the main methodology that guides the whole project. The stages are: planning, concept development, system-level design, detail design, testing and refinement and production ramp up. Highlighting the first five, that were considered more convenient for this project. The planning consists in stating the strategies, objectives and schedule to follow. The concept development is started by identifying the users and customer needs and wishes, then the product specifications are defined, and the concept generation is performed for later making a selection and testing the ideas created. By using a system level design is possible to decompose the problem into different subsystems, which is very helpful to perceive it in a simpler way and approach the problem separately. The main problem can be divided depending on the complexity of the product, by considering its functionality, the interaction with the user or the customer needs. This process makes also easier the ideation stage and encourages to have a considerable number of solutions for different parts of the product that can be further combined. The detail design mainly is the development of all the product specifications, considering all the parts that conform the product, features such as size, materials, etc. The testing and refinement works with prototypes and their evaluations and finally in the production ramp-up the product is made as it is intended to be produced, seeking any remaining issues (Ulrich & Eppinger, 2008).

Extra tools for exploring different approaches that could be applied to several stages of the project were searched, and the following were found:

IDEO Method cards, tools that guide the design process with a human centred design approach, there are 51 cards that explains some methods that the American company IDEO has used to explore, gain new perspectives, and get inspired. This are examples and suggestions for finding new insights, not straight rules (IDEO, 2003). Although, after an analysis of them, only 5 cards were chosen to work with: shadowing (users observation), scenarios, competitive product survey, scale modelling, and experience prototype.

In general terms the methodology for the development of the concepts for the family of acoustic panels is based principally in the guide of five steps of the Design Thinking, and secondarily influenced by the product development process of Ulrich & Eppinger and the chosen IDEO cards.

3 LITERATURE REVIEW

Research in acoustics was necessary to generate a background of general knowledge in themes that could influence sound and the room acoustics, some phenomenon were studied such as reverberance, clarity, sound absorption, workspace acoustics. An emphasis in sound absorption is made to have a clear understanding of the functionality of the acoustic panels that are being developed and to find potential improvements for it. Some other factors that could influence the design direction were also investigated, such as workspace characteristics, materials, patents and user experience.

3.1 Basic Acoustics

To start with the literature review, an investigation of concepts about basic acoustics was made in order to have a foundation of this field, and be able to understand the complexity of the papers found about the next topics.

3.1.1 Sound

Ermann (2015, p.2) says:
“A sound is made when an oscillating membrane disturbs the molecules in an elastic medium-and that disturbance is heard.” Which means that the sound is produced by the motion of some objects, and it needs a medium to be transported to a listener, this is really easy to observe when someone plays musical instruments. Sound also depends directly on the changes of temperature and pressure (Ermann, 2015).

To understand the phenomenon of sound, it is useful to perceive that it behaves as waves in fluids, thus it is necessary to take into account other concepts as period, frequency, wavelength, and speed. The period refers to the time that takes the motion in being done (Long, 2005). The frequency expresses a way for differentiating the sound depending on the wave repetitions per second. Usually, sound frequencies are divided in octaves. This octaves are divided in different frequencies, which middle points are twice of the previous starting with 63 Hz (Ermann, 2015). The speed gives the value of how fast the waves move, and the value in air at 20ºC, according to Long (2005), is approximately around 344 m/s. The wavelength is the distance measurement between two peaks of the wave. This value helps to analyse how the different waves behave in the space, for example long wavelengths flow around objects when they have smaller measurements, and when small wavelengths meet bigger objects than themselves, they will be reflected (Long, 2005).

The wide range of sound intensities makes the need of using levels to express their values, this levels are perceived as fractions (10 times log of the ratio of two numbers). The units of these fractions are bels, and the multiplication by 10 has been established and agreed by the scientific community, in order to achieve numbers that have useful sizes. Thus the final units for levels are Decibels (dB). To express the strength that the sound has at its each cycle, exists a term called the sound power level (intensity), that is measured in watts, and is proportional to decibels (Long, 2005). A list of common sounds measured in Decibels is shown in *Table 1*.

Sound source	(dB)	I(W/m^2)	p(Pa)
Jet engine at 30 m	140	10^2	200
Car stereo contest winner	130		
SST takeoff at 500 m	120	1	20
Amplified rock concert	110		
Heavy machine shop	100	10^{-2}	2
Subway train	90		
Factory	80	10^{-4}	0.2
City traffic	70		
Subdued conversation	60	10^{-6}	2×10^{-2}
Quiet auto interior	50		
Library	40	10^{-8}	2×10^{-3}
Empty auditorium	30		
Whisper at 1 m	20	10^{-10}	2×10^{-4}
Falling pin	10		
	0	10^{-12}	2×10^{-5}

* While these are typical of levels that might be encountered in a variety of situations, individual examples could easily be 10 dB higher or lower.

Table 1. List of common sounds measured in dB (Hall, 1993).

3.1.2 Reverberance

Reverberance is one of the most common phenomena that affects work spaces, it is the process of reflection and attenuation of a sound. When a sound source for instance a speaker emits words and this message travels straight without obstacles to the listener, this type of sound is considered direct. However this rarely happens in rooms, what actually happens is that the sound emitted by the source is accompanied by later sounds that had being reflected in different surfaces like walls or furniture and did not follow a direct path to the listener, this is what is called reverberance. This later sounds grow in quantity but decrease in their energy level (Hall, 1993).

The reverberation time expresses the time length that this reflected sounds took to drop below the threshold of human hearing and to be inaudible for humans. The shorter the reverberation time, the better is going to be the acoustics of a room in terms of speech intelligibility (Parkin, 2015). The standard reverberation time has been established from the start of the sound until it decays 60 dB, which is the range that human perception could be able to notice (Hall, 1993). This is shown graphically in *Figure 3*.

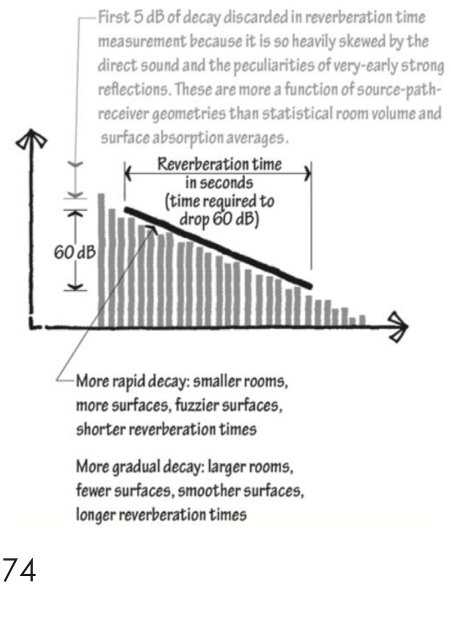


Figure 3. Reverberation time (Ermann, 2015).

Reverberation time tends to be longer in larger rooms with reflective walls due to the sound waves have a longer free route, without impacts in surfaces that produce loss of energy (Ermann, 2015). In architectural acoustics, reverberation is usually attenuated with sound absorbers in the ceilings, walls, carpets or other structures. Although some diffusers made with hard materials like wood are also used for the same purpose (Parkin, 2015). Their geometry can influence the room acoustics. Some shapes like convex curves, pyramids, angled surfaces, protruding pilasters, or craggy surfaces generate diffuse reflection because the waves impact on them and are reflected in an aleatory way. Diffusion is very helpful to reduce echo problems and improve the room acoustics, increasing the understanding level of sounds because when a sound is reflected in different directions, the reverberation time becomes shorter. In concert halls, diffusing surfaces are used to create a homogenized atmosphere, trying to avoid hard specular reflections (Ermann, 2015). *Figure 4* shows an example of the difference between specular and diffuse reflection.

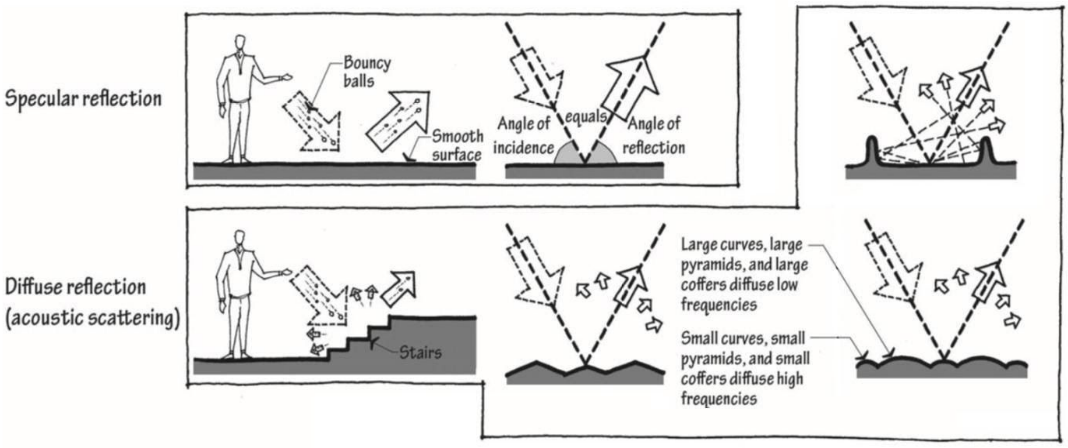


Figure 4. Specular and Diffuse reflection (Adapted from Ermann, 2015).

3.1.3 Clarity

People would like to hear words clearly without missing or confusing any of them. Clarity is based on having a firm direct sound with proper strength. If the direct sound does not have to compete with a long and continued reverberation, this sound will be more easy to understand (Hall, 1993).

Human brains mix the main sound heard with early-arriving reflections. In this way, humans are able to distinguish between different notes or syllables. This combination is called “Haas effect” or “precedence effect”. The brain combines reflections that arrive up to 200 millisecond, measured since the sound reach the listener and depending on the balance, the type of sound and the configuration of the room (Ermann, 2015).

By measuring the sound energy that arrives later than 80 millisecond and comparing it with the total energy averaged for three octave bands, it is possible to obtain the clarity index. In this respect, it is important to clarify that the clarity index only measures frequencies that are higher than 250 Hz because for humans auditory system is difficult to differentiate temporal effects in lower frequencies, commonly known as bass tones. This simply means that sounds would be clearer when the clarity index is high (Ermann, 2015).

3.1.4 Noise

Noise is a common problem in working spaces, where concentration is crucial to do daily tasks, in fact, it is directly related with the dissatisfaction of workers with job, especially in open offices. There are studies that show that about 60% of the people who work in spaces with more than seven people in the same room, manifest inability to concentrate (Lucerne University of Applied Sciences and arts cited in Schittich, 2011). Noise is always an issue in working spaces that affect a large amount of workers, especially in open offices. This noise, for instance, includes conversations and telephones' ringing that can create annoyance in certain areas because of their intensity. It also decreases the efficiency of tasks that require concentration such as administrative tasks, highly demand motor tasks, vigilance or dual tasks (Sundstrom, 1986).

There are different types of sounds that contribute to create noise, specifically in work spaces, but according to the limit to recognize a sound without perceiving it as separate thumps is 20 beats per second. The sounds with extremely low frequencies are perceived as noise for humans (Ermann, 2015). Some sounds distract people more than others depending if they perceived them as coherent or incoherent, so if someone is giving a speech, and you listen at the same time other coherent sounds, such as music, or people talking, it will catch your attention at disturb your concentration from the main activity you are developing (Copley, cited in Sundstrom, 1986). In working environments, noise can provoke loss of productivity and even physiological disorders, such as headaches, or heart problems (Munjal, 2013).

It exists a measurement of the reduction of noise that is commonly used to compare the absorption of some materials, it is called Noise Reduction Coefficient, and basically is obtained by the average of the absorption coefficient of the material for mid-frequency ranges, as it is shown in *Figure 5* (Ermann, 2015).

$$NRC_{noise\ reduction\ coefficient} = \frac{\alpha_{250\ Hz} + \alpha_{500\ Hz} + \alpha_{1000\ Hz} + \alpha_{2000\ Hz}}{4}$$

Figure 5. Noise Reduction Coefficient (Ermann,2015).

3.2 Human hearing

Humans perceive the sound through the eardrums that move when they catch the changes in pressure, transforming them into electrical stimulus for our brain (Long, 2005).

It is worth to mention that humans can not listen all type of sounds, humans can perceive only some sounds that have a specific range between 0 and 130 dB, considering zero as completely inaudible to most people, 20 dB as a whisper, and 130 dB as intolerably loud (Hall, 1993). The audible range for humans goes from 20 to 20 000 Hz, although the range between 500 Hz to 4000 Hz, known as "speech range" or middle frequency range, is the range that humans best hear (Parkin,2015). Humans are more sensitive to middle and high frequency (500Hz and above) than to those lower than 250 HZ because the sound wavelengths that these frequencies generate occupy a specific dimension that corresponds to the scale of the human ear canal diameter, unlike the ones generated by lower frequencies. For instance, to catch humans attention quickly, sirens, vehicle horns and alarms use generally high frequency sounds (Ermann, 2015).

3.3 Sound Absorption

The absorption of sound is the main function that the product in development needs to achieve. This is why a research has been done regarding how this effect works, how it could be measured and the different mechanisms to accomplish a high level of absorption.

The absorption actually occurs when sound waves interact with real objects by being reflected, transmitted and absorbed by the material, as it is shown in *Figure 6*, where also is possible to see how sound interacts with 3 different materials, having different percentages of absorption, reflection and transmission (Long, 2005).

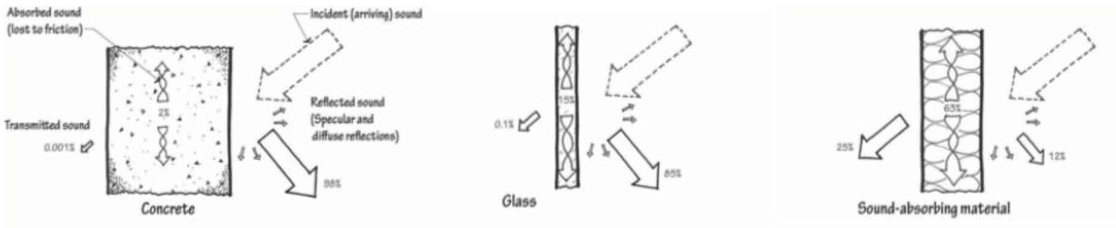


Figure 6. Sound absorption of 3 different materials (Ermann, 2015).

The absorption coefficient (α) is the most used value to express the material absorption. It is shown in different sources and material catalogues, this makes easy to identify and compare their functionality. Its value goes from zero to one, and determines the absorption level. It can be understood as the quantity of incident sound that is not reflected, and coming again in to the room. A higher sound absorption value is proportionally correlated with the amount of sound energy absorbed or transmitted, which means a low reflection level. Materials with more than 0.50 are considered absorbent materials and on the other hand, the ones with less than 0.20 are considered reflective (Ermann, 2015). The higher values are usually of materials that are more porous, lighter, thicker and less smooth. These high values are also often caused because of the fibres direction that forms interconnecting air spaces (Ermann, 2015).

Porous absorbers work due to a mechanism called viscous drag which is the one that makes them to be good acoustic absorbers, and basically consists in sound waves provoking air motion in the spaces that exist between the material fibres. This air movement goes in different directions and produces friction, losses of momentum, and heat, depending if they are high or low frequencies. There exists also a variant factor for thin porous absorbers, depending on the distance from them to the wall, the absorption coefficient would be influenced by the air space between them. If the porous absorber is positioned at a distance that corresponds to multiples of a quarter wavelength from the wall, an appropriate position for it will be achieved, because there is a point where the particle velocity is at a maximum point (Long, 2005).

This mentioned influence of the air backing of the porous absorber was confirmed in a positive way by the paper “Principles of Sound absorbers” (Qiu, 2016). The back air space increases the absorption at low frequencies because the velocity of particles next to rigid surfaces is generally zero, and with this space generated by having a layer of material further from the wall, a higher velocity of sound waves will be reached, providing a better absorption. *Figure 7* shows a comparison between the absorption coefficients curves of the same material with different thicknesses and different distances from the wall. The red line represents a 5 cm thick absorptive material placed on a rigid wall. The blue dot line represents the same material placed 10 cm away from the wall. And the dash-dot line represents a 15 cm porous material placed directly on a rigid wall. It was concluded that placing the material separated from the wall increases the absorption levels at lower frequencies (Qiu, 2016).

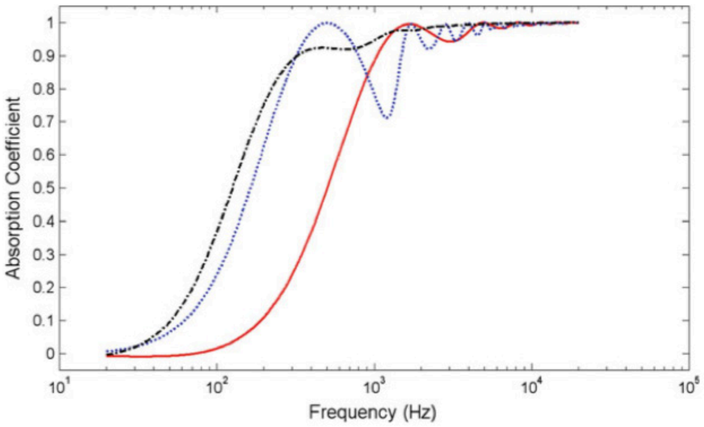


Figure 7. Chart of the influence that has thickness and air backing in the absorption coefficient of a material (Qiu, 2016).

The materials opposition against fluids passage through them, affects the absorption in absorptive materials. By perforating them, the mass gets lower and the air space that pores creates improve the absorption. Perforated panels with backing airspace act like a Helmholtz resonator, achieving a higher value of resonant frequency, affecting the sound waves. It is important to generate an enough open area for not blocking the flow of sound. These kind of panels are thought to absorb middle-frequency levels (Long, 2005).

The mentioned perforated panel act as the Helmholtz resonators-absorbers because the holes work as the neck of the resonator, the space between the panel and the wall act as the cavity, and finally the wall act as the surface of it, making a similar "mass-spring" system (Negro et al., 2015). Micro perforated panels are recently becoming more accepted as replacement of the porous absorbers (Wencheng & Hequn, 2015).

There are different materials that are used on architecture to improve the acoustics of the room, some are shown in *Figure 8*, it is interesting to observe the comparison between their absorption coefficients and it is also worth highlighting the improvement that some materials have when they are perforated, like the plasterboards, metal faced plains or wood.

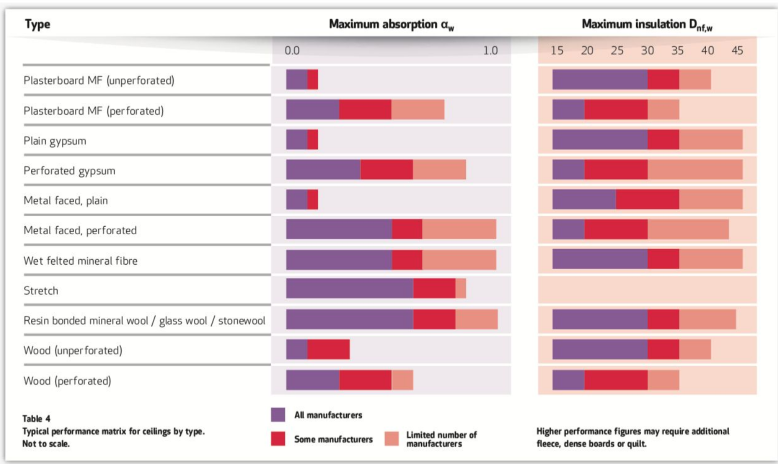


Figure 8. Typical materials used in ceilings of rooms (Parkin, 2015).

Absorptive materials can be overlaid without losing absorption properties. It is common to use wood or metal to cover these absorbers, and as can be seen in *Figure 9*, perforations in the facing are useful to maintain the absorption properties of the inner material. If the perforation percentage increases, the absorption is better, but from a 15-20% perforation percentage in the reflective surface, the inner material behaves as if it were unfaced (Long, 2005).

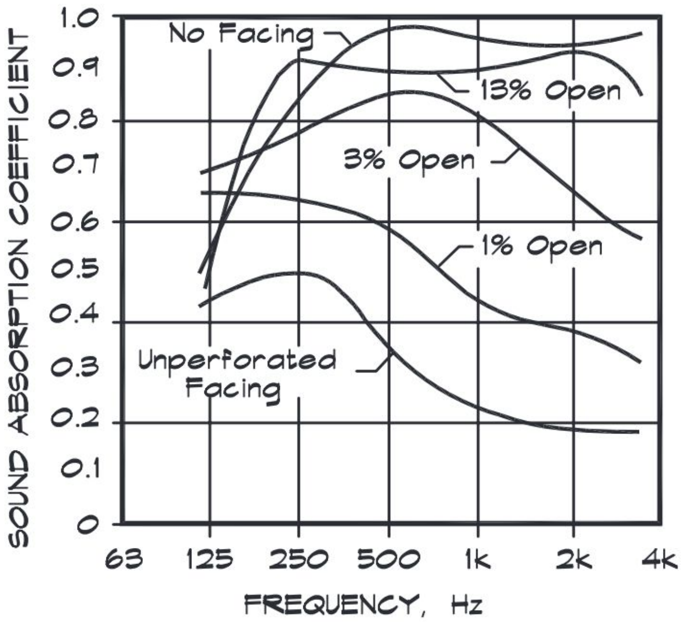


Figure 9. Comparison between perforated facings (Doelle, cited in Long, 2005).

Another absorption system called mass-air-mass is composed of at least two masses separated by an air space. It is very lightweight thanks to the air space that acts as a spring and attenuates the sound. The two masses act as one at very low frequencies (less than 66 Hz) and in the case of higher ones, having numerous air spaces can lead to a better absorption (Bradley, cited in Long, 2005).

3.3.1 Sound Absorption Testing

After visiting the company in charge of evaluating the current panels of Kinnarps, *Akustikverkstan* in Skultorp, some information about the absorption levels testing was obtained.

Kinnarps as a big amount of other Swedish companies, used the website www. acousticsfacts.se as a platform to show their acoustics results of a specific test based on three principal rules:

- ISO 11654:1997 – Acoustics - Sound absorbers for use in buildings - Rating of sound absorption
- ISO 354:2003 – Acoustics - Measurement of sound absorption in a reverberation room
- SS 25269:2013 – Acoustics – Screens or single objects – evaluation of sound absorption and screen damping.
(Akustikverkstan, n.d.).

Tests are placed in a reverberation room like the one shown in *Figure 10*. The test makes a comparison between the room's reverberation time without products and the reverberation time when the products are placed inside. It calculates the noise quantity that is absorbed thanks to the absorption coefficient in relation with the area of the product. After different frequency sounds are played at a constant level, the time is measured until the reverberation is reduced by 60 dB. Some surfaces are hanged in the reverberation room in order to diffuse the sound and generate different aleatory waves. For this test, sound is considered at a temperature of 20ºC and at a humidity range of 50-70%, due to this are the values considered normal for interior rooms. (Acoustic Facts, 2017).

Figure 10. Reverberation room.

The frequencies range that should be measured in these acoustic tests, following the Swedish standard SS 25269 is from 125 Hz to 4000 Hz. In the tests results is common to find a value called N_{10} that shows how many tested objects are required to have 10 m^2 of effective sound absorption area. This value has been established in Sweden to evaluate the absorption efficiency in the human speech frequency average (500 Hz) and it is obtained by dividing the number ten by the sound absorption surface. (Kammarkollegiet, 2017).

The "sound absorption area" is measured in the unit Sabins, and it could be obtained from adding the multiplication of the absorption coefficients by the surface area of the products materials in a room. (Ermann, 2015). The lower the value of N_{10} , the better the sound absorption is.

3.4 Existing patents

Research in patents about acoustic absorbers was performed in order to find any existing design, configuration or mounting way which should be avoided during the design process. The results were some existing layer distribution for achieving greater levels of absorption and some mounting systems to avoid, but not any aesthetic design limitation.

Here are shown the more relevant patent examples for the project regarding the layer distribution inside the panels (*Figure 11* and *Figure 12*) and the mounting system (*Figure 13* and *Figure 14*):

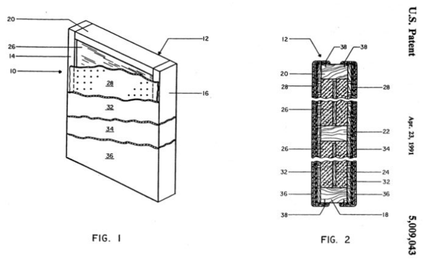


Figure 11. Acoustic panel (Kurrasch, 1991).

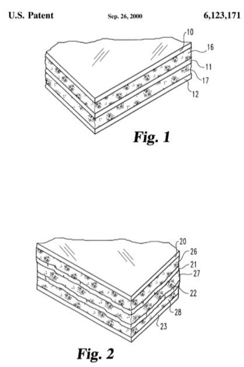


Figure 12. Acoustic panels having plural damping layers (McNett and McNett, 2000).

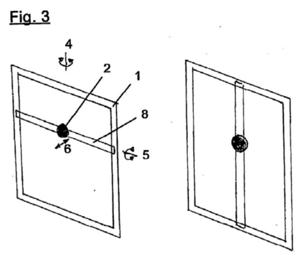


Figure 13. System for hanging different items on walls (Nicolaisen, 2009).

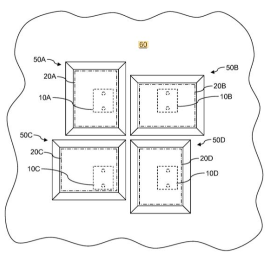


Figure 14. Magnet-based mounting systems for frames (Russo & Russo, 2011)

3.5 Absorbent materials

Kinnarps currently use “Re:fill” for the absorptive panels that they sell. It is a porous material made of 60% polyester fibres that come from their own textile waste and recycled PET. The absorption levels of this panels are published in www.acousticsfacts.se. As an example (*Figure 15*), “Prim” standing panel with dimensions of 800 mm x 1980 mm and a thickness of 55mm reaches a N_{10} value of 4 (N_{10} value is explained in the Section 3.3.1).

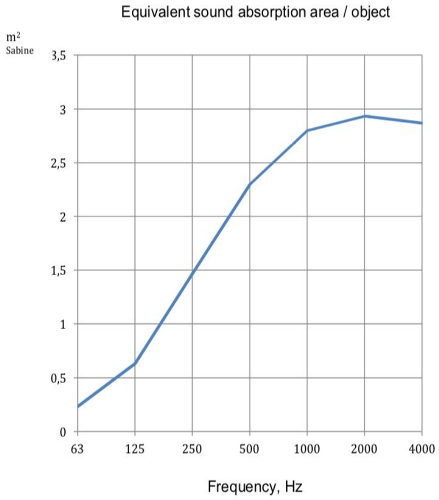


Figure 15. Prim acoustic test results (Acoustic Facts, 2017).

Many materials have absorptive properties and can be used for the acoustic panels, even though each material has a different sound absorption mechanism, and its performance relies on its interior crevice and pore (Bao-guo et al., 2002).

There are some other factors that influence the efficiency of absorptive materials that are necessary to analyse before choosing one for a product which functionality is based on this feature. It was found a list of these factors in a paper, although for the project, the following were considered as the most relevant: fibre size, airflow resistance, porosity, density and thickness. This paper mentions important facts about how these factors increase the sound absorption, and it could be used as an appropriate guide for the material selection. Within the relevant facts, the following can be highlighted, micro denier fibres have shown a high increase in acoustic performance, it exists a relation between high air flow resistance and high absorption in different materials but if the flow resistance exceeds 1000, the sound absorption would decrease due to the difficulty of movement within the material. For the fibres, if the surface area is bigger and the fibre size smaller, the absorption sound will also increase. An open structure of a material that has low density will perform better with low frequencies such as 500 Hz, while denser structures will absorb more high frequencies like above 2000 Hz. The air gap behind a layer of material will increase its absorption coefficient values. And regarding the thickness, it shows that for low frequencies, the best absorption will be achieved by having a thicker layer of the materials (Seddeq, 2009).

In *Figure 8* (Section 3.3), some absorption coefficients of different materials used for architecture are shown and it is possible to see that the higher ones are: mineral fibres and perforated gypsum. It was also found a paper about perforated okoumé plywood (4 mm) that shows interesting high values for the absorption coefficient of frequencies around 500 Hz (Negro et al., 2015).

On the other hand, as one of the most important values of the company is the sustainability, some natural and biodegradable materials were sought, to analyse their absorption coefficients and study their feasibility for improving the absorption levels that the current acoustic panel of Kinnarps has. These are shown in *Table 2*.

Table 2
Sound absorption coefficient values of the materials studied in this paper.

Material		Thickness [m]	Frequency [Hz]					NRC
			125	250	500	1000	2000	
Kenaf	(Light)	0.06	0.09	0.19	0.33	0.68	0.90	0.55
	(Dense)	0.04	0.08	0.18	0.32	0.70	0.94	0.55
	(Dense)	0.06	0.10	0.30	0.61	0.99	0.95	0.70
Wood	(Fibers)	0.06	0.20	0.40	0.50	0.65	0.91	0.60
	(Mineralized)	0.03	0.05	0.10	0.10	0.20	0.40	0.20
Hemp		0.03	0.01	0.15	0.25	0.51	0.70	0.40
Coconut		0.05	0.10	0.20	0.34	0.67	0.79	0.50
		0.10	0.25	0.42	0.83	0.81	0.94	0.75
Cork		0.03	0.01	0.02	0.10	0.30	0.86	0.30
Cane	(Mixed)	0.04	0.05	0.10	0.35	0.54	0.58	0.40
	(Mixed)	0.08	0.10	0.21	0.56	0.52	0.68	0.50
	(Only wooden)	0.04	0.01	0.06	0.12	0.47	0.43	0.25
	(Only wooden)	0.08	0.07	0.15	0.46	0.39	0.66	0.40
	(Only bark)	0.04	0.10	0.12	0.38	0.64	0.62	0.45
	(Only bark)	0.08	0.10	0.26	0.63	0.54	0.89	0.60
Cardboard		0.10	0.10	0.27	0.48	0.54	0.66	0.50
Sheep wool		0.04	0.10	0.14	0.36	0.73	0.94	0.55
		0.06	0.15	0.28	0.66	0.95	0.94	0.70

Table 2. Sound absorption coefficient of natural materials (Berardi & Iannace, 2015).

The highest values for Noise Reduction Coefficient (NRC) in *Table 2* are of coconut fibres (10 cm) with 0.75, dense Kenaf (6 cm) and sheep wool with 0.70, and particularly for 500 Hz, which is the human speech frequency, the highest values are for the coconut (10cm) with 0.83, sheep wool (6 cm) with 0.66, cane (8 cm) with 0.63 and dense kenaf (6cm) with 0.61. It is important to note that the thickness of the sample affects these results. Even though in general terms the Kenaf and sheep wool seem to be better absorptive materials (Berardi & Iannace, 2015).

3.6 User experience

User experience refers to how a product is able to cause effects in users thanks to their interaction with it. It is influenced by some factors such as usability, usefulness, functionality and emotional impact (Hartson & S. Pyla, 2012).

In the case of the acoustic panels it is possible to divide these factors into the different features that it has. Usability is focused on the mounters because they will be the ones that have a more direct interaction with the mounting system, and have to understand it properly in order to achieve a high quality result. On the other hand, usefulness, functionality and emotional impact are in this case more relevant for the main users of the product because they are the ones who will have the longer interaction, the ones who need proper acoustics in their spaces and that will perceive the benefit from its functionality. In the case of the emotional impact of the product, it may play a relevant role in offices environments because it affects the user feelings and mood, and these products could be used to achieve an improvement in the users attitude thanks to the workspace atmosphere accomplished.

3.6.1 Mounters ergonomics

Regarding the ergonomics of the mounting process, it was found that there are work-related upper extremity musculoskeletal disorders such as DeQuervain's syndrome, the second most common disorder in the working population (Violante et al., 2000) ganglions, and tenosynovitis caused by actions like inserting screws in holes repeatedly, or epicondylitis ("tennis elbow") caused by actions like turning screws and assembling small pieces. As well it was found that having postures where the shoulder has more than 60º of abduction or flexion for more than 1 hour might cause acute shoulder and neck pain (Salvendy, 2012).

The disorders mentioned previously depend on distinct factors like the posture, force applied, vibration or a combination of them. There is evidence for causal relationship between these factors shown in *Table 3*. However, it is important to mention that these positions depend directly in the type of space where the panels are going to be and the number of panels mounted.

Body Part	Risk Factor	Strong Evidence	Evidence	Insufficient Evidence	Evidence of No Effect
Neck and neck/shoulder	Repetition		x		
	Force		x		
	Posture	x			
	Vibration			x	
Shoulder	Repetition		x		
	Force			x	
	Posture		x		
	Vibration			x	
Elbow	Repetition			x	
	Force		x		
	Posture			x	
	Combination	x			
Hand/wrist Carpal tunnel syndrome	Repetition		x		
	Force		x		
	Posture			x	
	Vibration		x		
	Combination	x			
Tendonitis	Repetition		x		
	Force		x		
	Posture		x		
	Combination	x			
Hand–arm vibration syndrome	Vibration	x			

Source: Bernard (1997).

Table 3. Evidence for Causal Relationship between Physical Work Factors and MSDs (Bernard cited in Salvendy, 2012).

3.6.2 Sensorial ergonomics

Good acoustics is considered very important for concentration according to the office workers (Lesman cited in Tietema, 2017). Usually, acoustics are given less attention than other aspects such us engineering issues in architectural design (Salter C., cited in Tietema, 2017) because of the lack of architectural acoustics guidelines and the failures at the moment of executing them (Tietema, 2017).

People commonly relate noise with dissatisfaction in workspaces. It is a significant problem that affects a big amount of employees. This problem increases in open spaces where conversations or the ringing of phones are really common (Parkin, 2015). The office environment is usually full of different types of sounds that distract people from the principal activities they are developing. Sound in workspaces could be controlled in two ways: absorption, which involves reverberation and makes it a better space to work, done through ceilings, rafts and wall panels; and insulation, that controls the sound transmission from one place to another, done through partitions and cavity barriers. There are some aspects that may improve the room acoustics. It should be considered solutions such as absorbent panels (around 1.7 m height due to direct speech waves), not having a really high ceiling because this is the most reflective surface of an open office, having a carpeted floor, analyze internal geometries, rooms finishes, and determine acoustic requirements for each space.

It is important to take in account the room dimensions at the time of improving its acoustics because when the volume of the room increases, the reverberation time also do it (Parkin, 2015). This is shown in the *Table 4*.

Room volume	Reverberation time RT	
m^3	Speech	Music
50	0.4	1.0
100	0.5	1.1
200	0.6	1.2
500	0.7	1.3
1,000	0.9	1.5
2,000	1.0	1.6

Table 4. Reverberation time in different size rooms (Parkin, 2015).

To understand the efficiency of acoustic panels in workspaces, and their influence on the whole office environment, it was searched some evaluations of their functionality in rooms. A study shows how by replacing 100 square feet of gypsum board in an office with 100 square feet of a porous absorber, there was an increase in the total absorption of the room of more than fourfold the initial quantity, from 26 to 112 Sabins (Ermann, 2015).

Appropriate acoustics is an essential factor to consider in the design of a workspace. It is really important in spaces that have big areas of concrete and glass (reflective materials). Acoustic design does not consist only in reducing noise, it pursues optimising the reverberance and the speech intelligibility by integrating different absorbing surfaces, acoustic furniture, carpets and dividers in the rooms (Schittich, 2011). Intelligibility is also another important factor that is sought for offices. This factor can be affected by masking effects caused by background sounds or reflections on the speech source. Intelligibility can be improved by several aspects like an adequate loudness, a uniform sound level, an appropriate reverberation, and low noise levels (Doelle, cited in Sundstrom, 1986).

3.7 Sustainability

Kinnarps Group has a deep awareness regarding sustainable issues. The company highly considers environmental risks and has developed sustainability strategies for all their brands. For instance, by trying to avoid leakage, waste or process errors, by managing chemicals and waste with special plans and by educating their employees on this. Some priority areas in which they work to continue achieving a low environmental impact are: use of raw materials and resources verifying them with traceable sources such as the FSC certified or recycled wood, energy efficiency and the use of renewable sources, use of pure materials by utilizing fewer chemicals and avoiding hazardous materials for the environment or health, use recycled materials and ensure a circular flow that increases the products and materials lives. Their waste is used for different applications such as heating manufacturing sites with the wood waste, or creating new products with their textile wast. Some of their products can be easily upgraded, seeking the reuse of different parts. They also offer a service in which the company take care of the customers used furniture (Kinnarps Group, 2018).

Looking through Kinnarps value chain (*Figure 16*) it is possible to observe some similarities with the cradle-to cradle concept (*Figure 17*). Both follow a cycle where the materials of the final products can be recycled or reused, minimizing waste, pollution and natural resources depletion, and in this way reducing the environmental impact. The main goals are to have more than a single reuse of the final product and to reuse the waste of the manufacturing processes (Haggar, 2007). Cradle-to-cradle imitates nature's system of regenerative productivity by changing the concept of waste for a new raw material. Design plays an important role here because it is necessary to think in materials that can be safely manufactured, used, recovered and reused, trying to ensure a sustainable product life cycle. These considerations can also benefit the industries economy by using their own waste and converting themselves into their own material suppliers (Haggar, 2007).

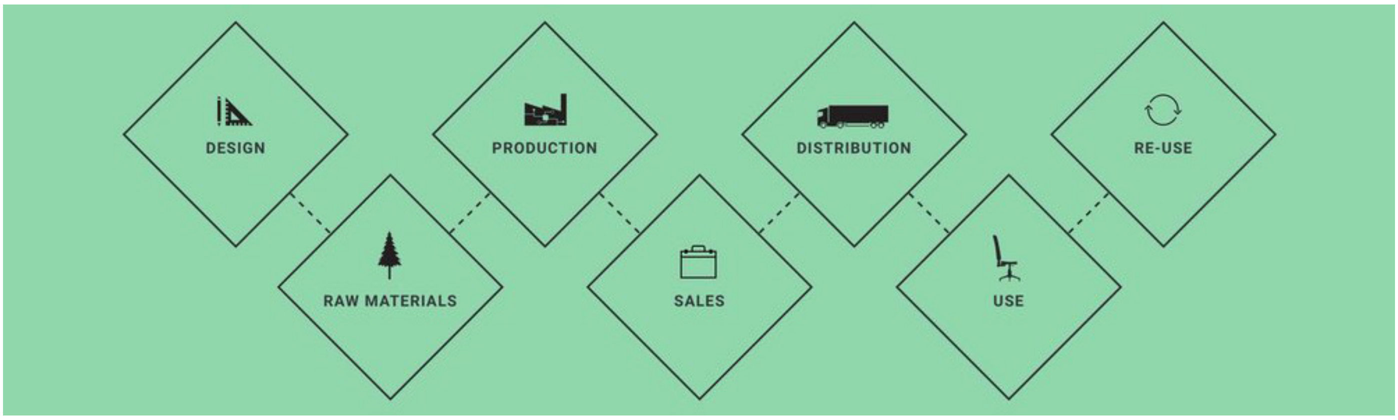


Figure 16. Kinnarps value chain (Kinnarps Group, 2018).

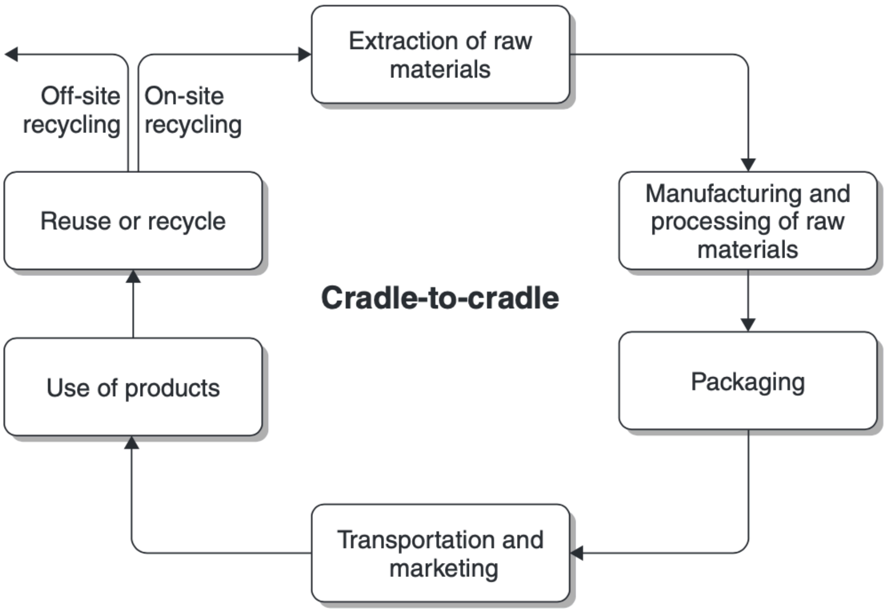


Figure 17. Life cycle analysis based on Cradle-to-cradle concept (Haggar, 2007).

Kinnarps Group has developed their own sustainability measurement called "The Better Effect Index". It consists in measuring each product in six different areas (some of them mentioned above): raw materials and resources, climate, pure materials, social responsibility, reuse and ergonomics. These are graded from 1 to 3 achieving a final result that is the average of them. The customers are able to use a sustainability filter in which they can look for a product regarding these characteristics on their website (Kinnarps, 2019). It is important to mention that there are other types of sustainability metrics, like the Life Cycle Analysis matrix, which is widely accepted for quantifying the environmental impact that a product generates in all the stages of its life. This method measures, among other things, the energy and resources needed, the distinct emissions, impacts in humans and environment, waste and the possibility of reuse (Mager & Sibilia, 2010). By comparing both methods is possible to see that Kinnarps index is covering a wider spectrum of sustainability, even though there are some factors that other methods like the Life Cycle Analysis cover more in depth.

One of the goals of the company is to have good working conditions throughout contributing to social development in the places they operate. An example of it is that they use some of their waste to provide artificial heat to their own factory and to the town where the company is located. The company follows the goals established in 2015 by the UN (United Nations). The ones where the company is having greatest direct or indirect impact are:

- Health and wellbeing: by creating working environments with good ergonomics and reducing unnecessary chemicals.

- Sustainable energy for everyone: efficient use of energy and increase of proportion of renewable energy.

- Decent working conditions and economic growth: good working conditions in their operations and supply chain.

- Sustainable industry, innovations and infrastructure: efficient industrial processes that make optimal use of materials.

- Less inequality: working on diversity and against discrimination and setting requirements for social responsibilities in their supply chain.

- Sustainable consumption and production: reducing the environmental impact of the production and supplier chain, working with pure materials avoiding unnecessary chemicals and creating circular flows of materials and products.

- Combating climate change: reducing the climate impact of the production, premises and transportation.

- Ecosystems and biodiversity: using certified wood from responsible forestry.

(Kinnarps Group, 2018).

The materials on which the project will focus (the most used by the company) are: chipboards covered with veneer (instead of using solid wood); water-based lacquers treatments to increase the durability; textiles from which 69% are EU Ecolabel certified to follow a sustainable manufacturing process; and recycled metal. Some other chemicals are applied in lacquer glue or paint but as they are not eco-friendly enough, the company has stated the goal of developing surface treatments that can be utilized in different environments in order to fulfil sustainability requirements and continue achieving high quality results (Kinnarps Group, 2018).

4 MARKET RESEARCH

This search was done in order to have a general background of the aesthetic styles of the past recent years, to know more about the products of the main competitors in this field and to avoid any kind of plagiarism. It was divided in three stages: a first web search on Swedish and international companies to have a first approach to them, and two visits to some of the most important furniture fairs in the world,: the Stockholm Furniture Fair and the "Salone del Mobile" during Milan Design Week. In these fairs it was possible to learn about the new trends, get inspiration from them and to talk with different sellers about their products' properties.

4.1 Moodboards of competitors' products

Two type of mood boards were done, one focused on Kinnarps local competition in Sweden, and the second one on international competitors. The companies chosen stand out from others due to their attractive designs. Looking through the images of *Figure 18* and comparing them with the limited absorbers that Kinnarps produces, it is highly noticeable that the company needs some new ideas that could help them to be positioned in the acoustic absorption market as a powerful office furniture company that offers attractive solutions for acoustic absorption in workspace environments.

Figure 18. Competitors mood boards.

4.2 Stockholm Furniture Fair

During the visit to the Stockholm Furniture Fair, observations were carried out (*Figure 19*) in order to find the current Scandinavian trends in the field. Conversations with different sellers were helpful to learn how their companies are currently developing the interior of the acoustic absorbers, what types of materials are using and which system of mounting they prefer.

Interesting features were found there, such as the use of three different materials inside one single panel of the brand Decibel, the acoustic properties of Nordgröna's panels made of reindeer moss that use air humidity to survive without the need of watering it, the recycled cork used in acoustic absorbers by Abstracta, the Baux pulp and wood wool, absorptive carpets of the company Ogeborg and the new cylindrical shapes of the ceiling-hanged absorbers of the company Offect.

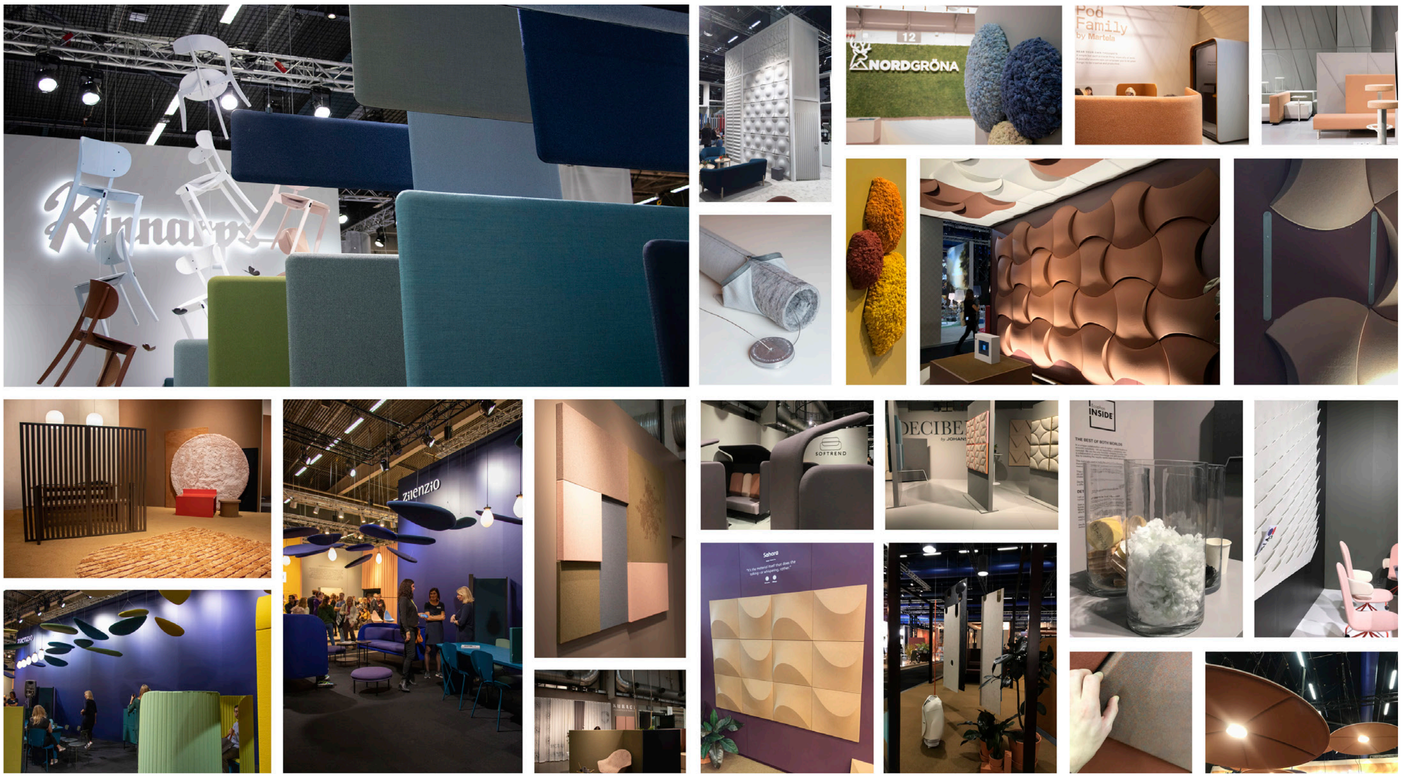


Figure 19. Stockholm Furniture Fair 2019 Market Research.

4.3 Milan Design Week

In the visit to the "Salone del Mobile" was possible to see a wide variety of international companies that offered several types of acoustic solutions. Here was also possible to talk with workers of some of the brands and to ask them about their products. Some highlighted products (*Figure 20*) were the absorbers of the company Sancal, that incorporated an absorptive material on a lamp, the use of cushions on the wall as acoustic absorbers by Santis, interesting textures on the fabrics made with seams by several companies, movable acoustic walls made of pressed felt, and wall panels with a mechanism that let the users choose the inclination.

Also an interesting material was found, a really thin absorptive material (textile felt of 10 mm) shown in different colours, that was interwoven and created an attractive appearance. This panel is of the brand Wandschappen, although the textile felt was purchased from the Danish company Really.

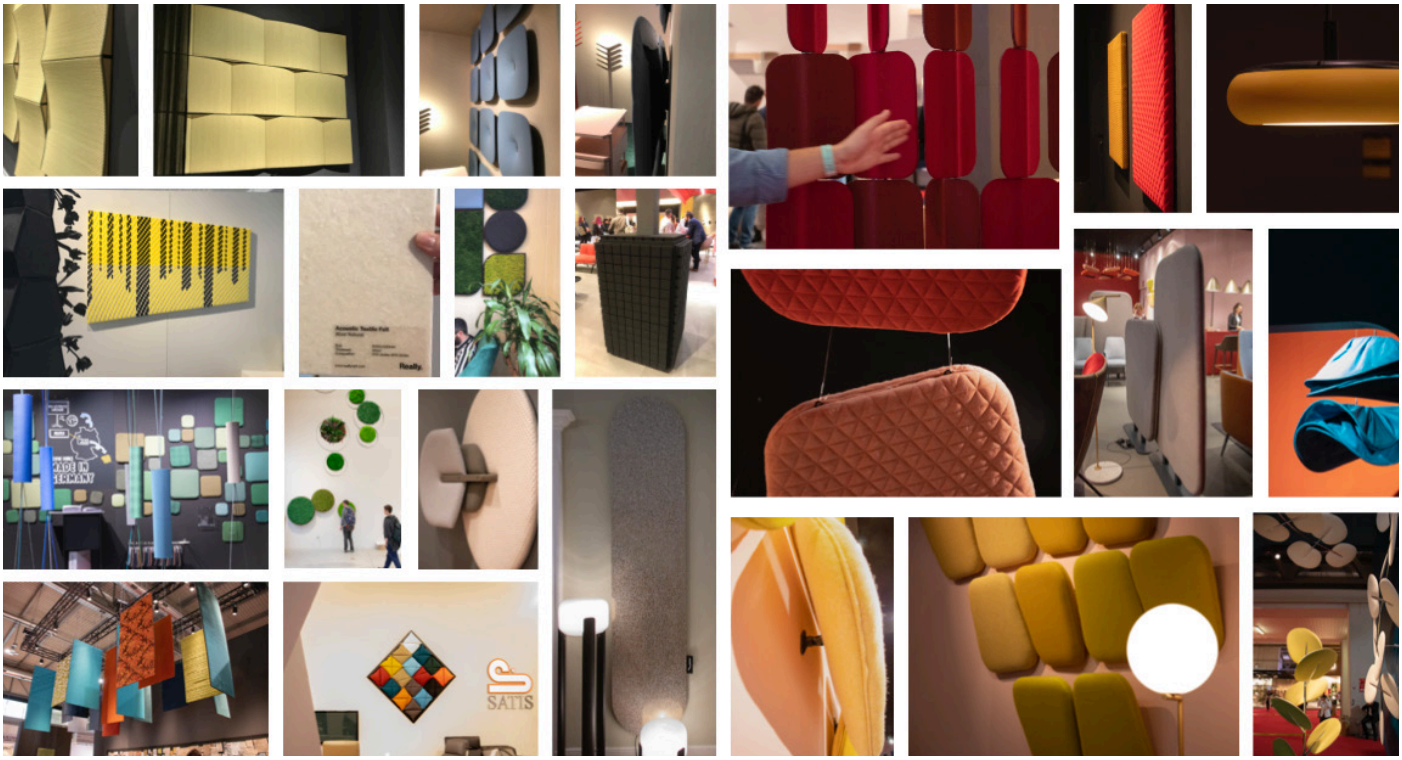


Figure 20. Milan Design Week 2019 Market Research.

5 USER STUDIES

As it is mentioned in the methodology, the project has a user centred approach. Therefore, some studies were done to get useful information of the target group, to work with in the ideation process. Different tools with different levels of interaction were used like questionnaires, interviews, observation, etc.

5.1 Web questionnaire

To get a general background about the perception, preferences and particular characteristics of a larger number of people, a 22 question survey was created. The questions provided information to know the users profiles, their work environment, their notion about acoustic panels and their insights about them. Specifically, it was asked their preferences on the absorbers position, type, and aesthetics, requiring an explanation for their choices in some cases. In the questionnaire, it was also included a Competitive Product Survey, making a comparison between different existing panels, including the Kinnarps solutions, in order to establish functional requirements, performance standards and other benchmarks. As well their point of view about aspects such as customizability and sustainability was asked, (IDEO, 2003).

The questionnaire was done by 31 people, however from those responses, 30 have been taken into account because one of them did not pass the control question. It was only sent to specific people such as office workers, teachers, interior designers, architects, and design students. A balance between males and females was achieved with 53.3% of men and 46.7% of women, and also between students (53.3%) and employees (46.7%).

The main conclusions of this questionnaire were that 90% of the participants knew what an acoustic panel is, and 100% thought they affect in a positive way the work environments. Wall panels were preferred (76.7%) against suspended and standing panels. At the time of selecting between acoustic panels from different images (including Kinnarps products), there was a clear preference for the panels with a modern style, mainly of the companies Abstracta and Offect, something that encourage the initial task of introducing Kinnarps in the sound absorbers market. According to the users responses, the election between different panels was justified by mentioning aspects such as modularity, decorative appearance, organic or simple shapes, combination of colours, easiness to integrate with furniture. It is also important to mention that the 96.7% thought that is interesting the customization of the colours and position of the panels. All the questionnaire responses can be found in the Appendix 1.

5.2 Interviews

Interviews offer a deeper contact with the target group, it gives the opportunity to know more about them. The principal aspects that the interviews were focused on are: their personalities, likes, the principle features they consider when they choose acoustic panels, preferences of type of sound absorbers, how important is sound absorption for them in their work environments and to know if they were interested in customizable factors for the acoustic panels, that was one of the first ideas that was wanted to evaluate in this stage. The potential buyers chosen to be interviewed were architects, managers of schools/nurseries, and sales people who were in charge of choosing the acoustic panels for different projects.

From these interviews, some conclusions were made such as:

- There is a tendency for choosing simple and discrete shapes for the panels, although other kinds of shapes are also suitable depending directly on the type of project they are working on.
- The price influence their choice, should not be unreasonably high.
- An relevant factor is to give the customers the possibility to customize the composition, size and colours.
- Exists an interest in good acoustic properties.
- The type of absorbers that they mainly use are wall and standing panels, although they also use furniture, and carpets.
- The appearance of the panels is a really important factor that was considered by the respondents.
- The interviewed people suggest creating innovative products that are not currently available in the market, develop a product with a “new thinking”.

The nurseries managers show a lot of interest in sound absorbers, they state that by having a big amount of sound absorbing panels is easier to create a calmer atmosphere and encourage concentration. They also mentioned that they like that the children can interact with the panels, for example by putting their drawings on them. In this last case the papers might reduce the panels’ absorption because they are covering the panel with a more reflective surface than the porous material they have under. The complete interviews can be found in the Appendix 2.

5.3 “Shadowing” Natural observation

In this stage, children, students, teachers, and office workers were observed in their schools and companies in order to understand their day-to-day routines and interaction with the absorbers. In this way it is possible to reveal design opportunities and show how the products affect their behaviour (IDEO, 2003).

In the nurseries it was possible to see how the children run next to the standing panels and how they touch them, while in schools for older students there was not a high interaction between the students and the acoustic panels besides that they put some papers on the panels with push pins. In the case of the companies, no interaction was observed. In these places, the most used absorbing panels were the ones that are mounted on the walls, and normally were located in places where a lot of people interact, like classrooms, halls, canteens and meeting/group rooms (*Figure 21*).

Figure 21. Nurseries and companies visited.

Other observations were carried out at the library study rooms of the University of Skövde, where there are five acoustic panels of 600 x 600 mm, with a thickness of 45mm in a 2x3x3 m space. In this room there are also 5 chairs with sound absorptive properties due to their filler covered by fabric. It was interesting to note how some people interacted with the acoustic panels in this room, they leaned on the panels as if they were "wall pillows" while they were studying due to the position in which the panels were mounted, at 95 cm from the floor (*Figure 22*). In other cases, some users seem to be curious and touch the fabric of the panel with their hands, but no other relevant interaction between them was found.

Figure 22. Study room at the University of Skövde library.

5.4 Keywords Survey

In order to have the general insight that people have of the Kinnarps brand, it was done a keywords survey (*Figure 23*) to 6 participants that know about the brand. These people were chosen because it was required a basic knowledge of the products of Kinnarps to be able to answer the survey and get relevant results. This information was collected to be used in the stage of concept generation, by taking into account people's view of the brand all the time and by trying to reflect it in the proposed concepts.

The most selected words that describe the company were "Scandinavian" and "offices". Other repeated selections were "ergonomics", "modern", "comfortable", "high quality" and "functional". By considering these words as a design guideline, it is a way to ensure that the Kinnarps "style" is followed.

Choose the words that you consider describe best the company **Kinnarps**. (Max. 10 words)

6 participants (Swedish furniture sellers, teachers, researchers and students)

Scandinavian (4)	**Technological (1)**	**Innovation (2)**	**Traditional**
Cozy	**Offices (6)**	**Light**	**Functional (3)**
Future (1)	**Schools (2)**	**Strong**	**Honest**
Heavy	**Co-working spaces (1)**	**Authentic**	**Artificial**
Ergonomics (3)	**Hospitals**	**Original (1)**	**Natural**
Acoustics	**Home**	**Beautiful**	**Craftsmanship**
Colorful (2)	**Luxurious**	**Wide variety**	**Genuine (2)**
Concentration	**Comfortable (3)**	**Bright (1)**	**Exclusive**
Modern (3)	**Neutral**	**Darkness**	**Good finish**
Sustainable	**Fun**	**High quality (3)**	**Soft & padded**
Contemporary	**Design (1)**		

Figure 23. Kinnarps keywords survey.

5.5 Personas

Inspired on the profiles of the interviewed people, three typical fictitious personas were created focusing principally on the ones in charge of choosing the acoustic panels. Two more personas were created inspired in the users that the company has as main target. The information is synthesized and visualized in a template that shows with concrete data their general information, goals, needs, personality and brand influencers. Doing these types of visualizations (*Figure 24, Figure 25* and *Figure 26*) makes easier to keep in mind the key characteristics of the identified users you need to design for, during the whole process.

The target group was established thanks to these personas, focused on the people that are in charge of choosing the acoustic panels for different environments, such as architects, sales workers of showrooms, and schools managers.

Hans

Age: 58
Work: Architect
Family: Married
Location: Skövde, Sweden

Personality

Introvert — Extrovert
Thinking — Feeling
Conservative — Liberal
Analytical — Creative

Goals

- Achieve a high quality project level
- Choose the appropriate elements for each project
- Learn about new trends in architecture world

Frustrations

- Not finding the correct products for each necessity
- Be clear enough with the project specifications in order to avoid building errors
- Not finding suitable measures of acoustic panels for some projects

Bio

Hans is an architect that works in his studio located in Skövde with more that 30 years of experience. He is in charge of directing all the projects that the studio carries out but his main interest is in interior design.
His main colleague is his wife Hannah, who helps him to be calm in the most stressful moments when they are working with several projects at the same time.

Motivation

Aesthetics
Functionality
Scandinavian
Acoustics
Ergonomics

Brands & Influencers

Kinnarps
OFFECCT
Zilenzio
Selling silence

Figure 24. Persona 1 (Xtensio, n.d.)

Mikael

Age: 40
Work: Seller
Family: Married
Location: Skövde, Sweden

Personality

Introvert — Extrovert
Thinking — Feeling
Conservative — Liberal
Analytical — Creative

Goals

- Obtain good sales by offering a wall developed project with a competitive price for the client
- Choose high quality elements for each project
- Fulfill the client demands

Frustrations

- Not achieving deadlines
- Not having a wide variety in acoustic panels made by Kinnarps.
- Loosing customers.

Bio

Mikael is the Manager of Kinnarps showroom in Skövde.
He is in charge of making proposals of interior design for several companies like Volvo, universities...
He has to be updated with design trends and to have a wide variety of products to offer to satisfy his customers needs.
He is always busy but he always tries to do his best.

Motivation

Aesthetics
Functionality
Scandinavian
Acoustics
Ergonomics

Brands & Influencers

Zilenzio
Selling silence
abstracta
GLIMAKRA OF SWEDEN
Kinnarps

Figure 25. Persona 2 (Xtensio, n.d.)

Figure 26. Persona 3 (Xtensio, n.d.)

5.6 Scenarios

Once the personas were done, scenarios (*Figure 27* and *Figure 28*) were developed for some of the profiles in order to illustrate the context of the product use and to have an insight of possible situations in which the user and the product could be involved. This is helpful to understand the user experience and to know how could the users benefit from a product in a possible environment of use (IDEO, 2003).

Mikael is working in a coworking open-space trying to concentrate because he has an important project in development and his colleague Sarah had to discuss an important aspect of another project with someone close to Mikael, so he got completely distracted by their conversation and decided to move to another place that has a less noisy environment.

Figure 27. Scenario 1.

Today, as every Friday, the company's marketing team are having a meeting to show the progress with the currently project in the conference room. Mark is seated at the end of the table while Anna is speaking about the work done during the week. Mark feels a bit stressed because he listen a lot of reverberation in the room during Anna's speech and also he got distracted with noise made by his colleagues that are constantly moving their feet and themselves in their chairs. Mark asked Anna if she could speak louder, and when Anna started to speak louder she felt that the reverberation increases in the room causing an annoying situation for her.

Figure 28. Scenario 2.

6 SPECIFICATIONS

6.1 Requirements List

The requirement list was done following the guidelines given by Ulrich & Eppinger (2008). As it can be seen in *Table 5* the requirements are divided in different fields and marked as wishes or demands (W or D). Evaluation methods have been established for each requirement.

Some guidelines for this list came from the Keywords survey (Section 5.4). The most chosen words of the survey were taken into account in order to establish requirements and reflect these words in the resultant concept. Some examples are “Scandinavian”, “Modern” which are included in the requirement “Follow brand aesthetics”, “High quality” and “Functional” included in “Function” by achieving a N_{10} value lower or equal to 4 (Kinnarps value of current absorbers), “Offices” included in “Encourage concentration” and “Improve workspace atmosphere” and “Ergonomics” in “Kinematics”.

In addition, the University and the company supervisors gave some feedback by suggesting changes in order to improve the requirements list and make it easier to check the fulfilment of all these specifications in next stages.

Högskolan i Skövde - Kinnarps	Requirements List Project: Family of acoustic panels		Issued on 02/27/19 Responsibles: Julián Soria de la Torre Gabriel Juárez Mejía
Changes	D/W	Requirements	Evaluation method
02/13/19 02/27/19	D	Geometry: Thickness 35-80mm	Measurement
	D	From wall to top of panel > 80mm	Measurement
	D	Kinematics: Easy to mount	Time and user test
	W	Fast to mount	Time
	W	Adjustable position	Yes/No
	W	Attachable modules	Yes/No
	D	Forces: Weight <1 kg + attachment parts	Measurement
	D	Function: (Sound abs) $N_{10} \leq 6$ (6 wall panels or 1 standing panel)	SS-EN ISO 354 and SS 25269
	W	Encourage concentration	Users test
	W	Improves workspace atmosphere	Users test
	D	Material: KCS Fabrics (If fabric is used)	Yes/No
	W	Recycled polyester filler	Yes/No
	W	Partly recycled	Yes/No
	D	Sustainable Value >2	“The Better Effect Index” by Kinnarps
	D	Safety: Operator safety	Swedish Work Environment Laws
	D	Mounter safety	Swedish Work Environment Laws
	D	User safety	Yes/No
	D	Manufacture: According to the industry standards	Yes/No
	W	Use existing facilities	Yes/No
	W	10.000-25.000 pieces per year	Yes/No
	D	Appearance: Brand colors	Yes/No
	D	Follow Brand aesthetics	Aesthetic analysis (Kinnarps keywords)
	W	Attractive to users and customers	Users/Customers questionnaire
	W	UX: Consider user studies conclusions	Yes/No
	D	Time: 5 months in development	Yes/No
	W	Price: 750 SEK	Yes/No
	W	Maintenance: Easy to clean	Users questionnaire

Table 5
Requirement list.

7 CONCEPT GENERATION

To generate different concepts for the acoustic panels family it was used as input the information collected from the literature review mainly regarding the sound absorption, and the data collected from the preliminary studies, making emphasis in the user studies and in the brand keywords.

The process began with the method "system level design" that consisted in dividing the problem in categories and subsystems to approach each separately, followed by a verbal brainstorming of possible solutions for this sub-systems, an exploration with sketching of different shapes and with rapid-prototyping (scale models).

7.1 System level design

The main problem of the design of this panels was decomposed in two main systems, improving the work space atmosphere and generate an easy way of mounting. These two were also divided into more sub categories, the first one in encouraging concentration, an attractive appearance for the target market, and improving the room acoustics by reducing the reverberance, while the second system was divided in a simple mechanical system and an easy production. This is shown in *Figure 29*.

Three main divisions were chosen to focus on during the concepts generation, the attractive appearance for the target group, the easy mounting, and the improvement of acoustics which is highly related with the interior of the panel and the materials properties.

By dividing the complex problem in different categories, it was possible to work with simpler subproblems in an organized way, and create solutions for specific parts of the product separately.

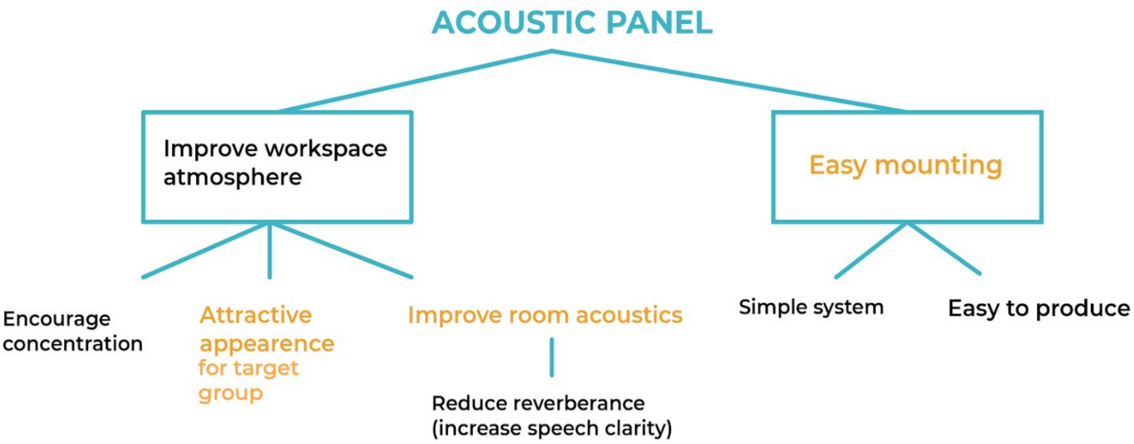


Figure 29. System Level design.

7.2 Brainstorming

In this stage, two different types of brainstorming were developed. The first one sought different solutions for the main problem and the features it involves, shown in *Figure 30.* Divergent thinking and ideas outside of the box were encouraged. Some interesting data from the information collected regarding sound absorption and the users studies were considered.

Among the solutions explored in the brainstorming some can be highlighted like the use of magnets for mounting the panels, an increase in the thickness of the panel for a better absorption, the use of perforated panels as an alternative for porous absorbers, layers of different materials for the interior of the panel, ones that have a better absorption for high frequencies and others that work better with lower, a simple and modern appearance, and customized panels.

Figure 30. Acoustic panels possible solutions brainstorming.

The main goal of the second brainstorming was to create a list of words that the company wants to reflect with their products in the present and in the near future. Feedback was given by the company regarding this brainstorming sessions. Minor corrections were done, including a change in one of the words, shown in *Figure 31*.

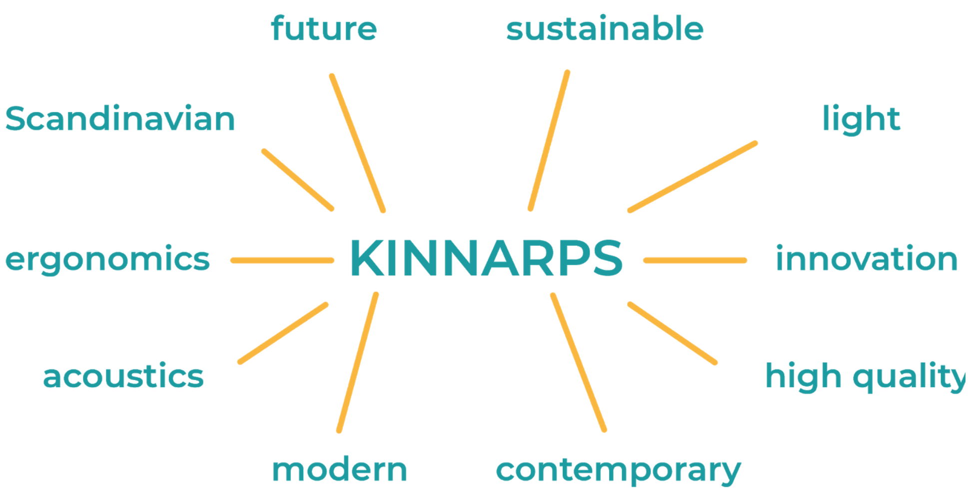


Figure 31. Kinnarps keywords.

7.3 Sketching and modelling

The sketching stage started at the same time as the literature review, market and users research in order to avoid losing ideas that were generated by reading or observing, although the major development of this stage was after finishing the initial research.

Some mood boards were developed as an inspirational tool in this stage, following the guidelines of "analogical thinking" (Rodgers & Milton 2011) that basically suggests to have an extra input and influence of products from another context (*Figure 32*). Other mood boards were made with interior designs of Kinnarps that help the designer to keep in mind the brand aesthetics all the time. (*Figure 33*)

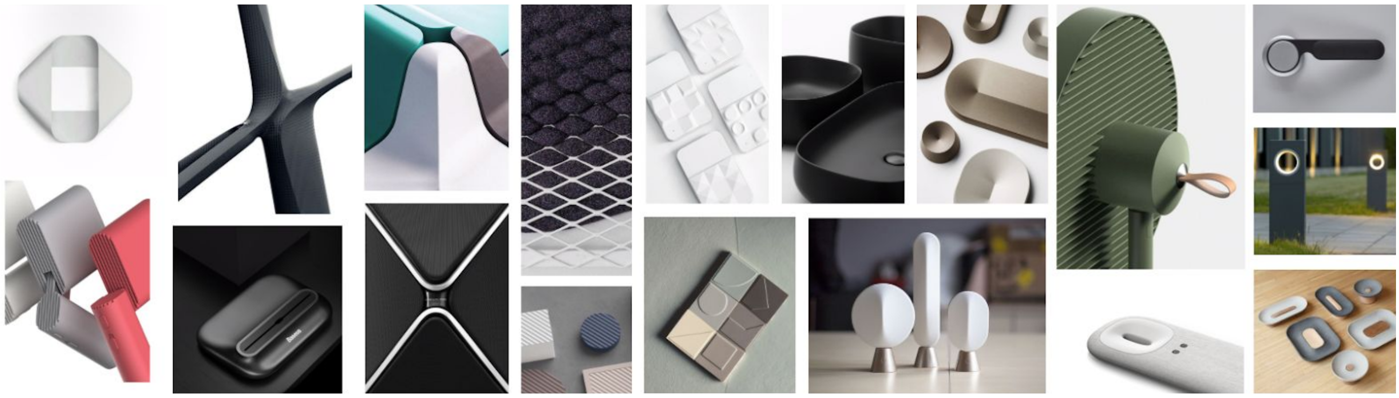


Figure 32. Analogical Thinking Moodboard.

Figure 33. Kinnarps aesthetics Moodboard.

The main goal of this divergent stage was to rapidly create different concepts, trying to generate as many ideas as possible, that could be combined and matured in later stages. During the process of sketching (*Figure 34* and *Figure 35*) was possible to create new input from every sketch by itself, which helped to continue exploring more shapes and have a clearer understanding of some aspects of the problem.

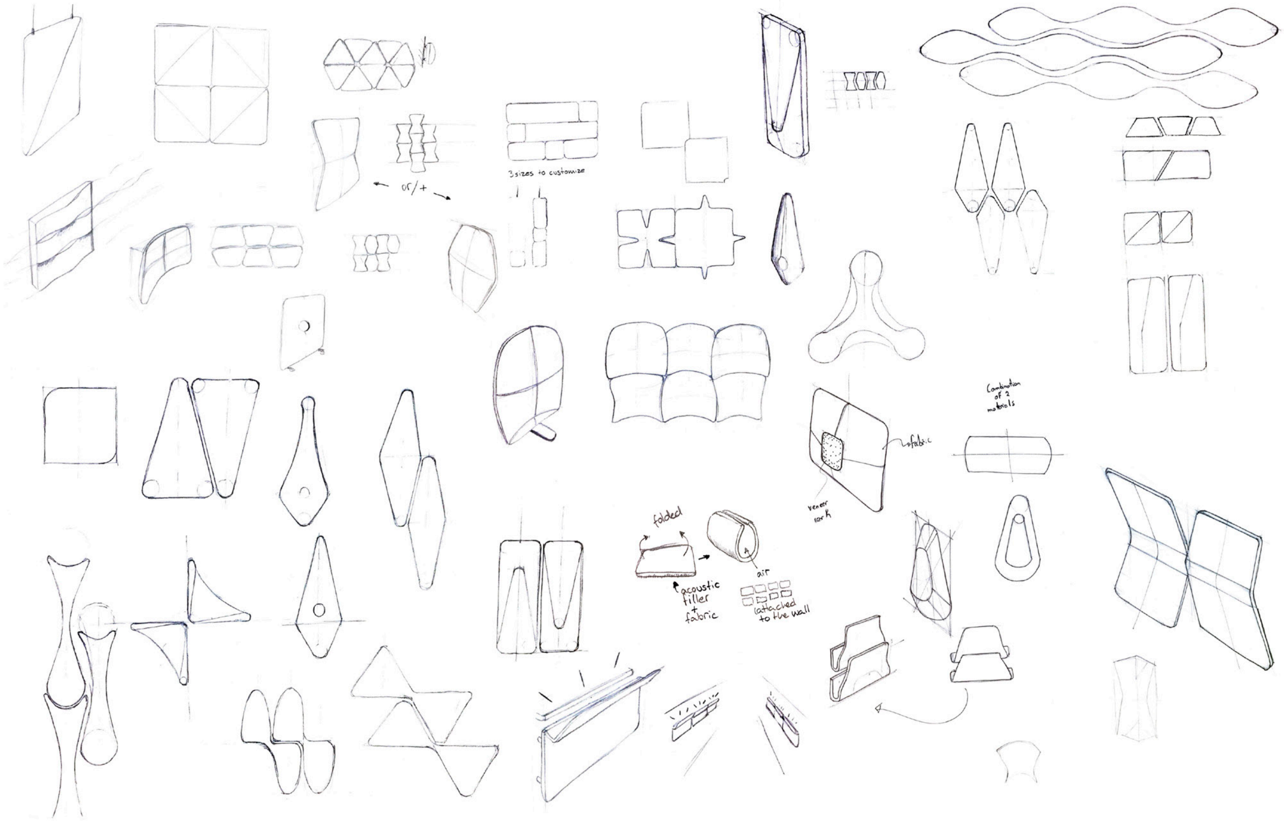


Figure 34. First idea sketching.

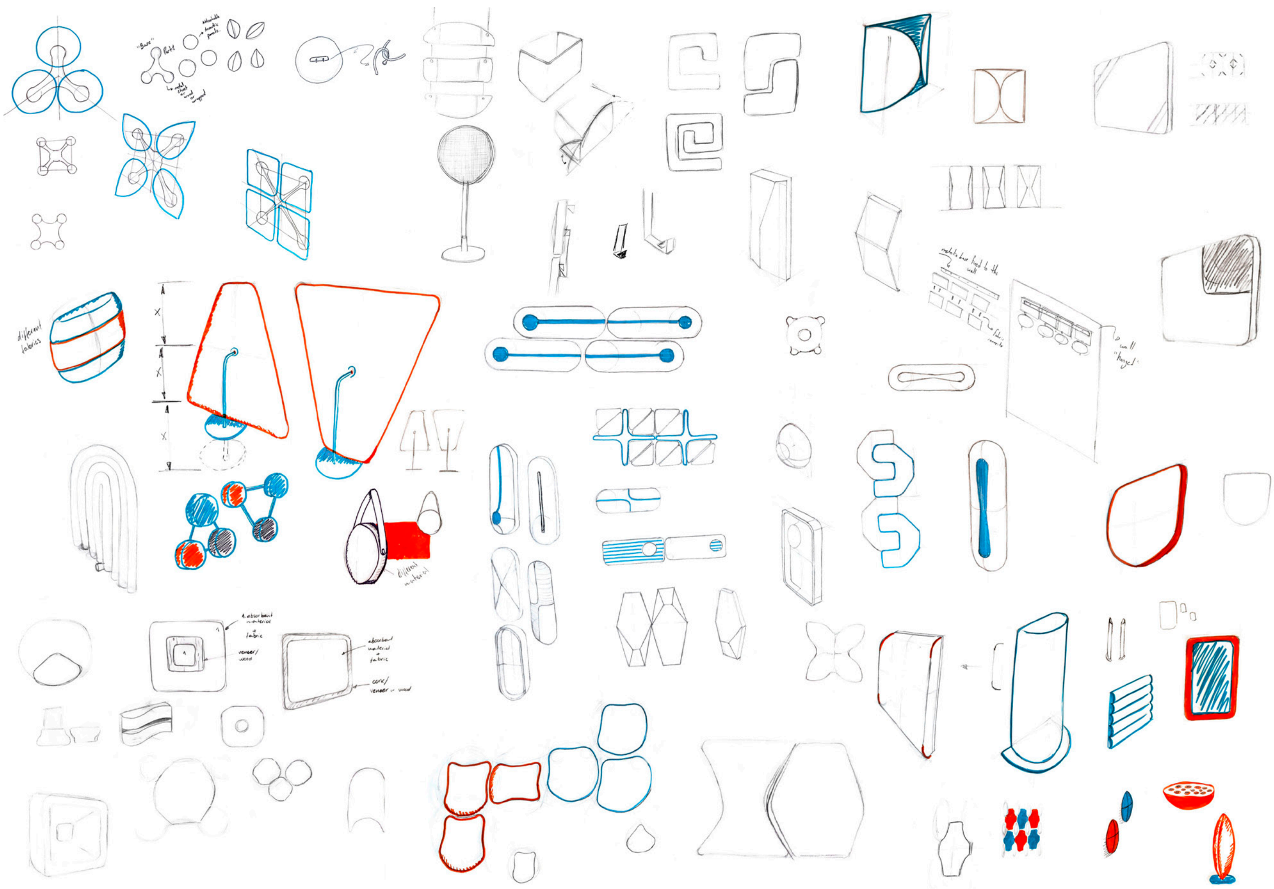


Figure 35. Second idea sketching.

Some of the concepts created in the sketching process were chosen to be developed in clay, cardboard and paper, following the guidelines of the IDEO Method Card (2003) "Scale modelling". This method made easier the representation of the ideas in 3D, and gave more input to continue working further in the concept generation. It was also useful to create some variations of the chosen sketched concepts and to get a different and more realistic perception of the geometry than the one obtained through 2D sketches. (*Figure 36* and *Figure 37*).

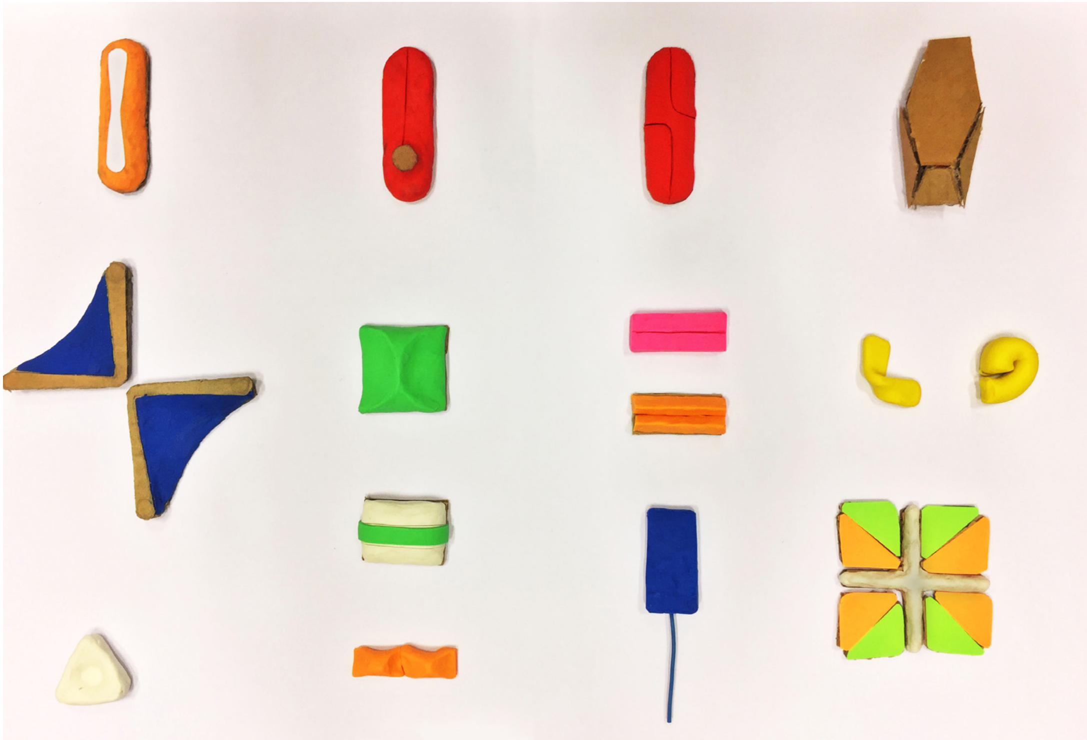


Figure 36. Rapid-prototyping (sketch model).

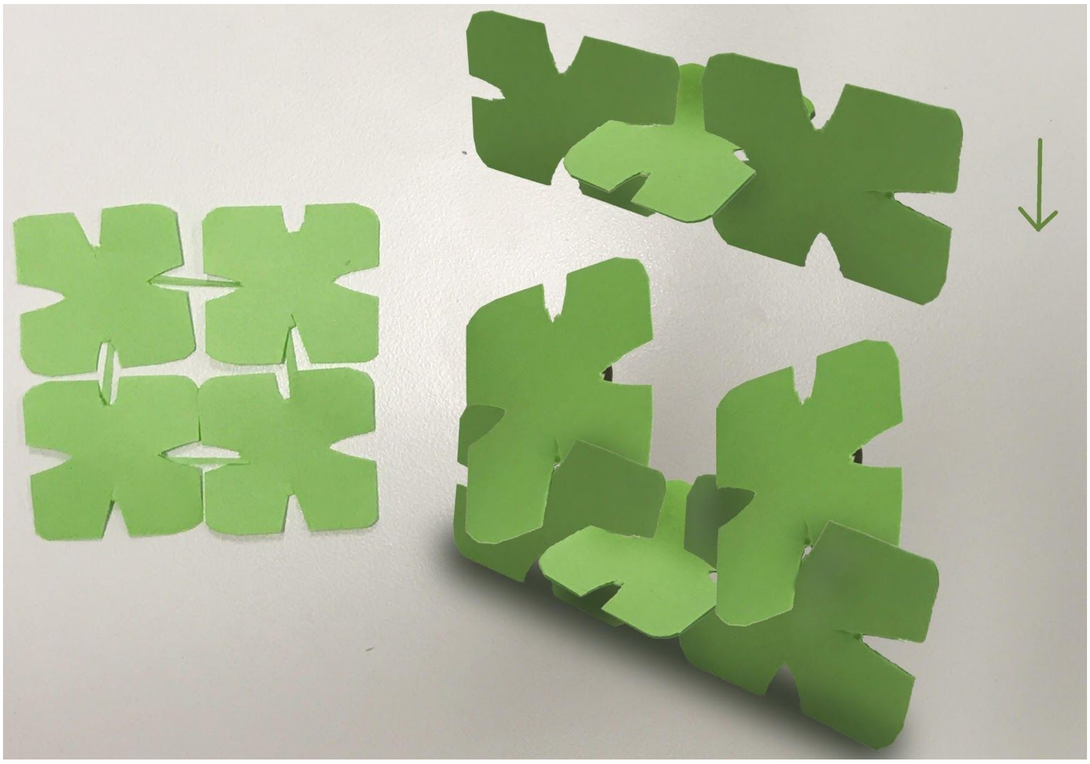


Figure 37. Rapid-prototyping (sketch model).

After having several ideas represented in sketches and models, a convergent thinking phase started. The company chose three potential ideas that set the routes to continue the concept generation (*Figure 38*).

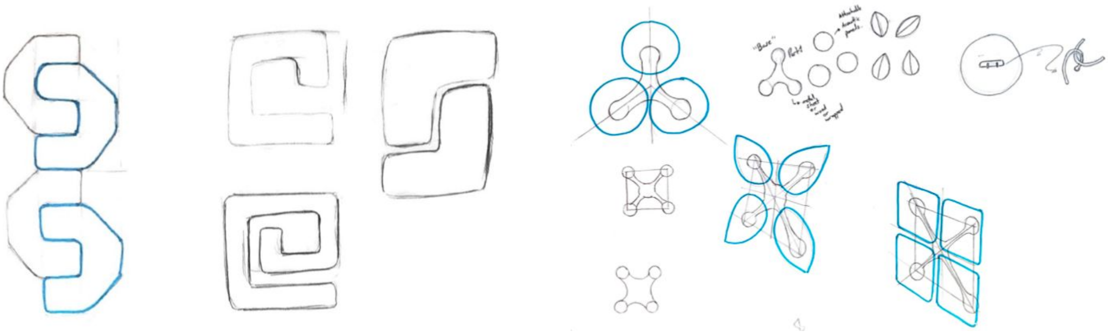


Figure 38. Kinnarps first selection of potential routes.

The concept generation continued further by following the selected routes. Study sketches (Evans et al., 2010) were developed for two purposes, define the geometry of the panels and generate more variants. (See *Figure 39*). This sketching session was developed in a showroom of the brand in Skövde in order to be inside of the environments that their products create, and to be able to interact with the materials, colours and shapes of the brand.

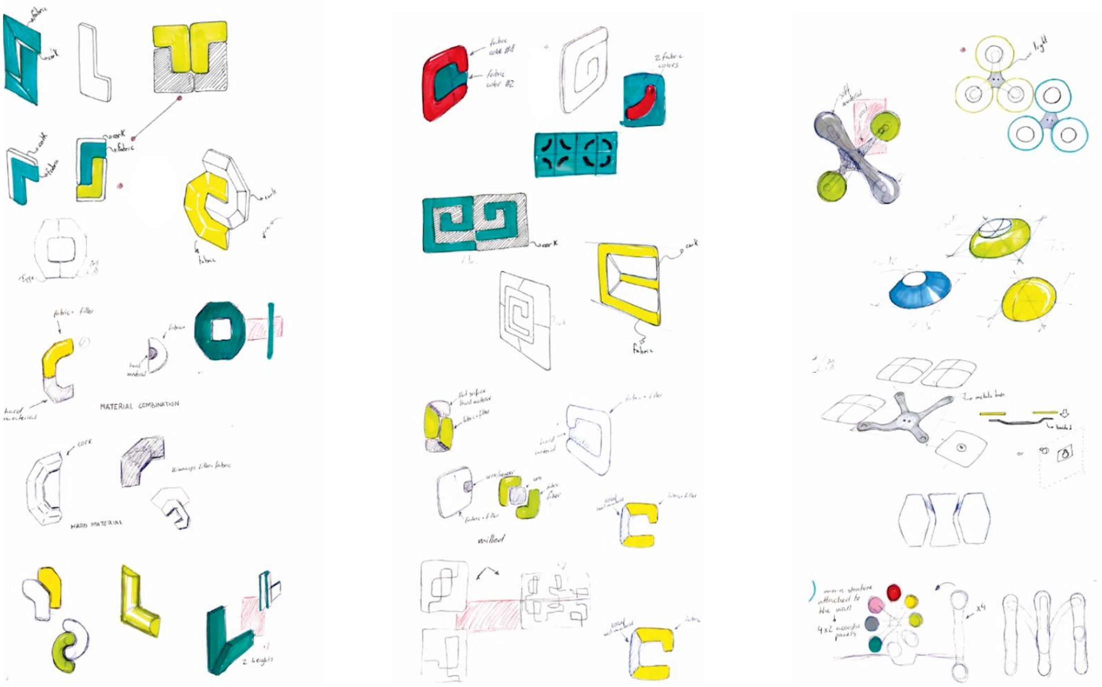


Figure 39. Study sketching.

The purpose of the next sketching sessions was to create new solutions for the mounting system. All of these solutions were based on reducing the number of attachments to the wall of each panel and in this way provide an easier installation system, as it is established in the requirements list. Some solutions identified are: Mount metallic sheets on the wall with screws and put magnets in the base of the acoustic panels, hang the panels with ropes from a metallic structure on the ceiling, wood bases mounted on the wall with 2 screws that can hold 4 panels. (*Figure 40*).

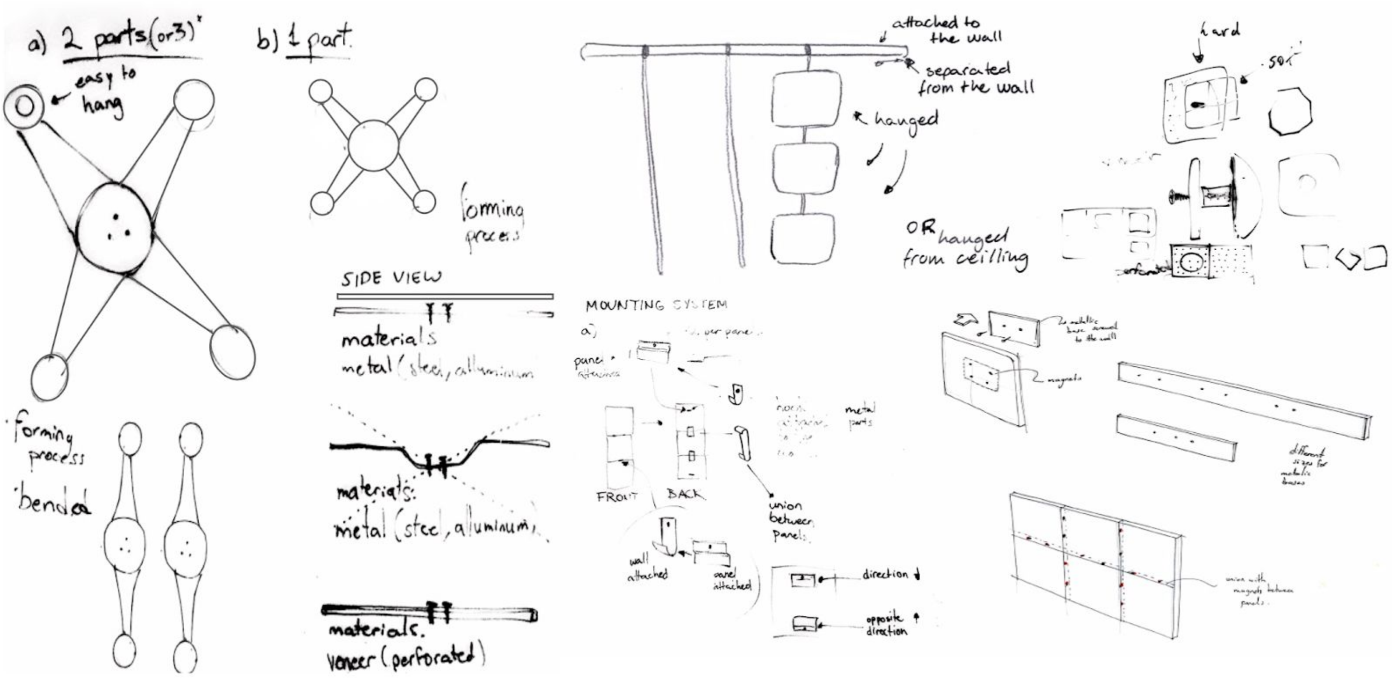


Figure 40. Mounting system ideas.

More sketches regarding this topic are shown in the Appendix 3.

8 CONCEPT SELECTION

This stage aims to converge ideas, to make a preliminary selection of potential solutions from the concept generation in order to develop them further and subsequently make a final selection of the most appropriate concept for the company.

In this part of the process is possible to see how the ideas were converged, evolved and evaluated. At the end, the final selection of the concept that better fulfils the requirements was made based on an appearance test with the target users, on the designers intuition and on the opinion of Kinnarps managers.

8.1 First selection

Basing on the intuition of the designers, there was a selection of the top ten concepts (*Figure 41*) that have an interesting appearance and have the potential to fulfil the initial requirements of the project. This first selection was made to frame the possible solutions and to have less concepts for the concept screening evaluation (Ulrich & Eppinger, 2008).

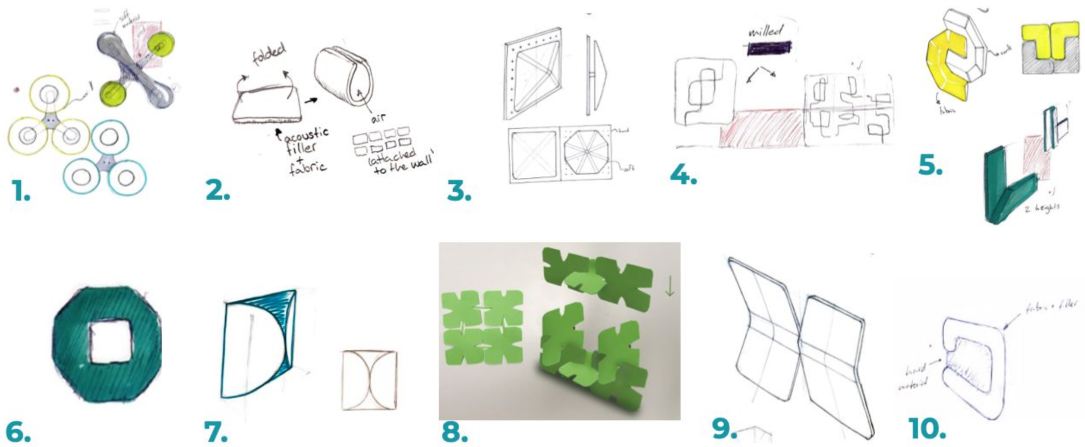


Figure 41. Selection for concept screening.

8.2 Concept screening

With the 10 selected ideas shown in the *Figure 41*, a concept screening (Ulrich & Eppinger, 2008) was carried out in order to find the potential concepts that were going to be developed more in detail. The baseline chosen to compare the concepts was “Triline” a panel from the company Abstracta (*Figure 42*) which was the most popular choice of wall panels in the web questionnaire performed as a preliminary study.

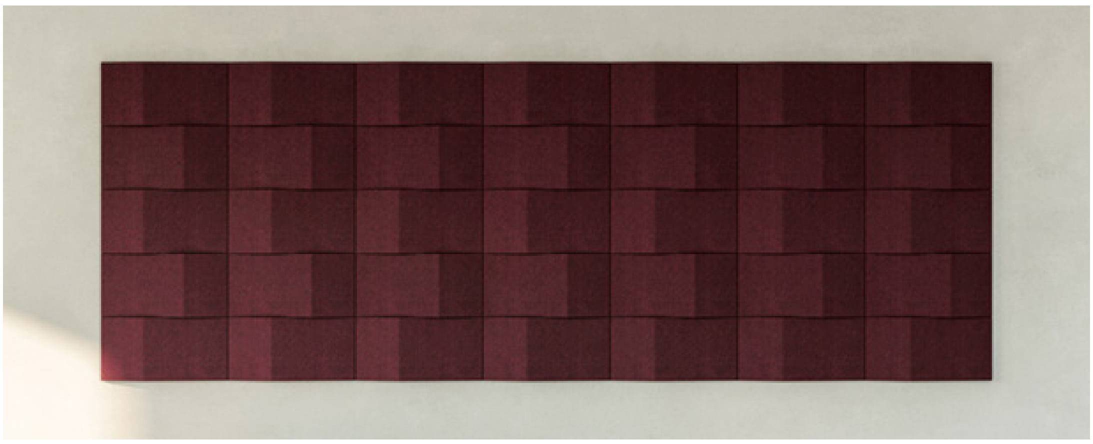


Figure 42. Baseline (Abstracta AB, n.d.).

As it is shown in the *Figure 43,* five main criteria from the requirement list were used for the concept screening: geometry, aesthetics, maintenance, manufacture and sustainability. If the evaluated concept was considered better than the baseline it received a positive point, if it was considered equal it received no points, and if it was considered worse it received a negative point. The points were summed and the results showed that the concepts that should be developed further were concepts 1, 2, 3, 5 and 8.

Concept screening

Selection critieria	Concept										
	1	2	3	4	5	6	7	8	9	10	N (BASELINE)
GEOMETRY											
Thickness	1	0	1	1	1	1	0	1	1	1	0
AESTHETICS											
Encourage concentration	1	0	1	-1	0	0	1	-1	0	-1	0
Improves workspace atmosphere	1	0	0	0	1	0	1	1	0	-1	0
Attractive appearance	0	1	0	0	0	-1	1	1	1	1	0
Material choices	1	0	1	-1	1	1	0	0	0	0	0
Color choices	1	0	0	-1	0	0	0	0	0	0	0
Shape variety	1	0	1	1	1	0	0	0	0	0	0
MAINTENANCE											
Easy to clean	-1	1	-1	1	-1	0	-1	0	1	0	0
Manufacture											
Easy to manufacture	-1	0	-1	0	-1	-1	-1	0	-1	-1	0
Sustainability											
Materials with low environmental impact	0	1	1	1	1	1	1	1	0	1	0
Final score	4	3	3	1	3	1	2	3	2	0	0
Ranking	**1**	**2**	**2**	**4**	**2**	**3**	**3**	**2**	**3**	**5**	
Continue?	Yes	Yes	Yes	No	Yes	No	No	Yes	No	No	

Figure 43. Concept screening.

8.3 Kinnarps selection

The five concepts chosen were developed further by doing some referential sketches and 3D printings, each concept was explained more in detail, considering their mounting system and functionality. These concepts were presented to the company and according to their preferences, three were selected as the concepts that would be developed with prototypes and subsequently evaluated.

8.3.1 Referential sketches, concept development

Concept one (*Figure 44*) provides different types of MDF structures that work as a base, where 2, 3 or 4 acoustic panels can be easily attached with hooks, magnets or ironworks. This concept seeks to reduce the number of holes on the wall per panel in comparison to the one that the company currently has (4 per panel). The structure has 2 parts that together create 26 mm of thickness, generating an air back space between the panels and the wall. The air backing space as it is shown in the literature review (Section 3.3) of this document increases the absorption of sound by catching the sound at a higher speed. This concept also gives the customer the possibility to choose and combine different types of panels in different positions.

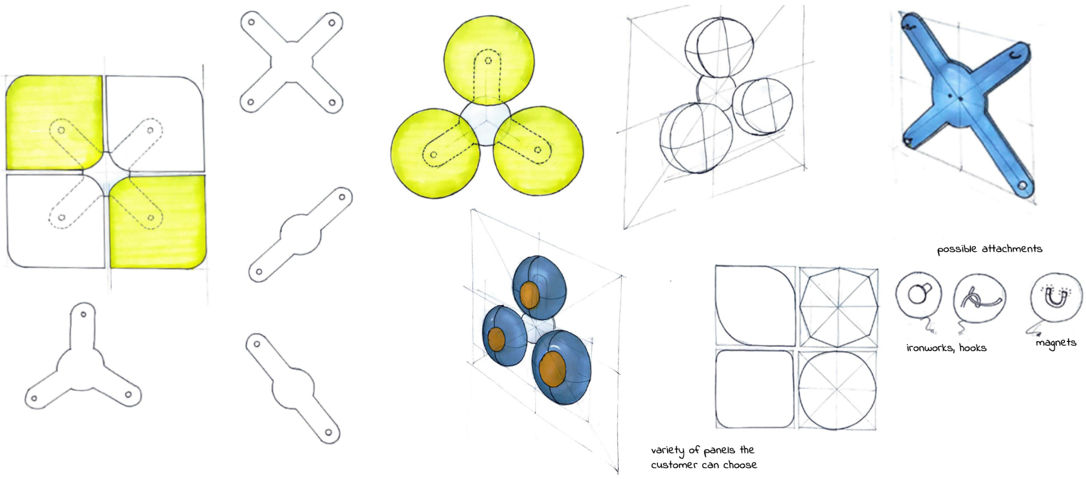


Figure 44. Concept 1.

Concept two (*Figure 45*) consists of three different folded panels that allow several compositions on the walls. The absorptive material would be moulded on this shape and covered with the fabrics used by Kinnarps. The appearance of this acoustic panel tries to differentiate from what was found in the market research (Section 4.1). This folding shape provides an air space (Section 3.3) between the surfaces where the sound goes through and this is expected to increase the absorption level.

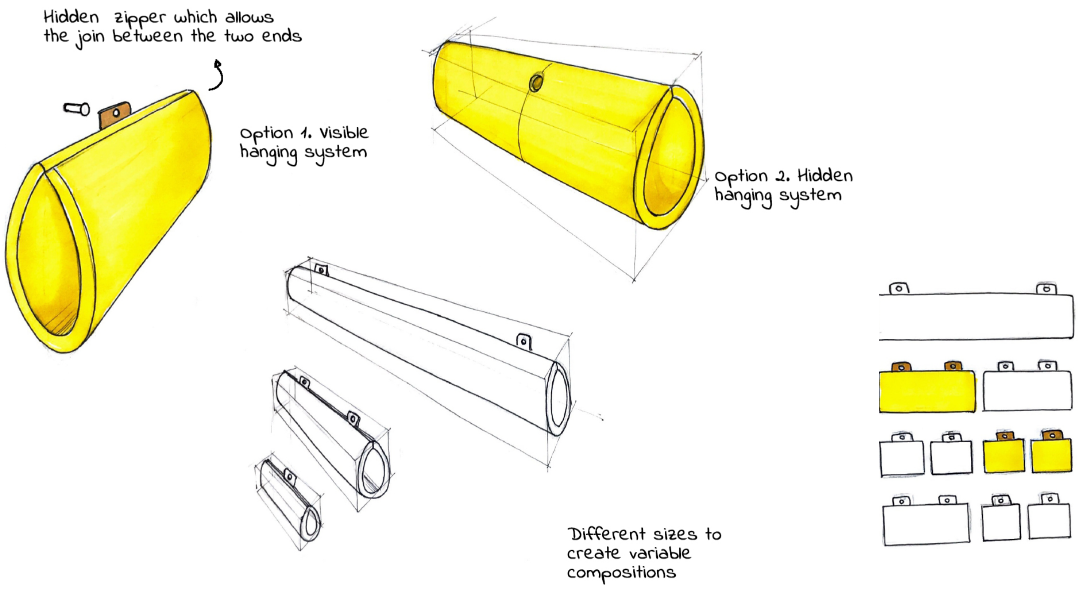


Figure 45. Concept 2.

Concept three (*Figure 46*) combines a perforated wood panel that has good absorption properties according to the literature review (Section 3.3) with an upholstered panel. The pyramidal geometry of these panels helps to create the diffusion of sound (as is shown in Section 3.1.2).

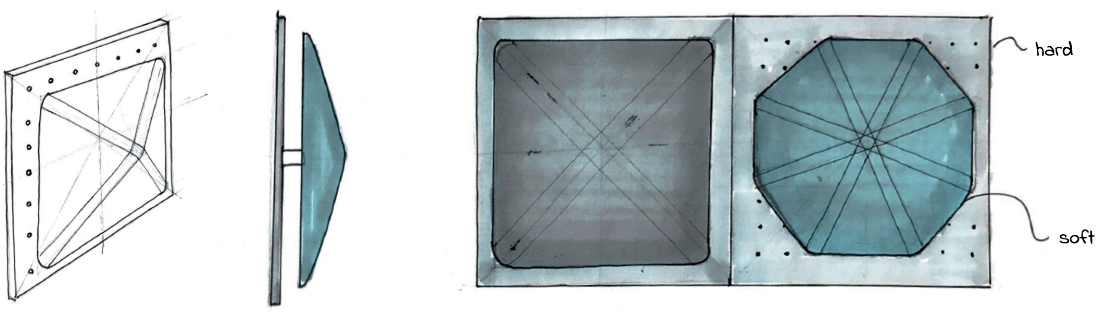


Figure 46. Concept 3.

The main purpose of concept four (*Figure 47*) is to combine different types of acoustic panels in a modular way. The customer would be able to combine different materials, colours and finishes of the same panel for various compositions.

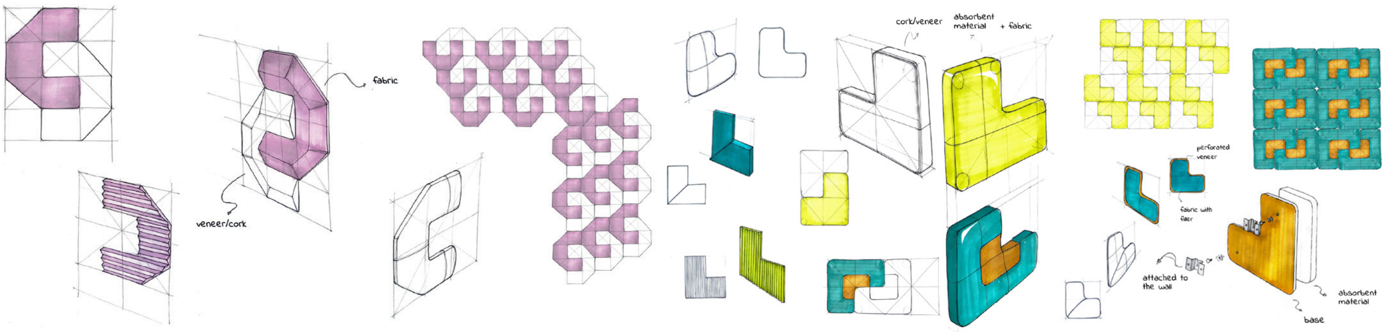


Figure 47. Concept 4.

Concept five (*Figure 48*) was developed to provide an interactive acoustic panel. It is a combination of a structure, an acoustic absorbent filler and fabric that gives the customer the possibility of joining different panels and generate a standing panel due to its shape. At the same time it gives the possibility of customizing the compositions due to the 2 different shapes it has available. This concept also can be combined with another version of it that is made of wood with grooves and a sound absorbent material inside.

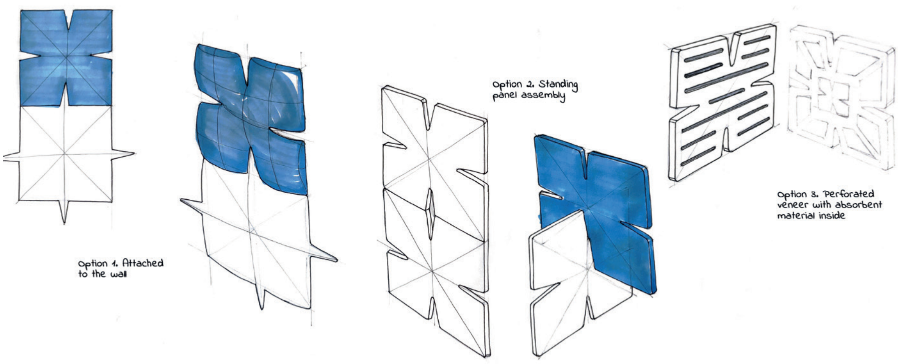


Figure 48. Concept 5.

8.3.2 3D prints

3D prints of the five concepts were performed to give a more realistic perception of the geometry that the designers want to communicate and to show the different compositions in scale (*Figure 49*).

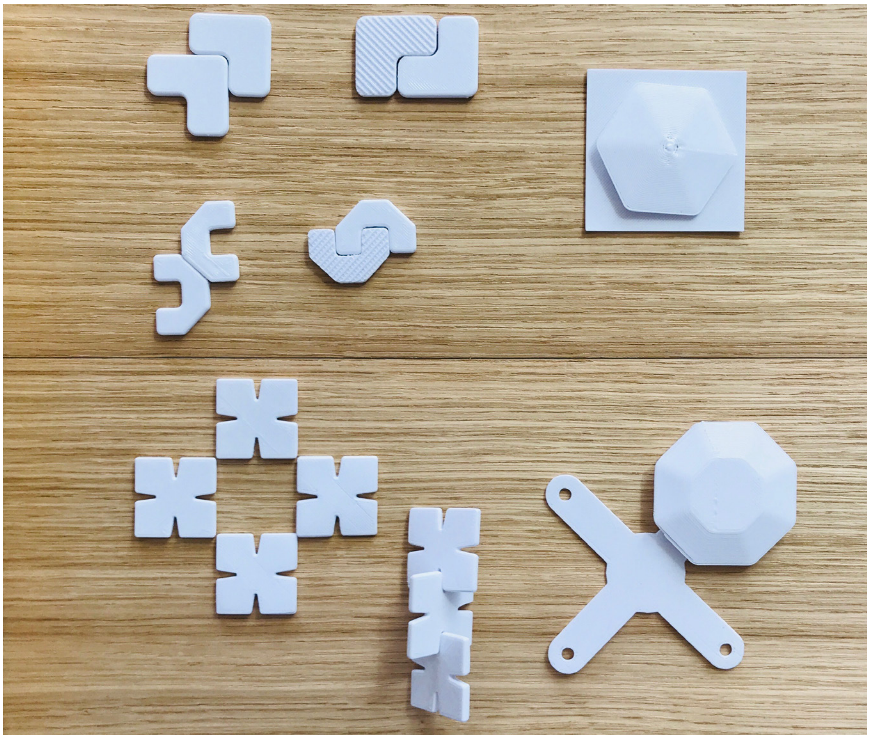


Figure 49. 3D Prints.

8.3.3 Selection

Of the five concepts that have been introduced to selected members of the company, three were chosen for further development. Concepts one, two and four were the ones selected based on their appearance, potential functionality, and mounting easiness.

8.4 Prototyping

Quick-and-Dirty Prototypes of the selected concepts were developed in order to have a better perception of their size, their manufacturing process, viability, and appearance. (IDEO, 2003). The absorbent material used was the one that the company currently uses.
Concept one mock-up was developed in a simple way (*Figure 50*), the MDF structure and the absorptive material were cut in scale 1 to 1 in order to observe the real dimensions and the composition possibilities. The feedback from the company design manager and the University supervisor was positive.

Figure 50. Concept 1 mock-up.

The mock-up of the concept 2 was developed by the company (*Figure 51*). The acoustic material was rolled over a metallic tubes and put inside ovens. The final shape was not completely achieved, the thickness and the folding radius were not the appropriate ones, although the length and width were correct. In this case it was decided that the manufacturing process should be studied deeply during the development, in order to achieve a better result by folding the acoustic material.

Figure 51. Concept 2 mock-up.

The prototypes for the concept 4 were made as well by cutting an MDF structure and absorptive material in scale 1 to 1. These prototypes were tried to be covered with fabric and some problems were found. The interior angles hindered the process of stapling the fabric and gave a bad aesthetic result (*Figure 52*). Thus, the shapes were changed, the corners were rounded and other mock-ups were developed, achieving a better result (*Figure 53*). Despite this good result it was suggested by the company´s supervisor to stop the development of this concept in order to focus on the concept 1 and 2, that were considered more attractive for the company.

Figure 52. Concept 4 mock-up problem.

Figure 53. Concept 4 mock-up process.

8.5 Evaluation

An acoustic test of the concept two (*Figure 51*) prototypes was done by Kinnarps staff, taking the opportunity that they had rented the acoustic lab (Figure 54) for the evaluation of other products. The results obtained were not as good as expected, N10=25 for four acoustic panels. Even though it was possible to get some conclusions from this test in order to achieve better results with the next prototypes:

- The thickness of the prototype (20 mm) was not appropriate, it should be bigger (40 mm).
- The number of panels tested were not enough to achieve 100% proper results (according to the tester).
- The interior space of the concept should be bigger in the whole product.
- It should be covered by fabric, that is also an absorptive material.
- There should be an airspace between the panel and the surface behind.

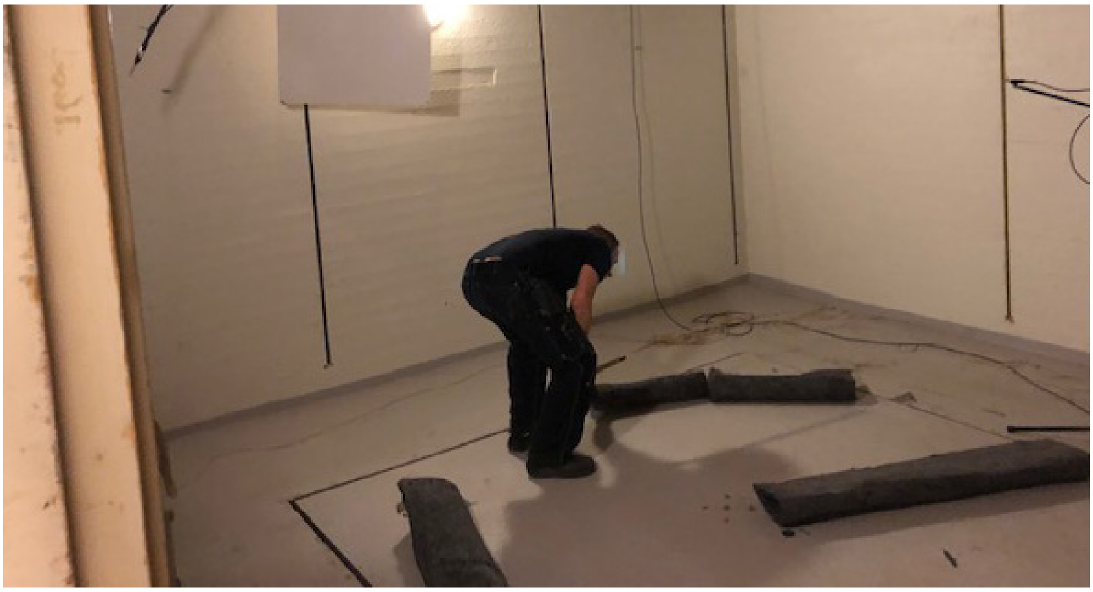


Figure 54.
Concept 2 test in Akustikverkstan

8.6 Final prototypes

Prototypes were developed in detail in order to select the final concept and have a closer similarity with the final products. These prototypes helped to make an appearance evaluation and to continue developing specific characteristics for each concept.

Thanks to this stage some solutions for specific parts of the prototypes were developed, in the case of the concept 1, the creation of a way of mounting the same panel in two different positions on the base with the same ironworks (*Figure 55*). The panels for this concept were weighted and it was found that they did not fulfil the requirement of weight (Section 6.1), due to each panel exceed it by having a total weight of 2.1 kg each. The solution proposed for the excess of weight was to have a small square of MDF in the middle of the panel, instead of the complete shape of the panel in MDF. This solution was tried and the resulting weight was 750 g per each panel (*Figure 55*).

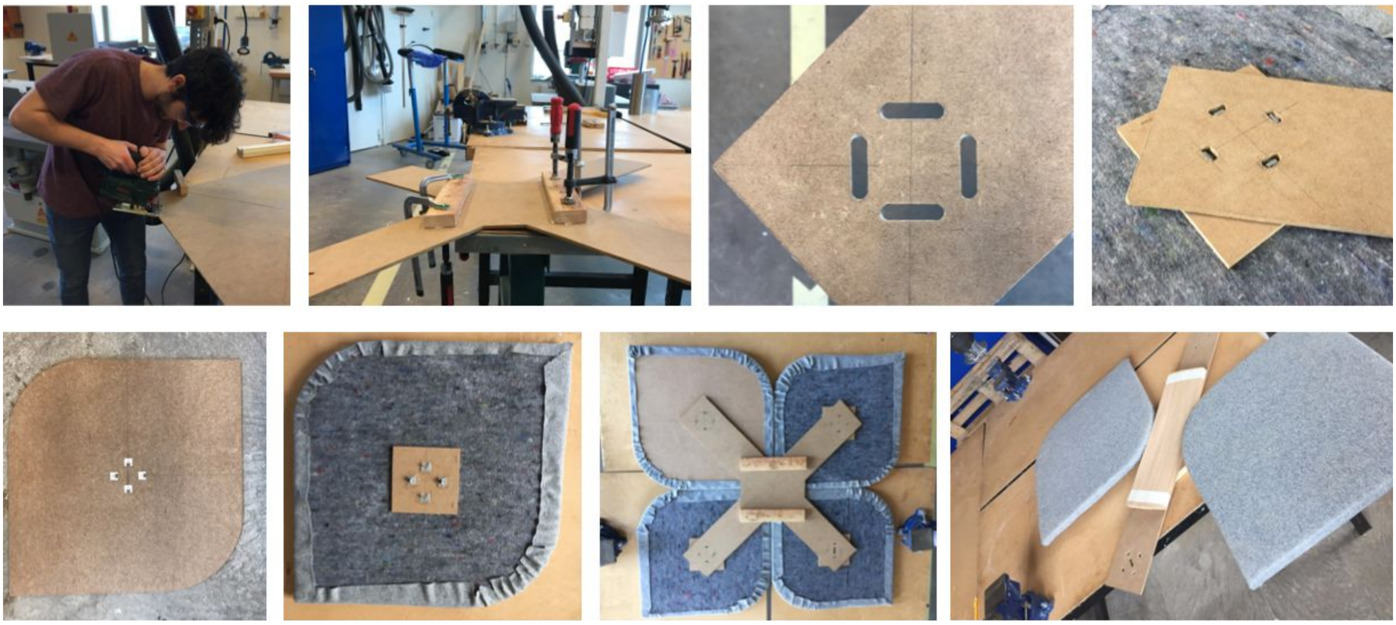


Figure 55. Concept 1 prototype process.

A second prototype was developed for the concept 1(*Figure 56*), the base that has three arms with circular panels. For this version it was decided to try a different way of mounting using magnets, which might facilitate the process for the mounter and also make the product easier and faster to be manufactured. In this way it is not necessary to attach four hangers to each panel nor make four holes in each arm of the structure. The magnet system is composed by a metal sheet glued on the backside of a square hole in each arm of the main structure. The acoustic panels have a magnet glued to a MDF square in the middle back part that fits in the hole of the structure arms, allowing the attachment of both parts.

Figure 56. Concept 1 prototype 2, magnet system.

In the case of the concept 2, side MDF structures were made to keep the desired shape. Other type of solutions were tried and did not work as expected, like some grooves in the absorptive material to facilitate the folding without heat (*Figure 57*).

Figure 57. Concept 2 prototype process.

A material exploration was also done in this stage with the purpose of finding one foldable acoustic material that made possible to achieve the desired radius of concept two and at the same time might increase the absorptive properties of the panels. Some samples of different materials were requested from different suppliers in order to know more about their properties and test their flexibility. Three absorptive materials were provided by the company Horda Stans AB: Airfelt TK, Soundfelt Rec and Soundfelt Rec White (*Figure 58*). After trying to fold each of them was found that the Airfelt TK was easier to fold than the other two options, however as its absorption coefficients were not provided by the supplier, it was decided not to continue further with these materials.

Figure 58. Horda Stans AB samples (Airfelt TK, Soundfelt Rec & Soundfelt Rec White).

As in the literature review (Section 3.5) was founded that the sheep wool had interesting high absorption coefficients, a sample of an acoustic textile felt (*Figure 59*) made of this material was requested to the Danish company Really, discovered in the market research. Also a sample of a cotton acoustic textile felt (*Figure 59*) was requested due to the high absorption value (NRC=0.95 with 40 mm of thickness) available on their website. This value was tested with the standards ISO 354: 2003. (Really, 2019).The flexibility of this samples was not appropriate for the folding but they had a variant with some cuts that could be applied for the concept 2 (Figure 60).

Figure 59. Really Acoustic Textile Felt.

Figure 60. Really foldable Acoustic Textile Felt (Really, 2019).

The resulting prototypes (*Figure 61* and *Figure 62*) received feedback from the supervisors at the university and at the company. The screws in the middle of the panel were decided to move 70mm higher in order to hide them with the acoustic panel, also it was suggested to edit the pictures to show different possibilities of colours (Appendix 4).

Figure 61. Concept 1 prototype.

Figure 62. Concept 2 prototype.

8.7 CAD modelling and rendering

For having a better understanding of the shapes and being able to choose the appropriate appearance for each concept, some CAD models were done using the Rhinoceros 3D software (*Figure 63* and *Figure 64*). It was interesting to explore shapes that were difficult to explore with the materials available for the prototypes. For instance, pyramidal shapes that help to diffuse the sound (Section 3.1.2) and bigger fillets were modelled.

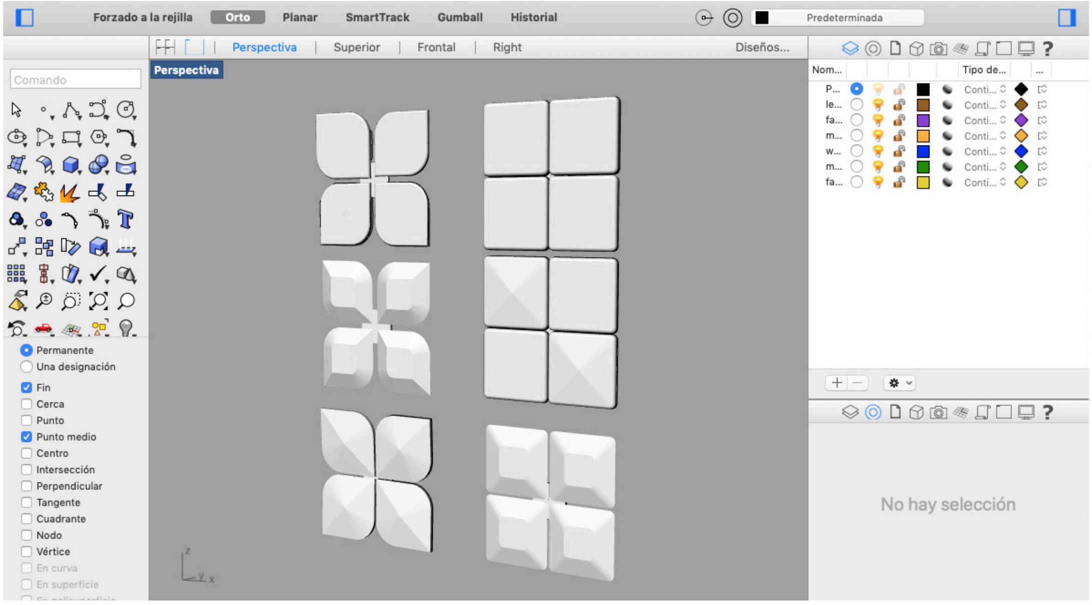


Figure 63. 3D Modelling concept 1.

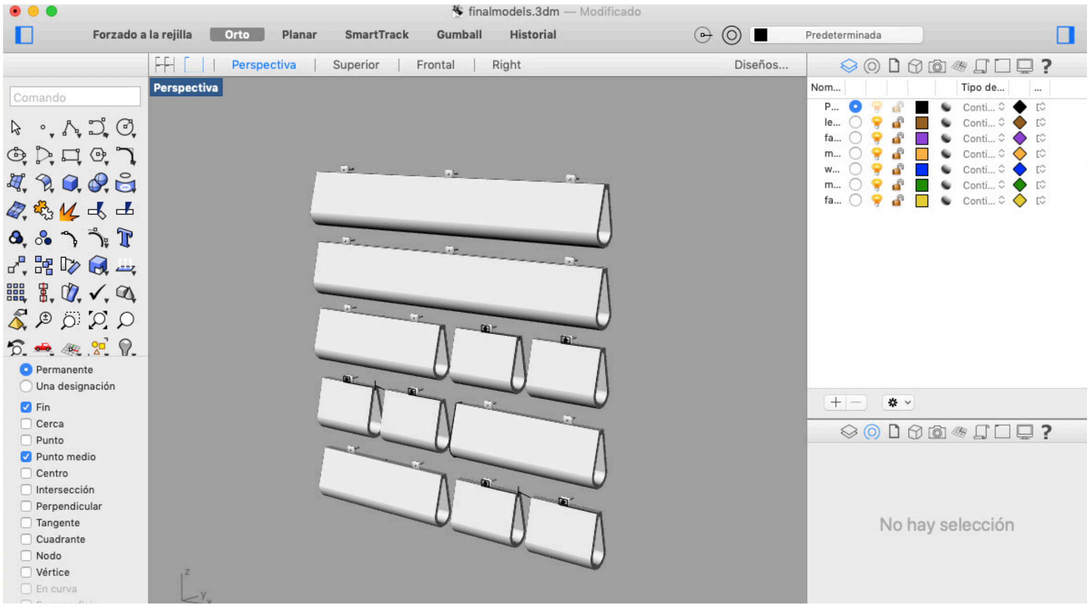


Figure 64. 3D Modelling concept 2.

8.8 Appearance Test

The main goal of the appearance test was to select the final concept according to the company aesthetics. To achieve it, 3D visualizations in Kinnarps environments were done to show the concepts. Adobe Photoshop was used to edit the prototype pictures and to integrate the renders into the Kinnarps environments downloaded from the company website (From *Figure* 68 to *Figure 71*). The colour palette chosen for the test was based on the new colour combinations of the company, presented on the Stockholm Furniture Fair (*Figure 66*).

Figure 66. Kinnarps colour palettes

The appearance test was performed at the Kinnarps showroom in Skövde. The people evaluated were the sales workers in charge of choosing the acoustic panels for the interior design of several companies. *Figure 56* was shown to explain the shape and mounting system of each concept and from *Figure 68* to *Figure 71* is shown the possibilities of both concepts integrated in offices environments.

Figure 67. Final prototypes appearance.

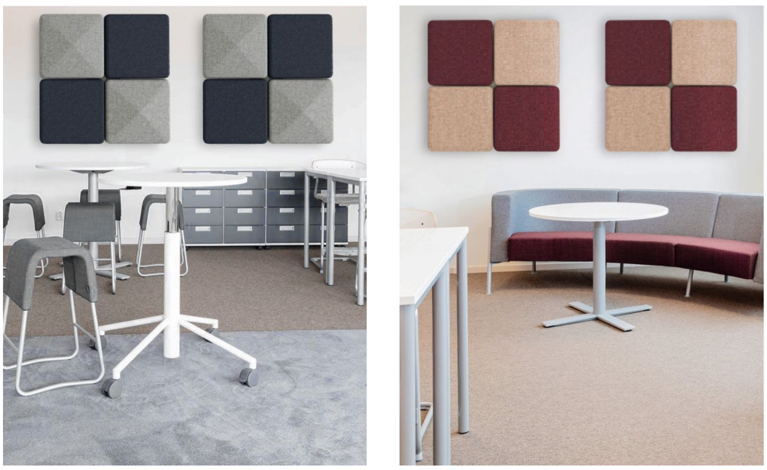


Figure 68. Concept 1 square panels.

Figure 68. Concept 2 Circle panels.

Figure 70. Concept 1 leaves panels.

Figure 71. Concept 2.

Once all the possibilities were shown, they shared their opinions and preferences, being concept one the best for them, with specific emphasis in the variant 2 and 3 (circle and leaves panels). They decided to choose these ones because of the following aspects:

- Nice looking
- Considered easy to sell
- Easy mounting system

- The panels give a luxury plus to the environment

- The combination of fabric and veneer is a good idea because the customers can play with colours and combine with the rest of the furniture of the offices

Concept two received a positive impression regarding how it looked, creating a big difference from what is already on the market, however it was not considered as easy to sell as concept one. One important comment of the manager was that this concept should have an interesting story to justify its shape and make it more attractive for the clients.

9 RESULTS

The final concept of the acoustic panels family is described, regarding its main distinctive characteristics, sound absorption, materials, mounting system and the manufacturing processes needed. The selection of the following concept was based mainly in the appearance test and intuition of the designers.

9.1 Description of final concept

The final concept consists in three different types of MDF structures, that work as bases where two, three or four acoustic panels can be easily attached with magnets. This concept seeks to:

- Give the customer the possibility to choose and combine different types of panels in different positions, depending on the type of environment they have.
- Reduce the number of holes on the wall per panel in comparison to the one that the company currently has (four per panel).
- Generate an air backing space between the panels and the wall in order to catch the sound at a higher speed and increase the sound absorption. (Section 3.3)

The panels shown in *Figure 72* have the same mounting system, which enable them to be fixed in the three different types of structures designed (*Figure 73*).

Figure 72. Panel versions.

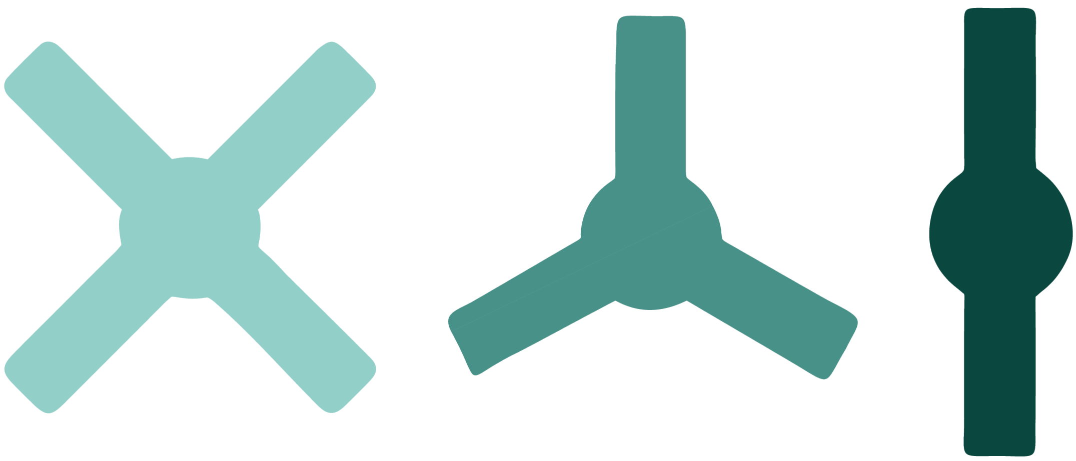


Figure 73. Structures versions.

9.2 Mounting test

Two mounting systems were developed and tested. The first system (*Figure 74*) consisted of two wall hooks where the structure would be hanged, the hooks were fixed to the wall using one screw for each. The second system (*Figure 75*) consisted of two perforations on the structure where two screws would be placed directly in the wall. The magnet system that attach the panels to the structure was also tested in order to know its effectiveness.

The mounting test was developed to observe if the mounting process was intuitive, and fast enough for the mounter in comparison with the company's previous acoustic panels. The evaluation was divided into two parts: the first one where two Kinnarps workers tried to mount two types of systems without any information provided and the second one where they repeated the mounting after reading the intended instructions of this process. Both of them were video recorded and time measured. Surprisingly, the mounters did not need any instructions for mounting the two systems. There was a small conversation after the mounting, in order to receive some feedback regarding the aspects with possible improvements. The preferred mounting system and the fastest was the one with two holes in the structure (1,5 minutes). The main inputs received by the mounters were:

- The system of the two hangers would need an extra screw on each hanger of the wall to be more stable.
- They preferred the system of the holes because it is a more stable system.
- The combination of the structure and the magnet system was considered a big improvement for them to the current panels' mounting system. They consider this combined system would make faster to mount a big number of panels.

Figure 74. Mounting test hangers-system.

Figure 75. Mounting test two holes-system.

9.3 Final mounting system

Six fittings are necessary for mounting each panel: two wall plugs, two flat M6 washers and two M6 screws (60 mm long). A storyboard (Evans et al., 2010) was done to explain how the mounter will interact with the product. This process is divided in the in certain steps (Figure 76).

1. The mounter measures and marks the distance between screws on the wall.
2. The mounter makes the holes in the wall with a hand drill.
3. The mounter inserts the wall plugs on the wall.
4. The mounter inserts the washers and the screws in the structure holes.
5. The mounter screws the structure to the wall.
6. The mounter attaches the panels in the desired position by aligning the magnets to the holes in the structure.

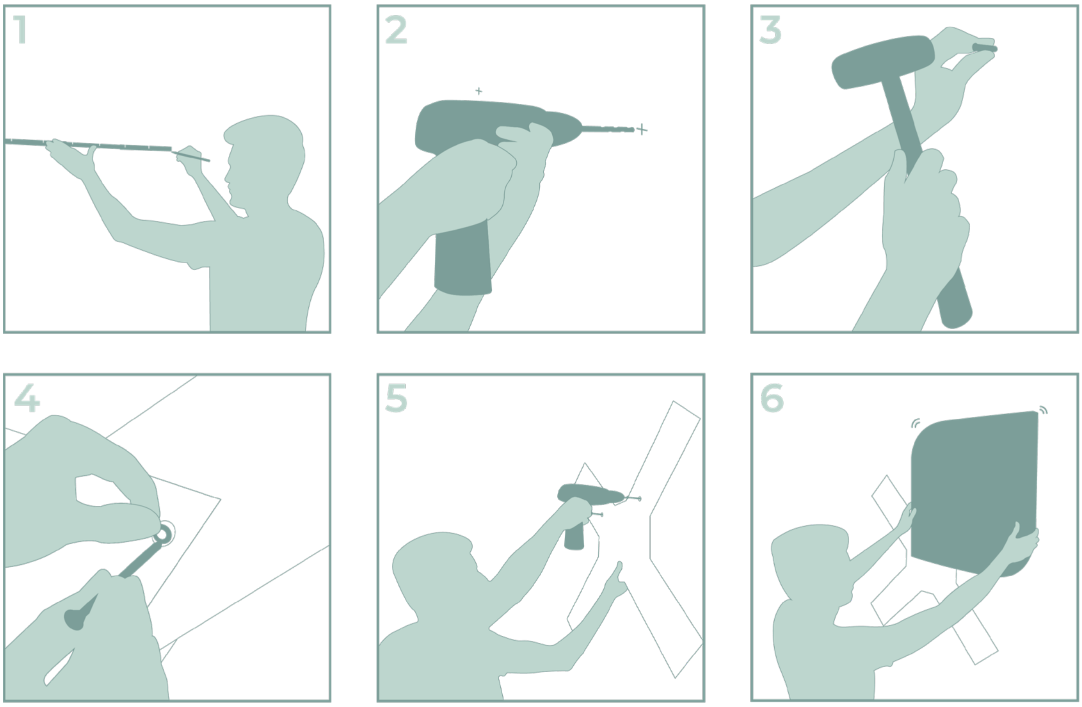


Figure 76. Mounting graphic process.

9.4 Aesthetic results

The aesthetics of the panels is based on regular and simple forms (circle, square, and a "leaf"), that mounted on the structures create attractive compositions. All the panels have the edges rounded and are symmetrical in one direction. The style is mainly based on the keywords of the brand Kinnarps (Section 5.4 and Section 7.2), in the analogical thinking and in moodboards of the environments designed by the company (Section 7.3). One of the panels has a pyramidal volume because this type of geometries diffuse the sound waves (Section 3.1.2). A rendered visualization of the final structure of three arms with circular panels is shown in *Figure 77*, and an integration in one of the Kinnarps´ environments is shown in *Figure 78*. Other visualizations of the rest of the panels are available in Appendix 5.

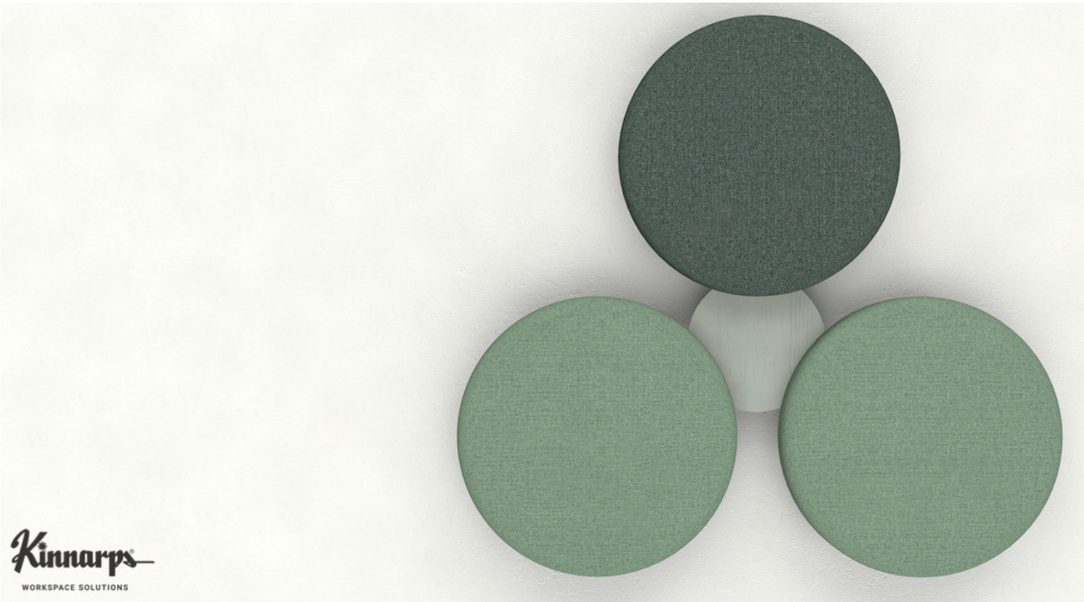


Figure 77. Three arms version.

Figure 78. Integrated panels in an office environment designed by Kinnarps.

9.5 Absorption

It is proposed to have two layers of different absorptive materials (*Figure 79*), combining 20 mm of Kinnarps acoustic filler made of their recycled polyester fibres that has shown efficient acoustic properties in their current products (See Section 3.6), with the Wool Acoustic textile felt of 20 mm of thickness from the company Really, which has one of the highest Noise Reduction Coefficient of natural fibres (NRC=0.70). This proposed combination and the air backing space might improve the absorption results for the panels. Even so, to verify that this solution provides an optimal absorption and fulfil the requirement, it would be necessary to test them in the Acoustic Room. Unfortunately, the company is not going to test any of their products before this project ends because it is too expensive to rent the laboratory just for the evaluation of the prototypes generated in this project.

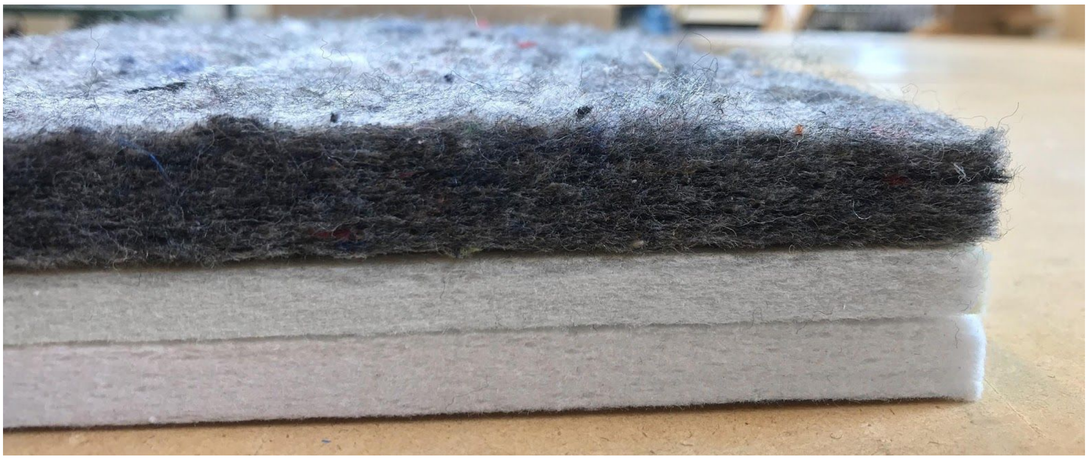


Figure 79.
Absorbent material composition inside the panels.

9.6 Manufacturing process

Two main goals were sought in the manufacturing processes: achieve a good sustainable value according to the Kinnarps rating and ensuring the operators safety. To fulfil them, Kinnarps materials and currently used processes are proposed to be continued due to the company already pays special attention to the high standards of them, and this will fulfil their sustainability requirements and also ensure the safety of their manufacturers.

The manufacturing processes required for the development of this concept will be divided in the manufacturing of the structures and the panels.

Structures:

- CNC router for manufacturing the pieces of each structure. As it is shown in *Figure 80*, the main structure is divided into separate arms which are glued to each other thanks to a central part. This strategy increases the full use of the MDF boards, avoiding the waste of material. Also small parts attached to each panel are cut with the router in the restant board parts.

- One operator station: for gluing the arms, the veneer to the central piece, and the separators to the backside.

- For creating the air backing space was decided to put four rubber pieces on the back.

Panels:

- A mould to manufacture the acoustic panels by pressing the fabric to the acoustic materials with heat.

- Another operator will glue the MDF central pieces with the magnets to the panel.

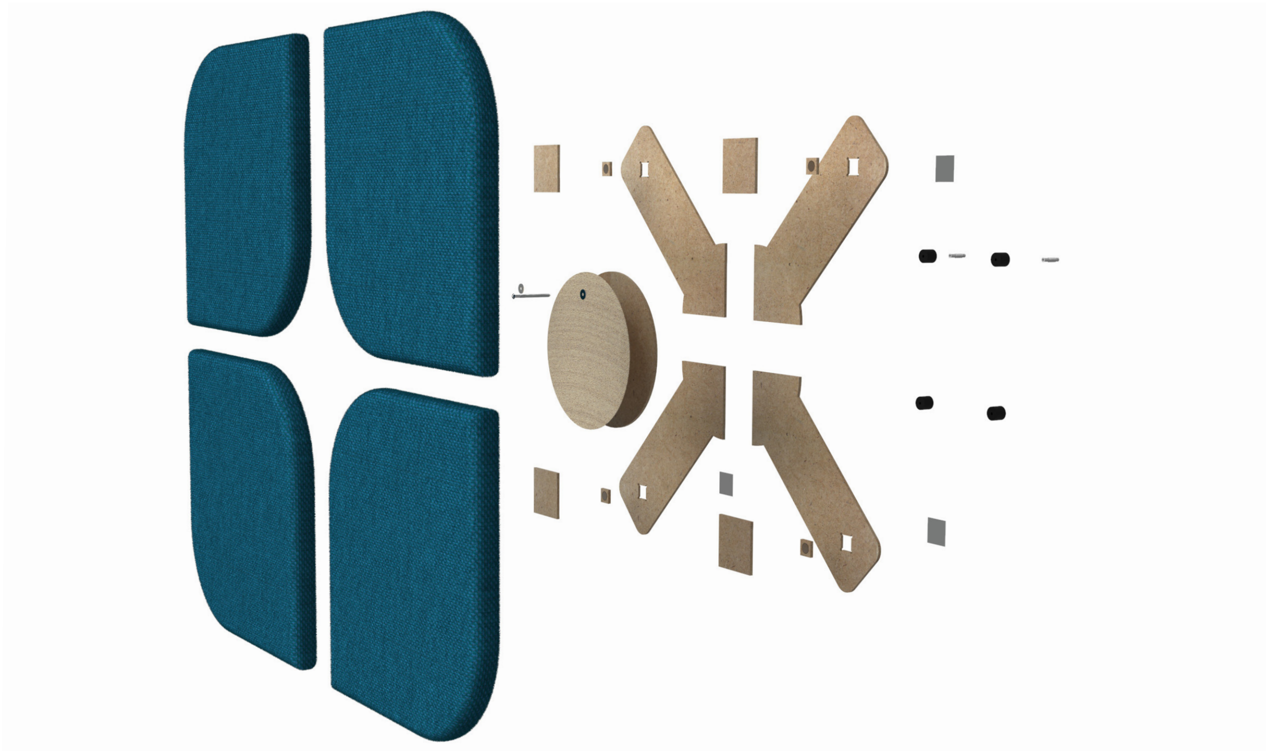


Figure 80. Exploded view.

10 DISCUSSION

After the development of this project some conclusions and a discussion regarding the whole process were done. It was taken in consideration all the stages and make a special emphasis in the fulfilment of the product specifications, methodology chosen, results and learning from the whole process.

10.1 Requirements

The requirements fulfilled are marked in green, and the ones that require further development and testing are marked in orange in the *Table 6*.

Högskolan i Skövde - Kinnarps	Requirements List Project: Family of acoustic panels		Issued on 02/27/19 Responsibles: Julián Soria de la Torre Gabriel Juárez Mejía
Changes	D/W	Requirements	Evaluation method
02/13/19 02/27/19	D	Geometry: Thickness 35-80mm	Measurement (50mm)
	D	From wall to top of panel > 80mm	Measurement (81mm)
	D	Kinematics: Easy to mount	Time and user test
	W	Fast to mount	Time (2 minutes)
	W	Adjustable position	Yes/No
	W	Attachable modules	Yes/No
	D	Forces: Weight <1 kg + attachment parts	Measurement (0,9 kg)
	D	Function: (Sound abs) $N_{10} \leq 6$ (6 wall panels or 1 standing panel)	SS-EN ISO 354 and SS 25269
	W	Encourage concentration	Users test
	W	Improves workspace atmosphere	Users test
	D	Material: KCS Fabrics (If fabric is used)	Yes/No
	W	Recycled polyester filler	Yes/No
	W	Partly recycled	Yes/No
	D	Sustainable Value >2	"The Better Effect Index" by Kinnarps
	D	Safety: Operator safety	Swedish Work Environment Laws
	D	Mounter safety	Swedish Work Environment Laws
	D	User safety	Yes/No
	D	Manufacture: According to the industry standards	Yes/No
	W	Use existing facilities	Yes/No
	W	10.000-25.000 pieces per year	Yes/No
	D	Appearance: Brand colors	Yes/No
	D	Follow Brand aesthetics	Aesthetic analysis (Kinnarps keywords)
	W	Attractive to users and customers	Users/Customers questionnaire
	W	UX: Consider user studies conclusions	Yes/No
	D	Time: 5 months in development	Yes/No
	W	Price: 750 SEK	Yes/No
	W	Maintenance: Easy to clean	Users questionnaire

Table 6. Fulfilled requirements.

The project fulfils the requirements that were demands, however some fields are debatable. In the case of the functionality, formal tests with proper equipment are still needed to corroborate this feature with the proposed dimensions, shapes and materials but a N_{10}<4 is expected due to the materials used show good absorption levels with official results that follow the SS-EN ISO 354. Regarding the sustainability, a deeper study taking into account the six different areas of the "The Better Effect Index" rating should be performed to achieve the mentioned punctuation. Although a good punctuatuion is expected, due to the project suggests materials that do not have a high negative impact in the environment, and the parts of the structure were developed to avoid the waste of material. As well, further testing for the mounter and users should be done in next stages.

The literature review and preliminary studies gave the main base for the decisions taken along the whole project, and justify the features of the proposed final concept. The literature review of sound absorption and materials influenced the choice of materials proposed, the use of a backing space in the panels to increase the absorption and the pyramidal geometry of one panel to diffuse the reflected sound waves. Regarding the user studies, the type of chosen panel to develop (wall panel) was the most popular from the users web questionnaire. The customizable feature of choosing different shapes, positions and colours was found as an interesting and attractive characteristic for the target group in the interviews and in the web questionnaire. The appearance was based on simple forms with a modern style, due to they were repeated words that influenced the decision of the target group at the moment of choosing a panel. The aesthetics of the brand were taken into account by using as reference the moodboards of the environments created by Kinnarps with their products and the keywords at the moment of defining the shapes. Providing an easier and faster mounting system was one of the main requirements of the project and thanks to the structures proposed, this requirement is fulfilled by reducing the number of holes in the wall to only two of them for each type of structure instead of four per panel as in the previous design. Using a lower amount of screws also reduces the risk to the mounter of having different disorders (explained in Section 3.6.1).

This final concept presented is the proposal that was able to be done within the time limit. Therefore, if the project continued it could be still developed more in detail to get closer to a production phase. More evaluations and refinement in detail of the product would be done, for instance, the functionality evaluation and a focus on the manufacture of all the pieces, considering how the materials should be combined in the mould, the viability of this manufacture processes, a Failure Mode & Effects Analysis to examine potential failures (Ginn et al., 2004) and an analysis of all the costs involved.

10.2 The project, the company, the process and design by itself

- From the project in general it was learnt how to apply to the development of a real company's product some of the methods and strategies obtained from the education of product design engineers. It was also understood that the planification of the project is as essential as any other stage of the process because it marks a work rhythm, with stated goals that have to be achieved every certain time. As in all the projects, several difficulties were found, for instance, in the creation of the web survey´s questions, sometimes leading questions were done without noticing. In the case of the literature review, is considered that it took a lot of time due to a not structured planification, first a lot of information of the main fields was collected, then filtered and at last structured, resulting in a big amount of data that was not completely relevant and in time wasted. From this situation was concluded that it would have been better to make a more structured planning of this stage before collecting all the information. In addition, it was also difficult to deal with some limitations found on the development of the project such as depending on the material suppliers in order to do the prototypes, or not being able to test the final results on a proper lab. To work with a partner was considered an advantage in this project because all the parts were involved equitably, thinking with an open mind, being critics, helping each other, and seeking to achieve the best possible result. It was really useful to have another point of view during the entire product development process because it helped to cover the main problem from a wider perspective and also to generate a discussion and complement the knowledge and abilities of each other.

- From the company, besides the understanding of how a big company as Kinnarps works, including the factory, manufacture processes, and logistics, it was learnt that is important not to restrict the project too much since the beginning in order to leave some freedom and enhance creativity and innovation during the whole process. As well is important to mention that the communication between the people involved in the project was essential for its development. The constant feedback from the company (a weekly meeting) was considered a really good strategy to keep working on the right track and to not forget the main objectives of the project.

- From the process. it was considered that the methodology followed “Design thinking” is a really good tool to work with design projects that seek an innovative result, due to the mix of divergent and convergent thinking it suggests. It gives an appropriate mix of exploration and selection of ideas. Developing a wide variety of solutions with sketches and prototypes helped to gain input to continue working, for instance, shapes, different assemblies, dimensions, proportions, and pieces were evolved by using as reference these previous ideas created. The high level of users involvement that the approach followed suggested is considered really useful in two main stages of the project, at the initial phase because it gives important design opportunities and concrete characteristics of the target group to work in the concept generation, and in the concepts evaluation, because it has as outcome relevant feedback that guides the choice of the concept that best fulfil their needs. On the other hand, it was found that the iterations that characterized the “Design thinking” had positive and negative aspects. It was really useful for evolving the concepts by going back to develop specific parts that were found that had to be fixed, however this process may be risky if there is not a limit, sometimes it seems to be infinite and it requires a lot of time.

  The prototypes developed helped to refine the solutions and to have a better perception of the proposed solutions, although developing prototypes for three concepts was not considered a good decision due to the amount of time that this process required. It would have been better to only focus on the development of the prototypes for two concepts.

  The combination of different methodologies was considered effective for this project because their different approaches complemented each other. For instance, the Ulrich & Eppinger´s engineering approach suggested to state more concrete and technical data, that worked as limitations and references, while the IDEO method cards, and "Design thinking" suggested iterative tools more focused on the user and on creativity.

- From design in general it was concluded that the development of a product is a really complex activity due to all the variables involved. The process of keeping in mind the collected information, the company requirements, the user studies, and other relevant data can overwhelm the people that develops the project, however for this team, was very helpful to decompose the problem in order to have a better understanding of what had to be solved, to approach and solve system by system and to not forget the main objectives every time that a decision has to be made. Design is an activity that requires constant practice to gain experience and keep obtaining more knowledge and skills from every project.

11 REFERENCES

Abstracta AB, n.d. Triline Wall. Abstracta. URL https://abstracta.se/product/triline-wall/ (accessed 6.9.19).

Acoustic Facts, 2017. The calculation model. Acoustic Facts. URL https://www.acousticfacts.com/description-calculation-model (accessed 3.10.19).

Akustikverkstan, n.d. AKUSTIKVERKSTAN - SOUND ABSORPTION. URL https://www.akustikverkstan.se/sound-absorption.html (accessed 3.10.19).

Bao-guo, M., Hong-bo, Z., Rong-zhen, D., 2002. Development of a high sound absorption material CEMCOM. Journal of Wuhan University of Technology-Mater. Sci. Ed. 17, 5–8.

Berardi, U., Iannace, G., 2015. Acoustic characterization of natural fibers for sound absorption applications. Building and Environment 94, 840–852.

Brown, T., 2008. Design thinking. Harvard business review 86, 84.

Cooper, A., Reimann, R., Cronin, D., Noessel, C., 2014. About Face: The Essentials of Interaction Design, 4th ed. Wiley Publishing.

Cross, N., 2006. Designerly ways of knowing. Springer Verlag.

Ermann, M.A., 2015. Architectural Acoustics Illustrated. John Wiley & Sons, Inc.

Evans, M., Pei, E., Campbell, I., 2010. ID Cards. Loughborough University, Loughborough.

Garai, M., Pompoli, F., 2005. A simple empirical model of polyester fibre materials for acoustical applications. Applied Acoustics 66, 1383–1398.

Gheerawo, R., Eikhaug, O., Plumbe, C., Støren Berg, M., Kunur, M., Høisæther, V., 2010. Innovating With People - The Business of Inclusive Design. Norwegian Design Council, Oslo.

Ginn, D., Streibel, B., Varn, E., 2004. The Design for Six Sigma Memory Jogger. Goal/QPC.
Haggar, S. el-, 2007. Sustainable Industrial Design and Waste Management : Cradle-to-Cradle for Sustainable Development. Academic Press, Amsterdam.

Hall, D.E., 1993. Basic Acoustics, 2nd ed. Krieger Publishing Company.

Hartson, R., S. Pyla, P., 2012. The UX Book : process and guidelines for ensuring a quality user experience. Amsterdam : Elsevier.

IDEO, 2003. IDEO Method Cards: 51 Ways to Inspire Design. William Stout Architectural Books.

Inglis, K., n.d. Design Scenarios - Communicating the Small Steps in the User Experience. The Interaction Design Foundation. URL https://www.interaction-design.org/literature/article/design-scenarios-communicating-the-small-steps-in-the-user-experience (accessed 3.7.19).

International Organization for Standardization, 2003. ISO 354:2003, Acoustics — Measurement of sound absorption in a reverberation room [WWW Document]. URL https://www.iso.org/obp/ui/#iso:std:iso:354:ed-2:v1:en (accessed 3.4.19).

International Organization for Standardization, 1997. ISO 11654:1997, Acoustics - Sound absorbers for use in buildings - Rating of sound absorption. URL https://www.iso.org/obp/ui/#iso:std:iso:11654:ed-1:v1:en (accessed 3.4.19).

Kammarkollegiet, 2017. N10 A New Measure for speech absorption. Acoustic Facts. URL https://www.acousticfacts.com/news/n10-new-measure-speech-absorption (accessed 3.13.19).

Kinnarps, n.d. Kinnarps. URL https://www.kinnarps.com/ (accessed 3.24.19).

Kinnarps Group, 2018. The better effect: A sustainability report from the Kinnarps Group.

Kurrasch, A.J., 1991. Acoustic panel. US5009043A.

Kuttruff, H., 2000. Room Acoustics. Spon Press, London.

Long, M., 2005. Architectural Acoustics, Applications of Modern Acoustics. Academic Press, Amsterdam.

Mager, D., Sibilia, J., 2010. Street Smart Sustainability : The Entrepreneur's Guide to Profitably Greening Your Organization's DNA, The Social Venture Network Series. Berrett-Koehler Publishers, San Francisco, CA.

McNett, C.P., McNett, J.C., 2000. Acoustic panels having plural damping layers. US6123171A.

Munjal, M.L., 2013. Noise and VIbration Control. WORLD SCIENTIFIC / INDIAN INST OF SCIENCE, INDIA, India.

Negro, F., Cremonini, C., Properzi, M., Zanuttini, R., 2015.

Sound absorption coefficient of perforated plywood: An experimental case study.
Nicolaisen, P., 2009. System for hanging different items on walls. US20090140120A1.
Padhye, R., Nayak, R., 2016. Acoustic Textiles.

Parkin, A., 2015. Finishes and Interiors: A guide to office acoustics. FIS, Solihull.
Qiu, X., 2016. Principles of Sound Absorbers, in: Acoustic Textiles.

Really, 2019. Really. Upcycled textiles designed for circularity. URL https://reallycph.dk/ (accessed 4.29.19).

Really, n.d. Data | Acoustic Textile Felt | Data | Products | Really | Really. | Upcycled textiles designed for circularity. URL https://reallycph.dk/products/data/acoustic-textile-felt-data (accessed 5.13.19).

Rodgers, P., Milton, A., 2011. Product Design, Portfolio. Laurence King Publishing, London. Russo, K.M., Russo, S.J., 2011. Magnet-based mounting systems for frames. US20110042542A1. Salvendy, G., 2012. Handbook of Human Factors and Ergonomics. John Wiley & Sons.

Schittich, C., 2011. In Detail, Work Environments : Spatial Concepts, Usage Strategies, Communications, In Detail. Birkhäuser, Munich.

Scott Doorley, Holcomb, S., Klebahn, P., Segovia, K., Utley, J., 2018. Design Thinking Bootleg. Hasso Plattner Institute of Design at Standford.

Seddeq, H.S., 2009. Factors influencing acoustic performance of sound absorptive materials. Australian Journal of Basic and Applied Sciences 3, 4610–4617.

Sundstrom, E.D., 1986. Work places: the psychology of the physical environment in offices and factories, Environment and behaviour series. Cambridge University Press, Cambridge; New York.

Swedish Standards Institute, n.d. SS 25269:2013 – Acoustics – Screens or single objects – evaluation with regard to sound absorption and screen damping. URL https://www.sis.se/produkter/byggnadsmaterial-och-byggnader/skydd-av-och-i-byggnader/akustik-i-byggnader-ljudisolering/ss252692013/ (accessed 3.4.19).

Thapa, R., n.d. Living Documents and Presentations for Teams. Xtensio. URL https://xtensio.com/ (accessed 6.6.19).

The Interaction Design Foundation, n.d. What is Design Thinking? The Interaction Design Foundation. URL https://www.interaction-design.org/literature/topics/design-thinking (accessed 3.14.19).

Tietema, Y., 2017. How to create a brain friendly office? Sound Design for Brain & Cognition. Saint-Gobain Ecophon.

Ulrich, K.T., Eppinger, S.D., 2012. Product design and development, 5th ed. ed. McGraw-Hill/Irwin, New York.

United Nations, n.d. About the Sustainable Development Goals. United Nations Sustainable Development. URL https://www.un.org/sustainabledevelopment/sustainable-development-goals/ (accessed 5.30.19).

Violante, F., Kilbom, Å., Armstrong, T.J., 2000. Occupational Ergonomics : Work Related Musculoskeletal Disorders of the Upper Limb and Back. CRC Press, London.

Wencheng, G., Hequn, M., 2015. A Compound Micro-perforated Panel Sound Absorber with Partitioned Cavities of Different Depths | Elsevier Enhanced Reader 78, 1617–1622.

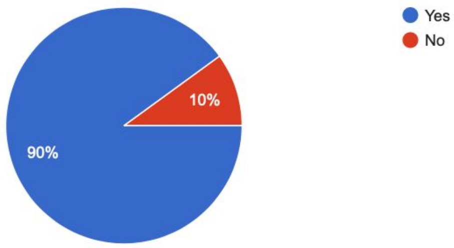
Zoltowski, C.B., Oakes, W.C., Cardella, M.E., 2012. Students' Ways of Experiencing Human-Centered Design. Journal of Engineering Education 101, 28–59.

12 APPENDICES

12.1 Appendix 1. Web questionnaire

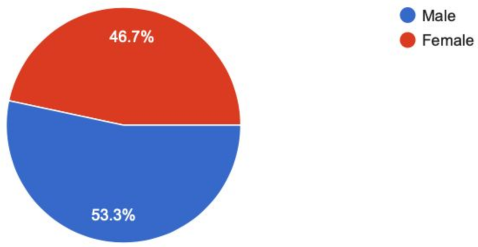
Do you know what an acoustic panel/sound absorber is?

30 responses



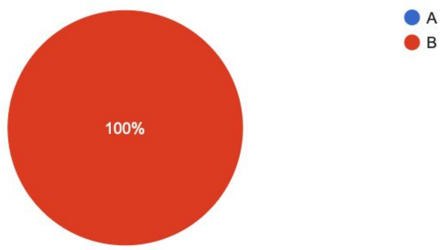
Gender

30 responses



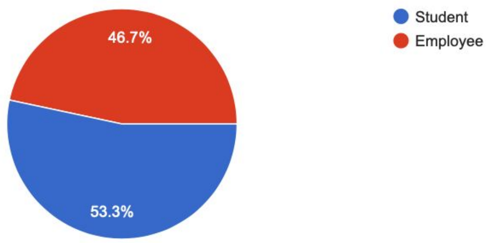
Select the correct option

30 responses



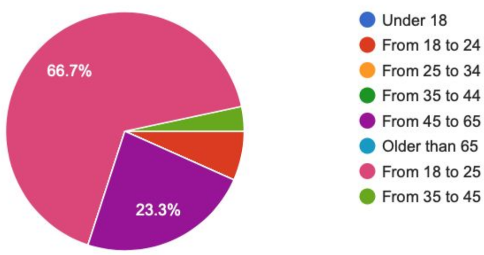
Employment Status: Are you currently...?

30 responses



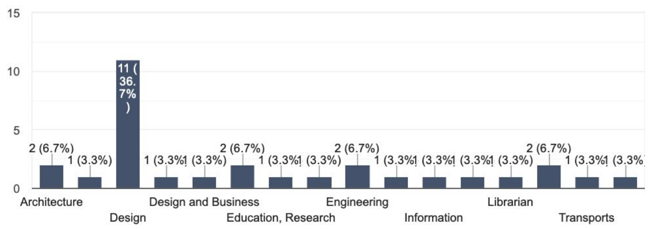
Age

30 responses



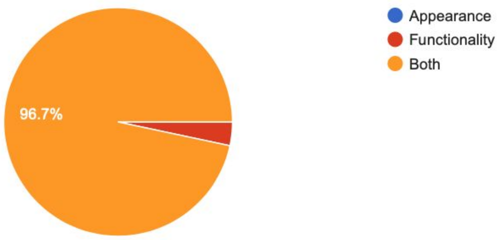
Specify your field (Business, Science, Architecture, Design, Education, etc)

30 responses



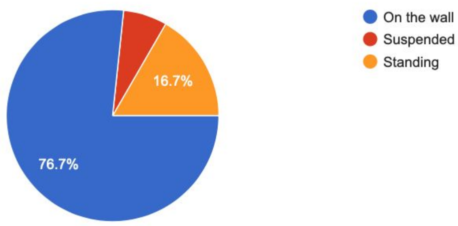
What do you think is more important for an acoustic panel?

30 responses



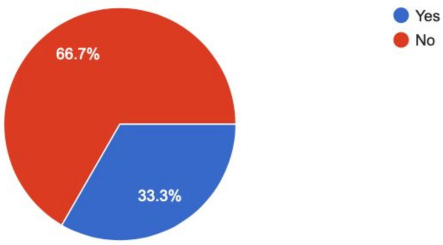
Which type of panel do you prefer?

30 responses



Do you have acoustic panels in your workspace ?

30 responses



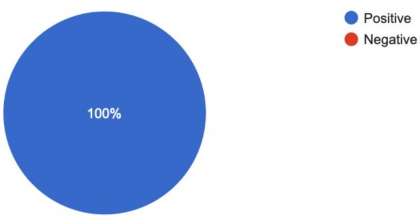
Specify your type of work space (Open office, home office, co-working space, single room office, classroom, library, etc)

30 responses

Single room office
Co-working room
Classroom and library
Biblioteca
Three room office
Studio/Co-working space
Open office
Single room
Classroom, library, home office
Single room office
Home studio
Cockpit

Do you think acoustic panels affect in a positive or negative way the work environment?

30 responses



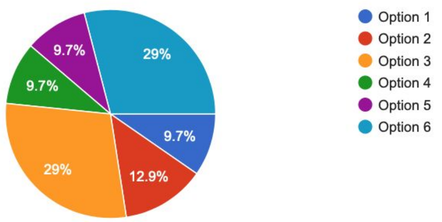
Explain briefly why

25 responses

The place will be more quiet, then paceful. In my area that gives you more opportunities to be creative
Helping the work environment by making it easier to concentrate in a quieter space
There are panels in the roof of my office room, which may reduce echoes a bit.
Reduce noise level, better concentration
Because them helps to have better conversations and work space
More quiet to the people outside the zone and more comfort for the people inside
Because of noise reduction improves co-working environmental team and helps brain concentration
Obviuosly in the library to create environments which allows people or groups to produce some noise but keep areas as undisturbed as possible and create more calmness, in the (in our) library also much as a design element to supply the library with positive colours
Man låta det bli en del av gestaltningen och förstärka uttrycket
Positive - they keep down the noise, Negative - they're ugly
it makes a more friendly and colorful environment to work, and reduces the noise

Which of these wall panels do you prefer?

29 responses



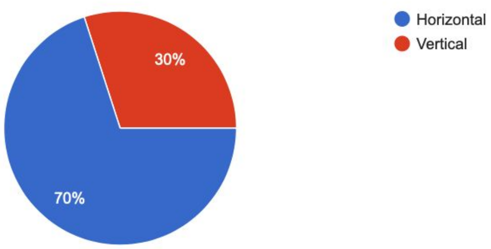
Brief explanation of your choice

25 responses

- Because this panels have design and you can removed to different places that helps to have different rooms with panels or improve rooms.
- Depends on the location and function needed
- More creative, better integration with the wall
- Modular panels in hexagons can be adapted to many types of walls, plus mixing colors can create great patterns.
- Multifunctional panel
- I would prefer option 6 becouse I think it is colorful, subtle and smart at the same time.
- It is also a good decorative method
- Great and simply design
- Is simple, modular, conservative and good looking
- Very simple yet nice design, not distracting
- It is possible to add images to the panels in a less limited way.

Which of these suspended panels do you prefer?

30 responses



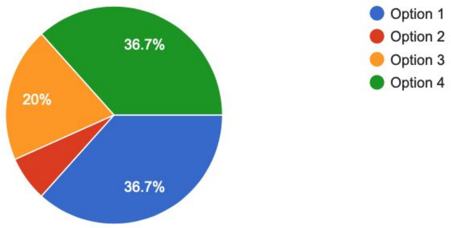
Brief explanation of your choice

23 responses

- Horizontal panel does not block the view of the room, also they would bring a nice dynamic to the space and would bring a perseption of height and three dimensionality especially to large open spaces if suspended on varying levels.
- It is not felt as a wall
- Me parece menos invasivo
- Because the sound expands and stops at the top with this type of panels.
- Looking better and to avoid collusions with other objects or your upper body
- Horizontal panels must be difficult to clean, while verticals seem to be easier.
- The roof space is used
- Horizontal panels bothers less to me
- It creates an open apace
- More space, it is more practical

Which of these suspended panels do you prefer?

30 responses



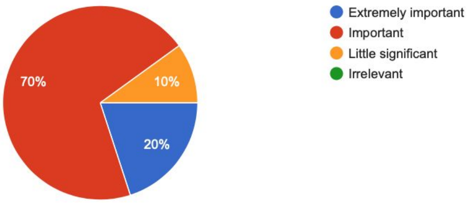
Brief explanation of your choice

24 responses

- Because you can use it to divide the rooms and continue the visual at the room space
- Looks most interesting
- You can see through
- They look a decorative object instead of a panel.
- Type ofemotional panel
- Option 1 lets the light go through it
- It is also a good decorative method
- Great design
- I chose this option more based on my design likes and also because the modulation of the panels, I also like the lattice, but I guess cannot be really useful in acoustic absorption focusing
- Dividing the room, not distracting, better design than the others
- The horizontal panel 4 does not act as a barrier, and it is visually attractive.
- Seems light and lively

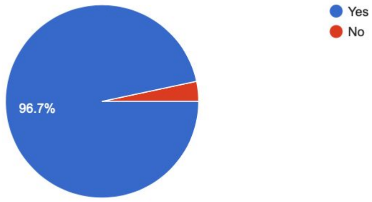
How important sustainability is for you, when you are choosing one of this products?

30 responses



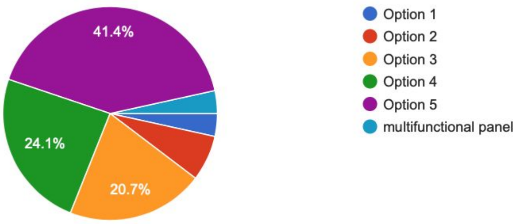
Do you consider interesting to be able to choose the position, color and pattern of the acoustic panels for your work space?

30 responses



Which of these standing panels do you prefer?

29 responses



Brief explanation of your choice

21 responses

- It seems to be a other fitmet at the house and not a panel
- Original and movable
- I like the natural shape of these panels.
- Because of its organic shape and
- It could be used also for separating the space into diverse areas
- Modular form
- If you want to use more space into the room you can hide part of the panels
- Nice eye catcher without being too overwhelming in a workspace
- It can be use more like a wall, but still flexibly it seems.
- enjoyable
- Is more organic, similar to a nature space
- I love the modular design

12.2 Appendix 2. Interviews

Interview 1.
Interviewers: Julián Soria and Gabriel Juárez
Interviewed: Architect of Ritningen Arkitektbyrå AB

What did you consider to choose the acoustics panels for the University of Skövde's library?
A: The freedom to choose the fabrics colour, and the prize.

Do you consider important to have a big amount of acoustic panels in order to absorb the sound?
A: It is better not to have so many, it depends in how many people will be there and other things, and also it depends if you can put something in the ceiling or not. We are not fan of the 60x60 cm "pladur" for the roof, although they are useful for the installations but not for the aesthetics of the space.

What type of acoustic panels do you prefer, wall, standing or hanged from the ceiling and why?
A: It depends on the project and the type of space. Acoustic panels are our last resource because you can also use other type of objects, as carpets, open shelves with books, furniture, etc.

If acoustic absorption represents a 10 and aesthetics a 0, which would be the balance/proportion between them for you?
A: It also depends on the project but In this case, in a library is very high the proportion for the acoustic absorption, 70-30 approximately.

From 1 to 10, being 1 irrelevant and 10 extremely important, how do you think acoustic panels could improve a working environment?
A: 8, yes it improves the working environment

What kind of shapes do you consider are more appropriate for an acoustic panel, simple and regular, based on basic forms or more complex ones?
A: Mostly Very simple, discrete, where you can put your stamp on it.

Extra comments
In general architects, we first look in the room, in what we want to create, which absorbents we are going to use, so we can build a room that will have proper acoustics. And we depend on the acoustic panel measures that the company provides but sometimes is an issue, and it could be useful to have a wider variety of sizes or be able to customize them.

Interview 2.
Interviewers: Julián Soria and Gabriel Juárez
Interviewed: Sales employee “A” Kinnarps showroom Skövde

Have you been involved in choosing acoustic panels for interior design projects?
Yes

What did you consider to choose the respective panels?
Price, How big the problem of acoustics is for the customer, the thickness, the interior material, but it depends in the project.

Where did you look for possible acoustic panels for your designs? (websites, catalogues, fairs, etc).
We have contacts in the companies, representatives come and talk about their products.

Do you consider important to have a big amount of acoustic panels in order to absorb the sound?
Yes, it depends in how much the sound bounce between the walls, and if they have a textile floor, or a hard roof.

What type of acoustic panels do you prefer, wall, standing or hanged from the ceiling and why?
I think that the hanged from the ceiling is the nicest looking one, but you should have both types at least to make the sound not bounce so much, often is not enough with one type. Maybe wall and standing or wall and roof. Horizontal panels are more for personal dinners, where many people interact, and the vertical are more for offices.

If acoustic absorption represents a 10 and aesthetics a 0, which would be the balance/proportion between them for you?
70% aesthetics, 30% functionality

From 1 to 10, being 1 irrelevant and 10 extremely important, how do you think acoustic panels could improve a working environment?
8

From 1 to 10, how important you consider is to have different size panels ?
8

From 1 to 10, how important you consider is to have the possibility of customize the composition with different shapes, patterns and colours?
The colour and textile are the most important for me. There are many different shapes, and if you have to come with a new panel, it must be something quite spectacular, and with new thinking.

Do you consider interesting to let the workers customize the office acoustic panels?
That would be great, a problem is that is not flexible today, you need to screw them on the wall.

What kind of shapes do you consider are more appropriate for an acoustic panel, simple and regular, based on basic forms or more complex ones?
I think that both are great depending on the type of project.

What company do you think is currently doing a great job in acoustic panels?
Glimakra, Abstracta and Zilenzio

Extra comments
We work with different companies that sell acoustic panels, but mainly three big companies, sometimes there's a request from the customer to have one type of panel or of a company has a product that is more unique.

Interview 3.
Interviewers: Julián Soria and Gabriel Juárez
Interviewed: Interviewed: Sales employee "B" Kinnarps showroom Skövde

Have you been involved in choosing acoustic panels for interior design projects?
Yes

What did you consider to choose the respective panels?
The roof and the floors, I choose the colours looking through Kinnarps and other companies and of course the preferences of the client.

Where did you look for possible acoustic panels for your designs? (websites, catalogues, fairs, etc)
Websites of different companies.

Do you consider important to have a big amount of acoustic panels in order to absorb the sound?
Yes

What type of acoustic panels do you prefer, wall, standing or hanged from the ceiling and why?
I prefer wall panels because it is nicer than a white wall, but it depends on the client.

If acoustic absorption represents a 10 and aesthetics a 0, which would be the balance/proportion between them for you?
6

From 1 to 10, being 1 irrelevant and 10 extremely important, how do you think acoustic panels could improve a working environment?
8

From 1 to 10, how important you consider is to have different size panels?
I think it depends on the project and how many absorption you need in the room, but I like to work with different sizes.

From 1 to 10, how important you consider is to have the possibility of customize the composition with different shapes, patterns and colours?
It is important for me to customize composition and colours.

Do you consider interesting to let the workers customize the office acoustic panels?
Yes it is very interesting, we also work with a company that prints pictures in acoustics panels' fabric.

What kind of shapes do you consider are more appropriate for an acoustic panel, simple and regular, based on basic forms or more complex ones?
Simple and regular combining different sizes in order to create a composition.

What company do you think is currently doing a great job in acoustic panels?
Zilenzio and Glimakra.

Interview 4.
Interviewers: Julián Soria and Gabriel Juárez
Interviewed: Manager of Trängens förskola

Can you notice the difference between being in a room with the children that has acoustic panels and in a room that has not?
Yes, of course. There are a lot of children, so we need them.

What kind of shapes do you consider are more appropriate for acoustic panels, simple and regular, based on basic forms or more complex ones?
In big rooms we prefer this one (point rectangular standing wood panel), and in smaller rooms we prefer the wall ones.

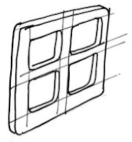
Do you think this objects distract the children? Why?
Yes but we prefer this one for smaller rooms (points a fabric wall panel) because the children can attach paintings and other things in the panels.

From 1 to 10, being 1 irrelevant and 10 extremely important, how do you think acoustic panels could improve a working environment?
While more acoustic panels in the place it improves the concentration in a better way. I work here so I need a concentration environment

What do you consider more appropriate, to have acoustic panels, or to have acoustic absorptive furniture as sofas, carpets, etc?
We need to have both kind of sound absorbers, panels and furniture.

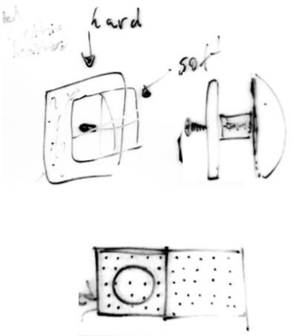
Do you consider interesting to have interactive customizable acoustic panels for the children? Why?
Our panels could not be moved from the walls or ceiling, so it would be interesting to make them softer as toys for children but the pieces should not be noisy when they fall on the floor, as the plastic box that we have to put the toys inside them.

12.3 Appendix 3. Interior parts and mounting system alternatives

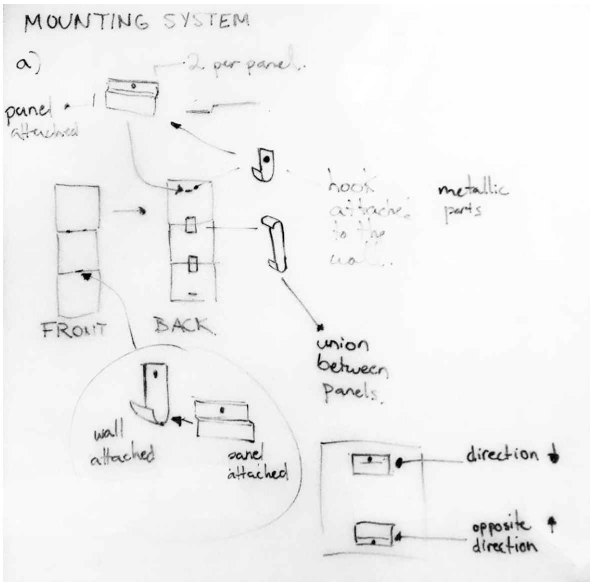


A frame in the back part of the panel that lets the air go through it.

A panel that has a space in the back due to its shape. Similar to a “shell”.



A double panel that has a central union that creates a space between them. The back panel could be a perforated veneer panel or a mdf panel covered with a fabric. While the front panel could be the one with the absorbent material and have different shapes.



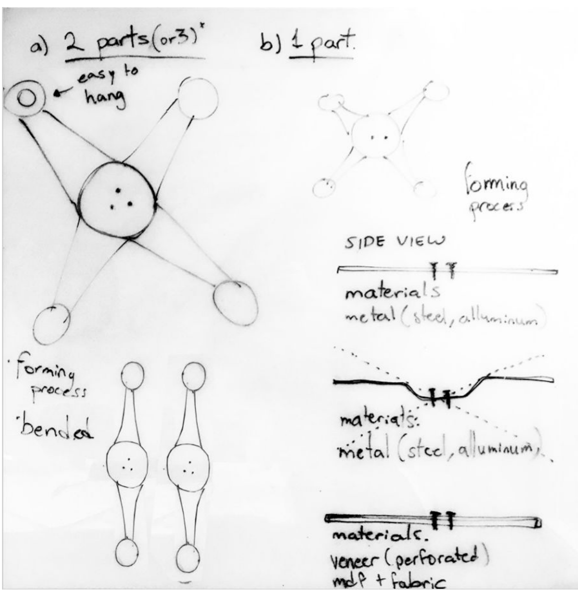
Attaching 1 panel to the wall, and the others are hanged from it with metallic parts.

The system is composed by **3 pieces**.

Two of the **first type** are **attached to every panel**.

The **hook** is attached to the **wall**.

The **double hook joins** the panels vertically.



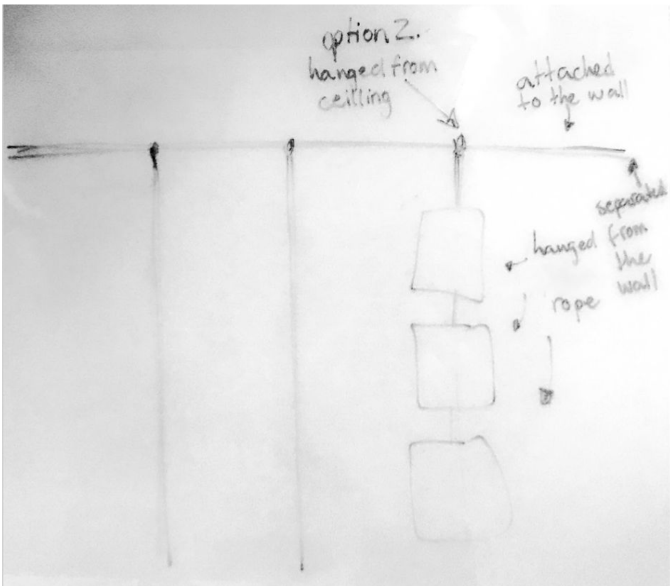
Base for hanging the panels

It can be a **4 “arms “** module or a **2 “arms”** module (as it is shown in the left side of the picture).

Possible **materials**:

- metal (steel or aluminum)
- Perforated veneer panel
- MDF + fabric

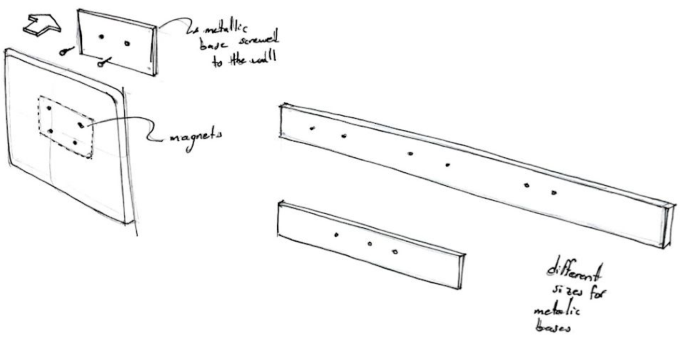
The acoustic panels are attached to each arm with a hook, velcro, or ironworks.



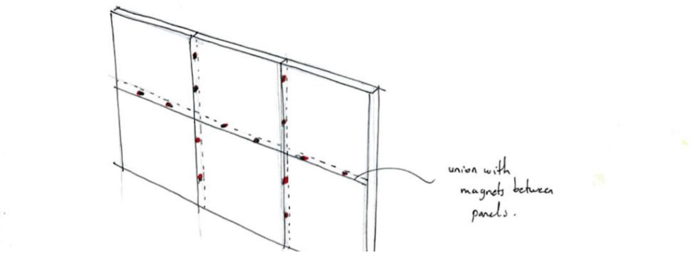
Rope system for hanging the panels

Bar separated from the wall

The panels and/or the rope had the union mechanism to hang them.

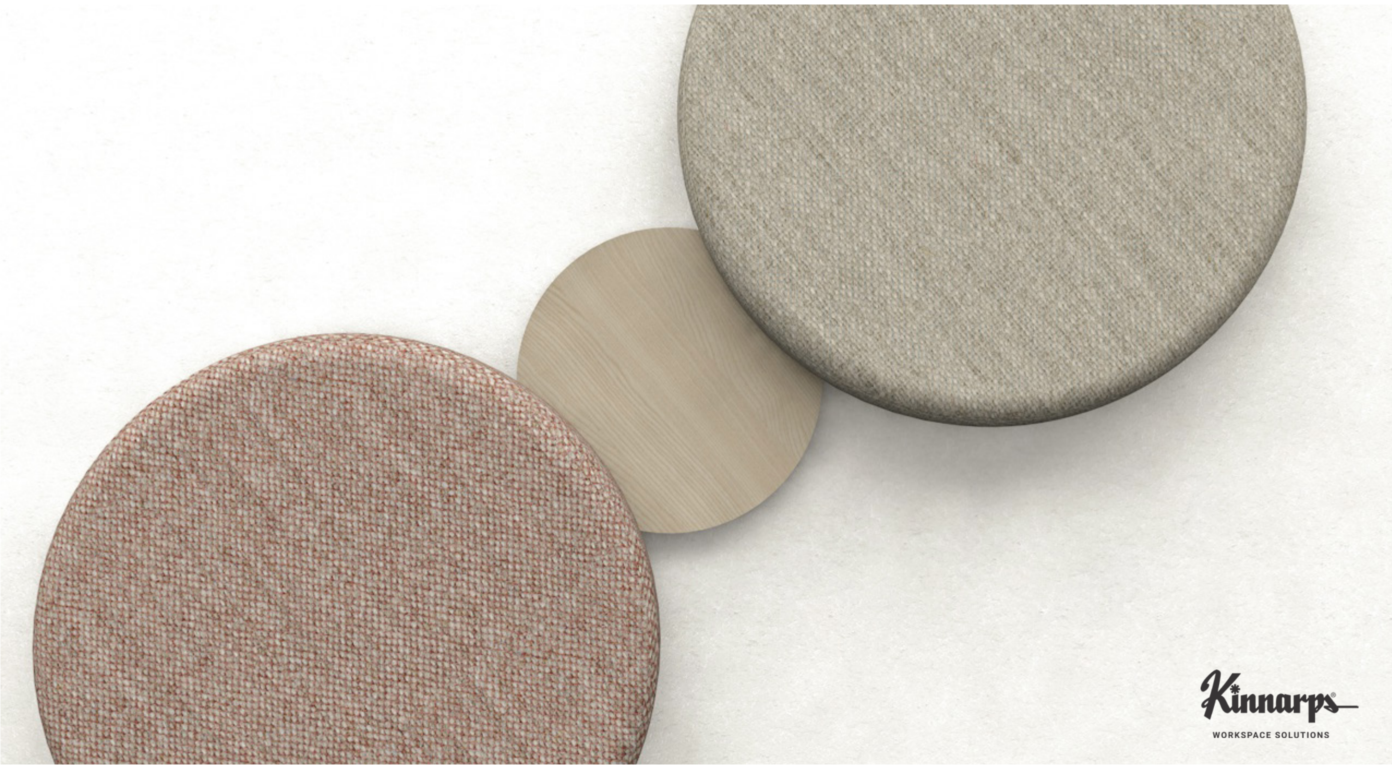


Magnets system for hanging the panels

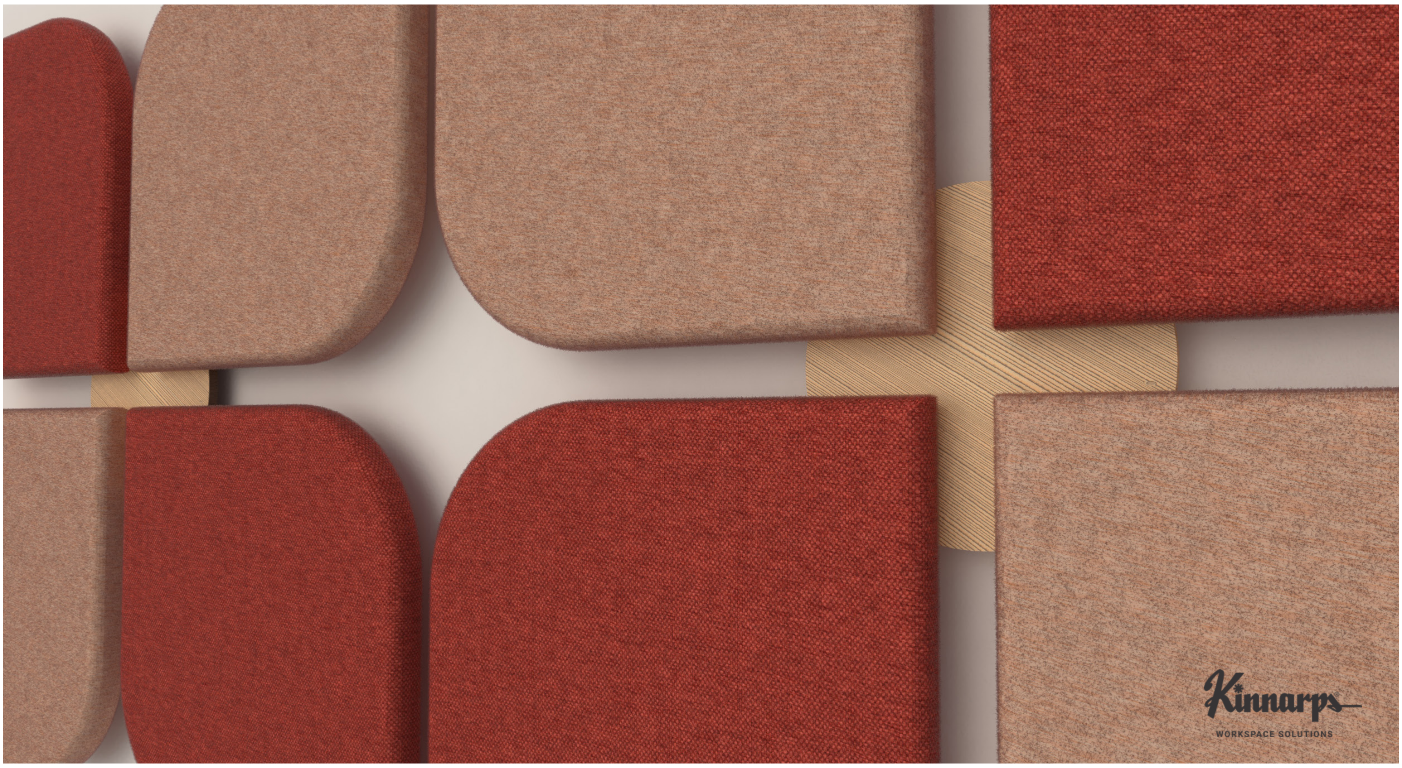


12.4 Appendix 4. Prototypes color versions

12.5 Appendix 5. Integrated final results


Kinnarps
WORKSPACE SOLUTIONS

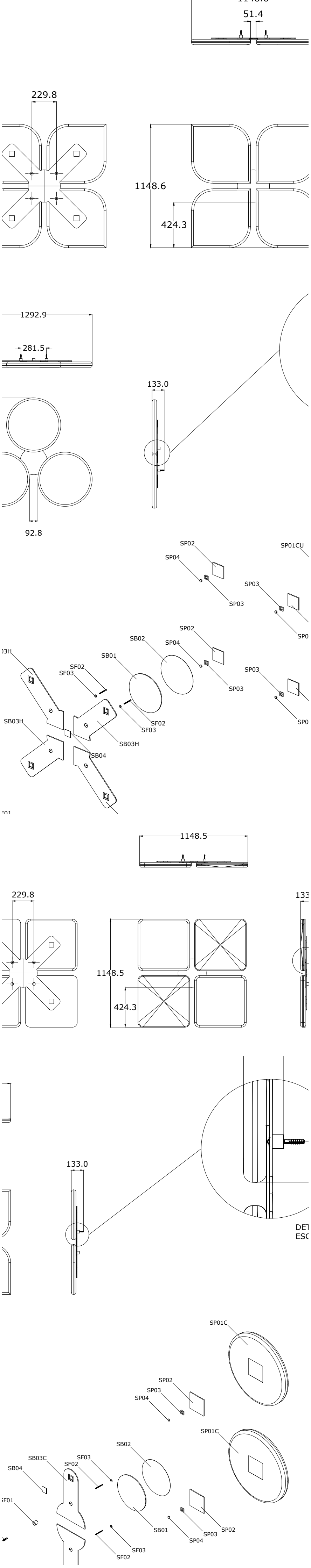

Kinnarps
WORKSPACE SOLUTIONS

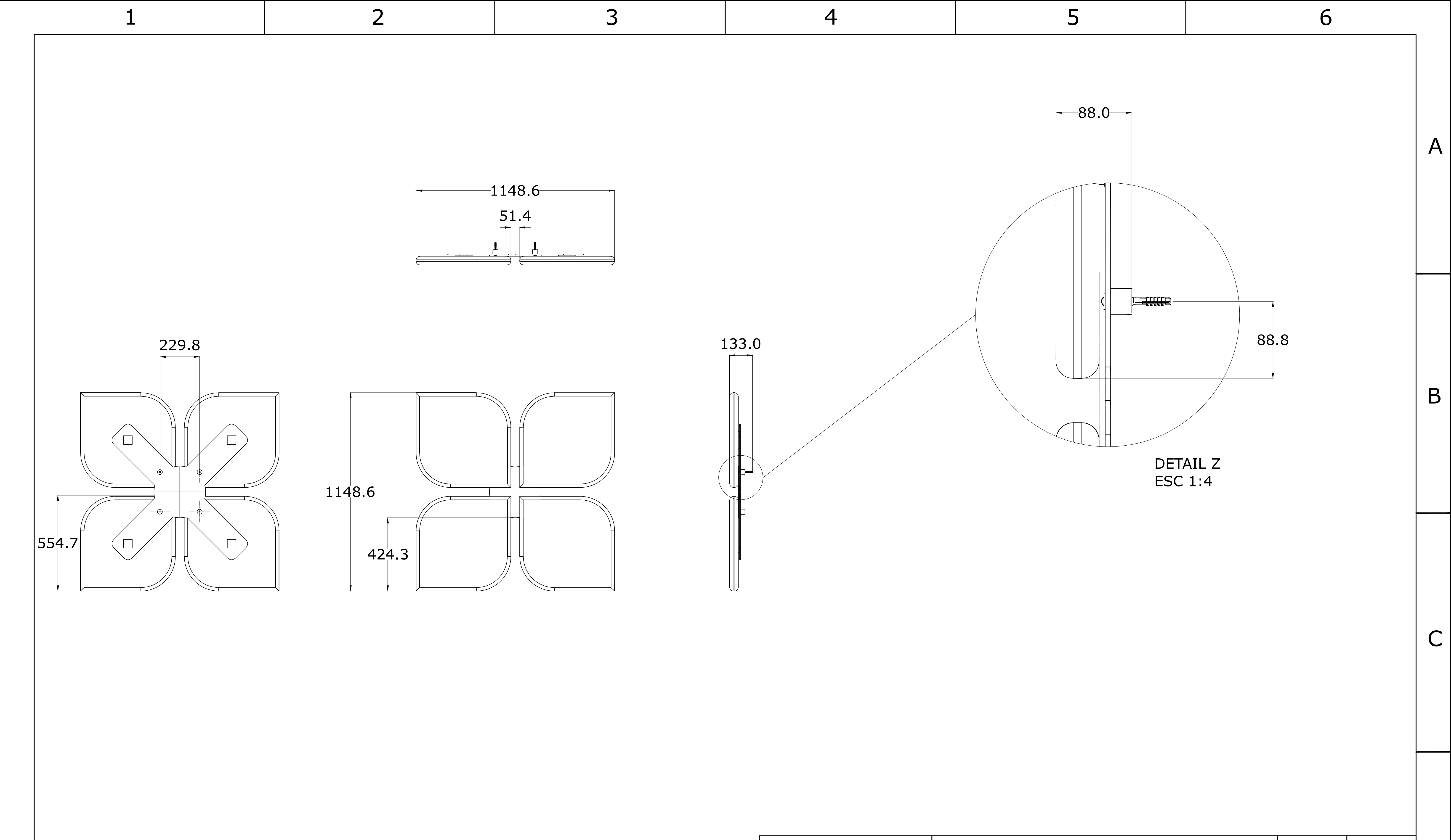

Kinnarps
WORKSPACE SOLUTIONS


Kinnarps
WORKSPACE SOLUTIONS

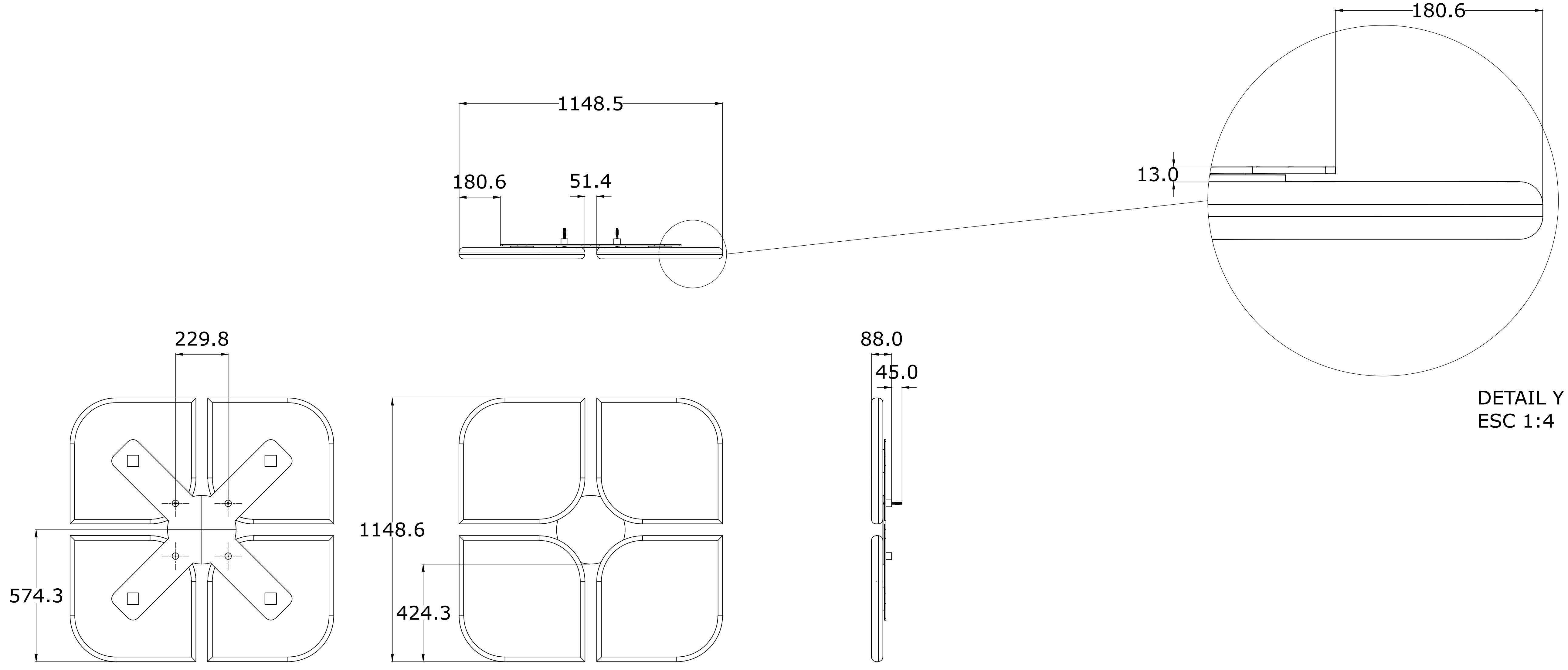
TERCERA SECCIÓN

Planos técnicos

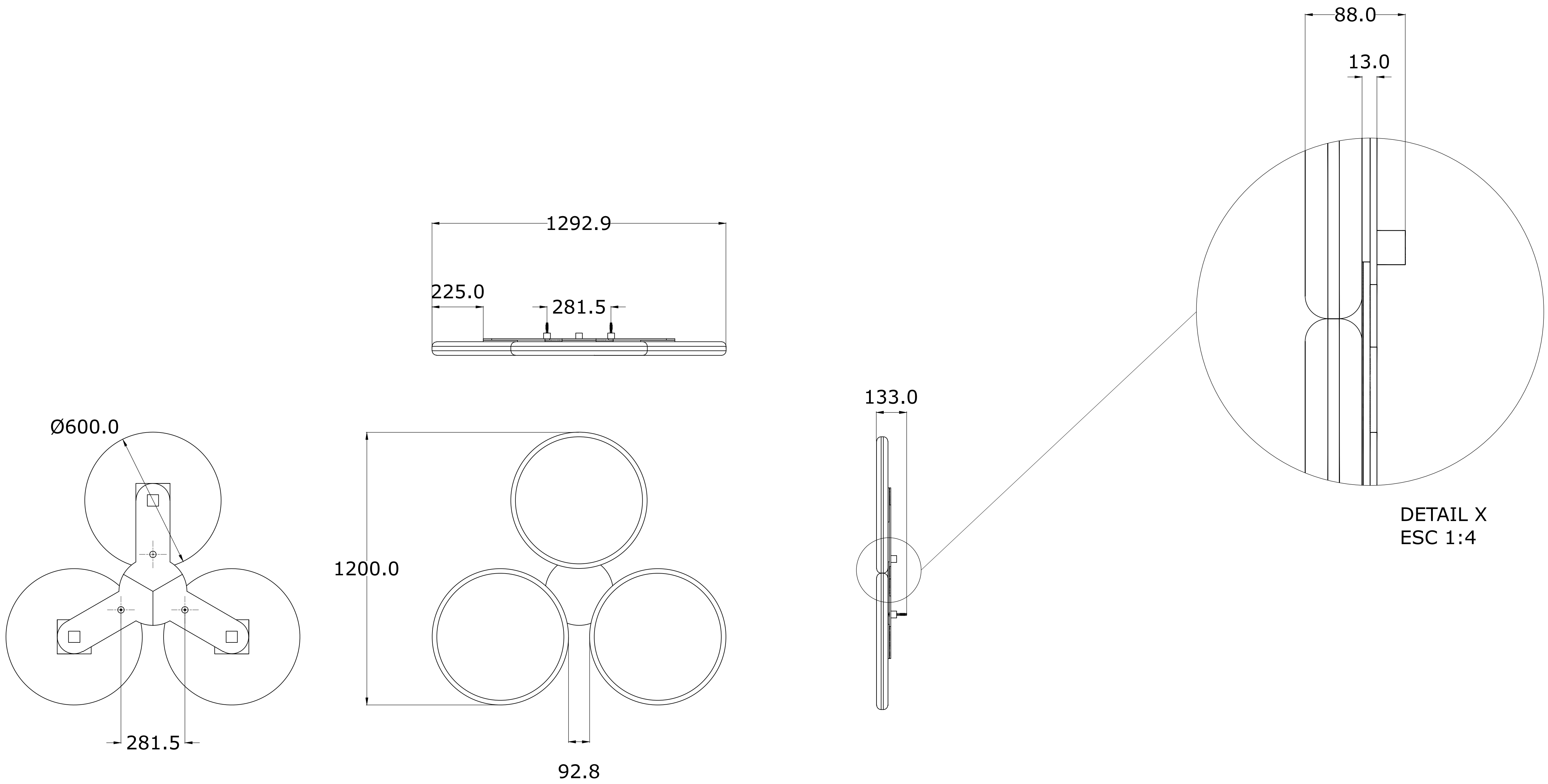




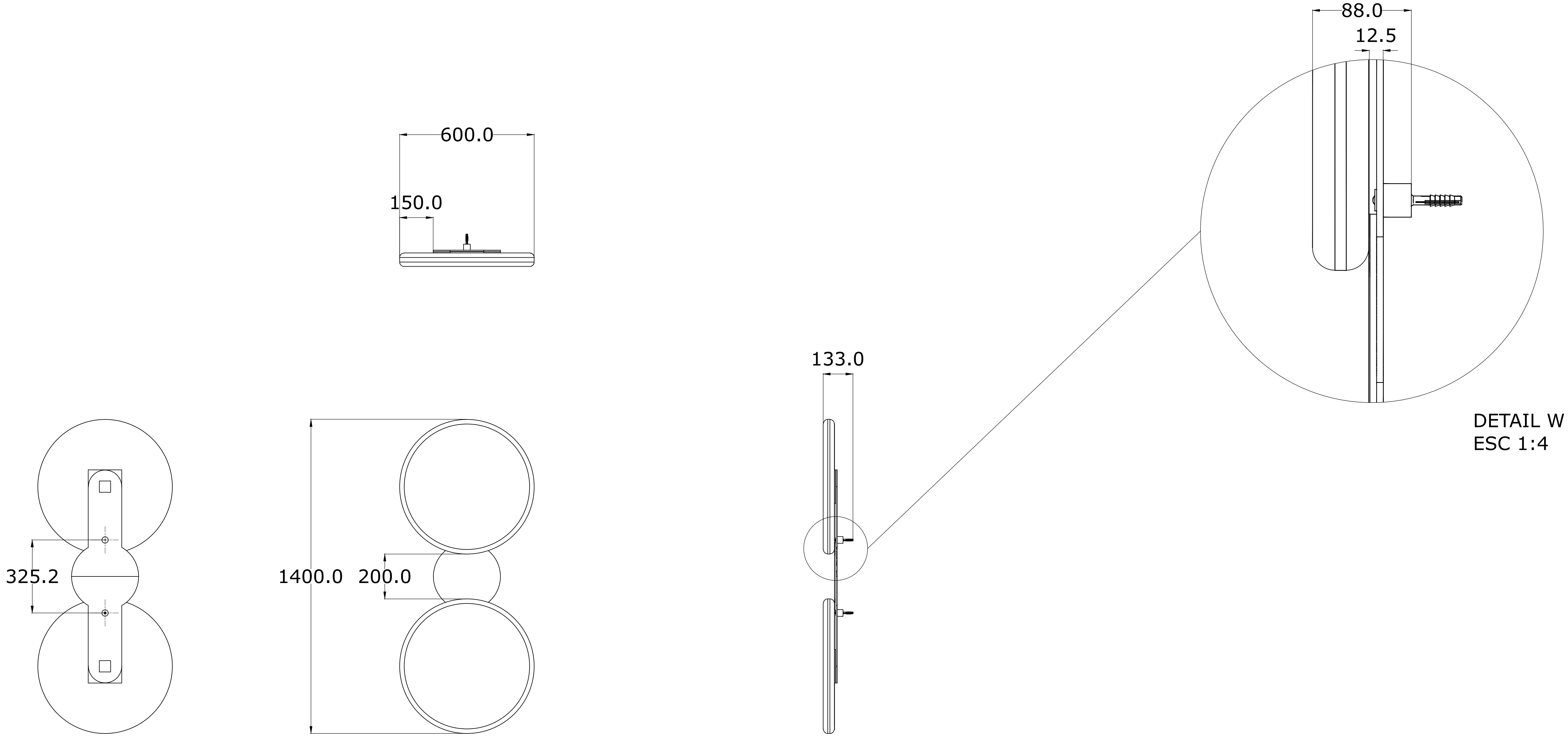
GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES PANEL A		Cotas: mm	1/16



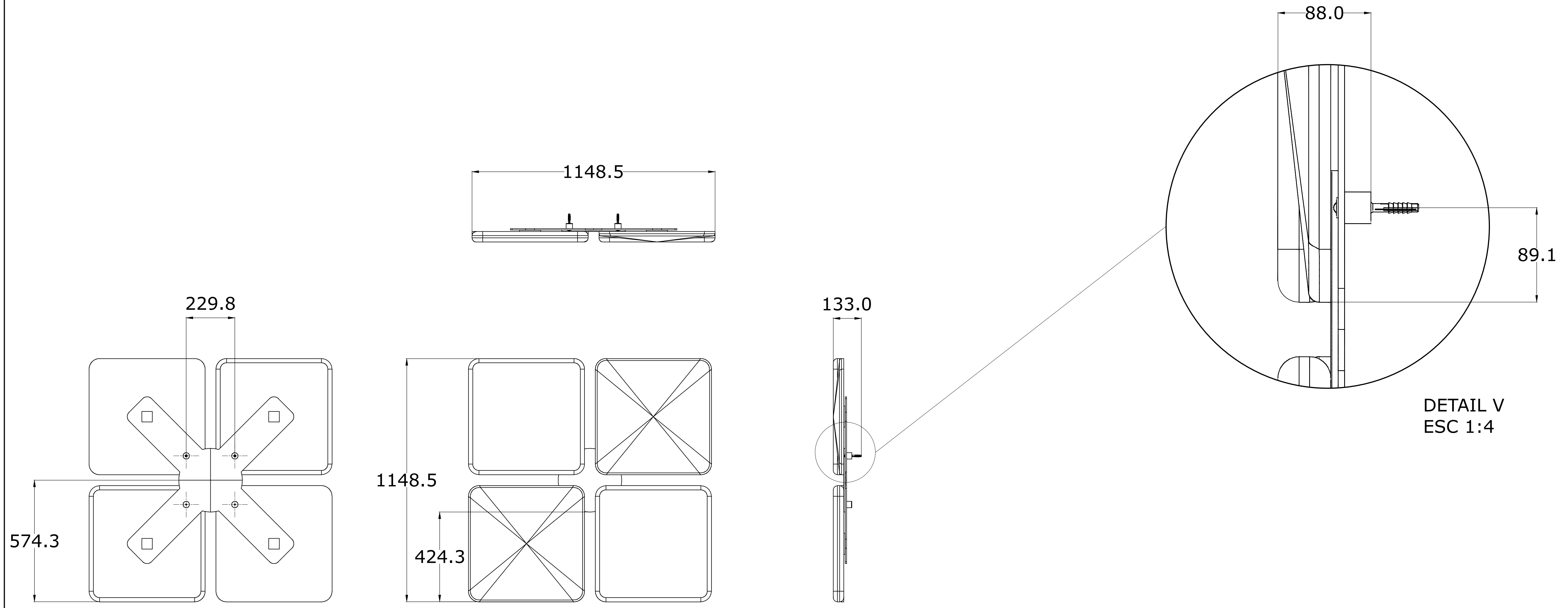
GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES PANEL A1		Cotas: mm	2/16



GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES PANEL B		Cotas: mm	3/16



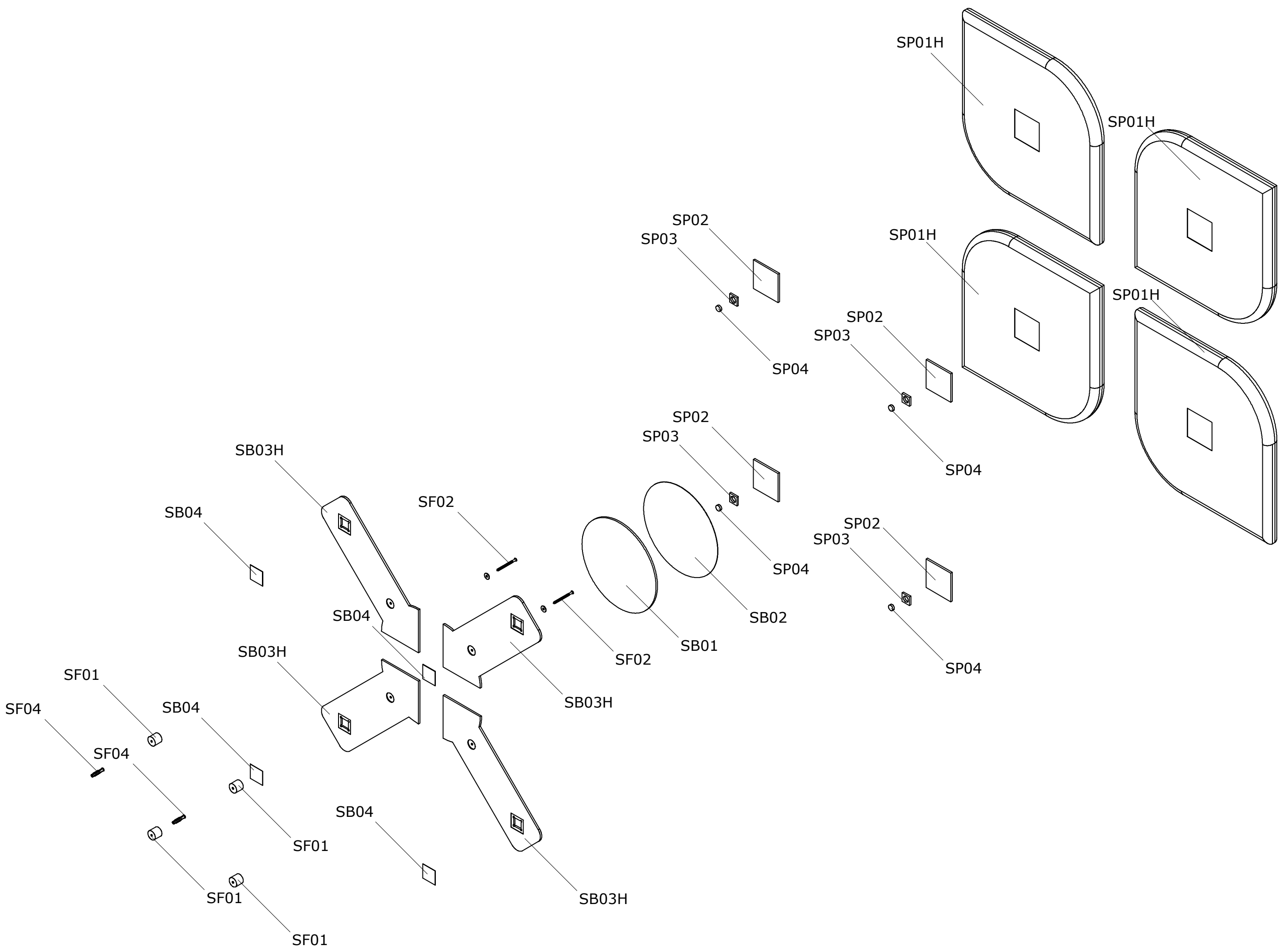
GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES PANEL C		Cotas: mm	4/16



GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES PANEL D		Cotas: mm	5/16

1 2 3 4 5 6

A B C D

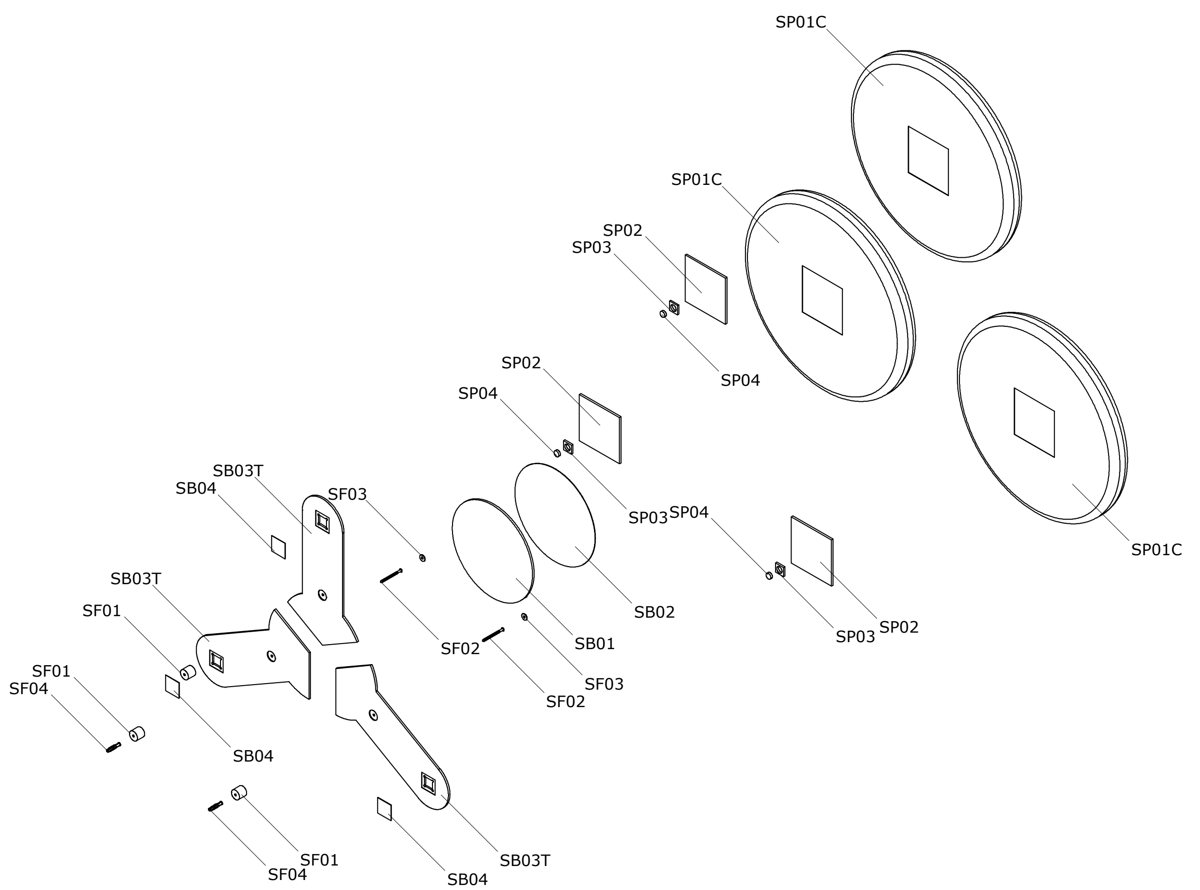


Clave	Cant.	Nombre	Material	Proceso
SF04	2	Anclaje plástico	Polietileno	Pieza comercial
SF03	2	Rondana $\frac{1}{4}$"int ,$\frac{3}{4}$"ext	Acero galvanizado	Pieza comercial
SF02	2	Pija $\frac{1}{4}$" 75mm	Acero galvanizado	Pieza comercial
SF01	4	Separador	Hule (Goma)	Pieza comercial
SB04	4	Lámina metálica	Lámina de acero calibre 20	Corte Láser
SB03H	4	Brazo Base-Hoja	MDF 6 mm	Corte y fresado con Roúter CNC
SB02	1	Chapa círculo central	Chapa roble	Cortado y pegado manual
SB01	1	Círculo central	MDF 6mm	Corte con Roúter CNC
SP04	4	Imán	Neodinio	Pieza comercial
SP03	4	Base Imán	MDF 6mm	Corte con Roúter CNC
SP02	4	Base Panel	MDF 6mm	Corte con Roúter CNC
SP01H	4	Panel acústico-Hoja	Poliéster reciclado	Corte y moldeo con calor

GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
DESPIECE PANEL A		Cotas: mm	6/16

1 2 3 4 5 6

A B C D

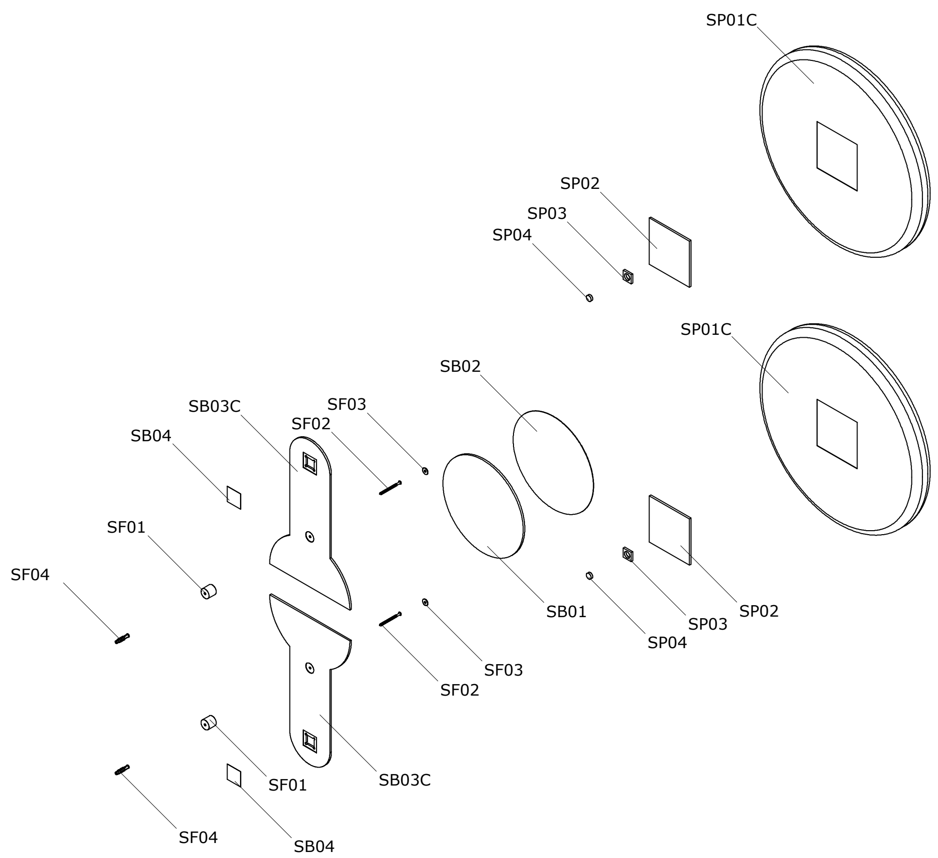


Clave	Cant.	Nombre	Material	Proceso
SF04	2	Anclaje plástico	Polietileno	Pieza comercial
SF03	2	Rondana $\frac{1}{4}$"int ,$\frac{3}{4}$"ext	Acero galvanizado	Pieza comercial
SF02	2	Pija $\frac{1}{4}$ " 75mm	Acero galvanizado	Pieza comercial
SF01	3	Separador	Hule (Goma)	Pieza comercial
SB04	3	Lámina metálica	Lámina de acero calibre 20	Corte Láser
SB03T	3	Brazo Base-Trébol	MDF 6 mm	Corte y fresado con Roúter CNC
SB02	1	Chapa círculo central	Chapa roble	Cortado y pegado manual
SB01	1	Círculo central	MDF 6mm	Corte con Roúter CNC
SP04	3	Imán	Neodinio	Pieza comercial
SP03	3	Base Imán	MDF 6mm	Corte con Roúter CNC
SP02	3	Base Panel	MDF 6mm	Corte con Roúter CNC
SP01C	3	Panel acústico-Círculo	Poliéster reciclado	Corte y moldeo con calor

GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
DESPIECE PANEL B		Cotas: mm	7/16

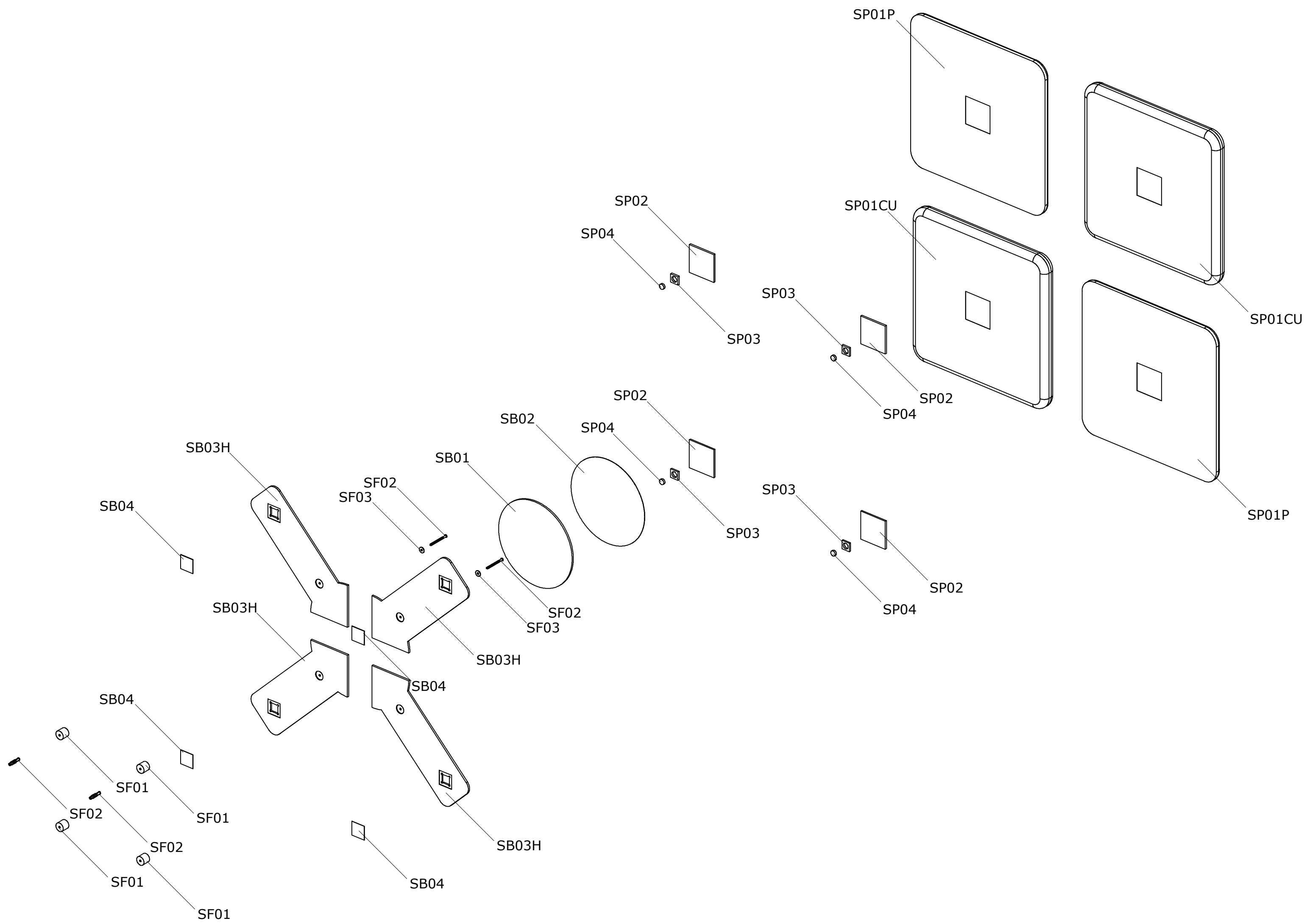
1 2 3 4 5 6

A B C D



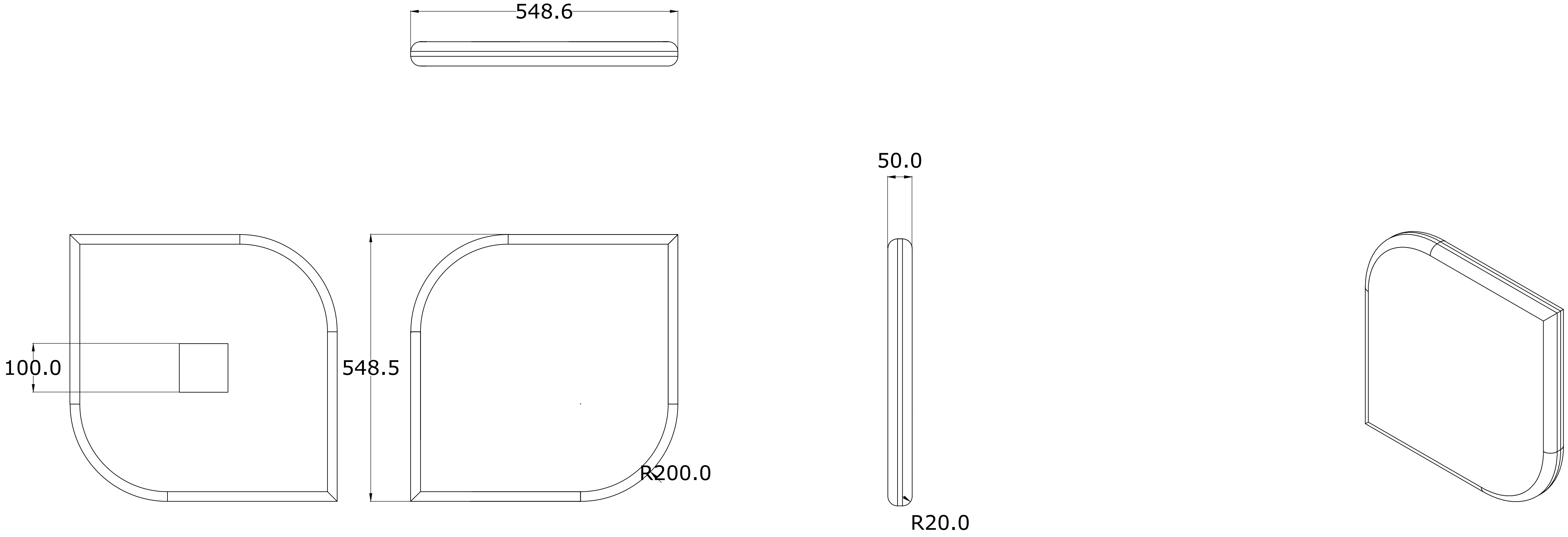
Clave	Cant.	Nombre	Material	Proceso
SF04	2	Anclaje plástico	Polietileno	Pieza comercial
SF03	2	Rondana $\frac{1}{4}$"int ,$\frac{3}{4}$"ext	Acero galvanizado	Pieza comercial
SF02	2	Pija $\frac{1}{4}$ " 75mm	Acero galvanizado	Pieza comercial
SF01	2	Separador	Hule (Goma)	Pieza comercial
SB04	2	Lámina metálica	Lámina de acero calibre 20	Corte Láser
SB03C	2	Brazo Base-Círculo	MDF 6 mm	Corte y fresado con Roúter CNC
SB02	1	Chapa círculo central	Chapa roble	Cortado y pegado manual
SB01	1	Círculo central	MDF 6mm	Corte con Roúter CNC
SP04	2	Imán	Neodinio	Pieza comercial
SP03	2	Base Imán	MDF 6mm	Corte con Roúter CNC
SP02	2	Base Panel	MDF 6mm	Corte con Roúter CNC
SP01C	2	Panel acústico-Círculo	Poliéster reciclado	Corte y moldeo con calor

GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
DESPIECE PANEL C		Cotas: mm	8/16



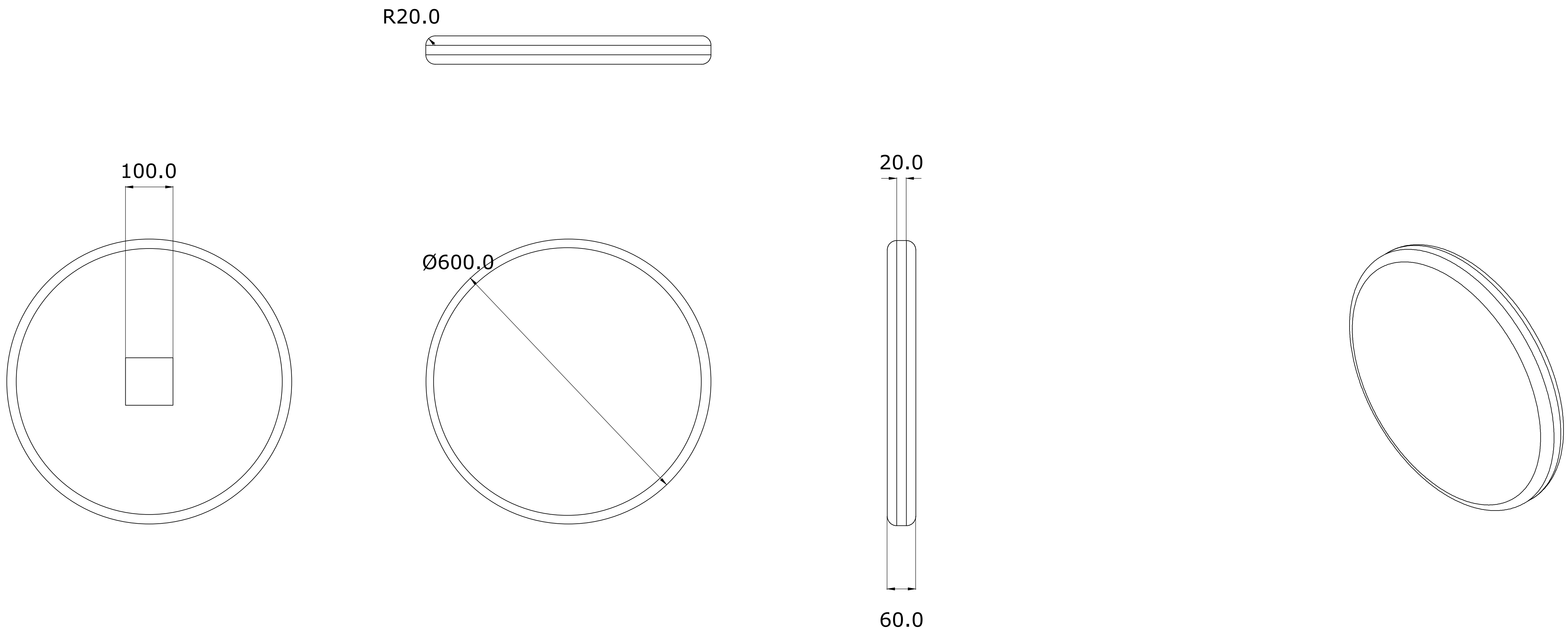
Clave	Cant.	Nombre	Material	Proceso
SF04	2	Anclaje plástico	Polietileno	Pieza comercial
SF03	2	Rondana $\frac{1}{4}$"int ,$\frac{3}{4}$"ext	Acero galvanizado	Pieza comercial
SF02	2	Pija $\frac{1}{4}$ " 75mm	Acero galvanizado	Pieza comercial
SF01	2	Separador	Hule (Goma)	Pieza comercial
SB04	2	Lámina metálica	Lámina de acero calibre 20	Corte Láser
SB03H	2	Brazo Base-Hoja	MDF 6 mm	Corte y fresado con Roúter CNC
SB02	1	Chapa círculo central	Chapa roble	Cortado y pegado manual
SB01	1	Círculo central	MDF 6mm	Corte con Roúter CNC
SP04	2	Imán	Neodinio	Pieza comercial
SP03	2	Base Imán	MDF 6mm	Corte con Roúter CNC
SP02	2	Base Panel	MDF 6mm	Corte con Roúter CNC
SP01P	2	Panel acústico-Pirámide	Poliéster reciclado	Corte y moldeo con calor
SP01CU	2	Panel acústico-Cuadrado	Poliéster reciclado	Corte y moldeo con calor

GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
DESPIECE PANEL D		Cotas: mm	9/16



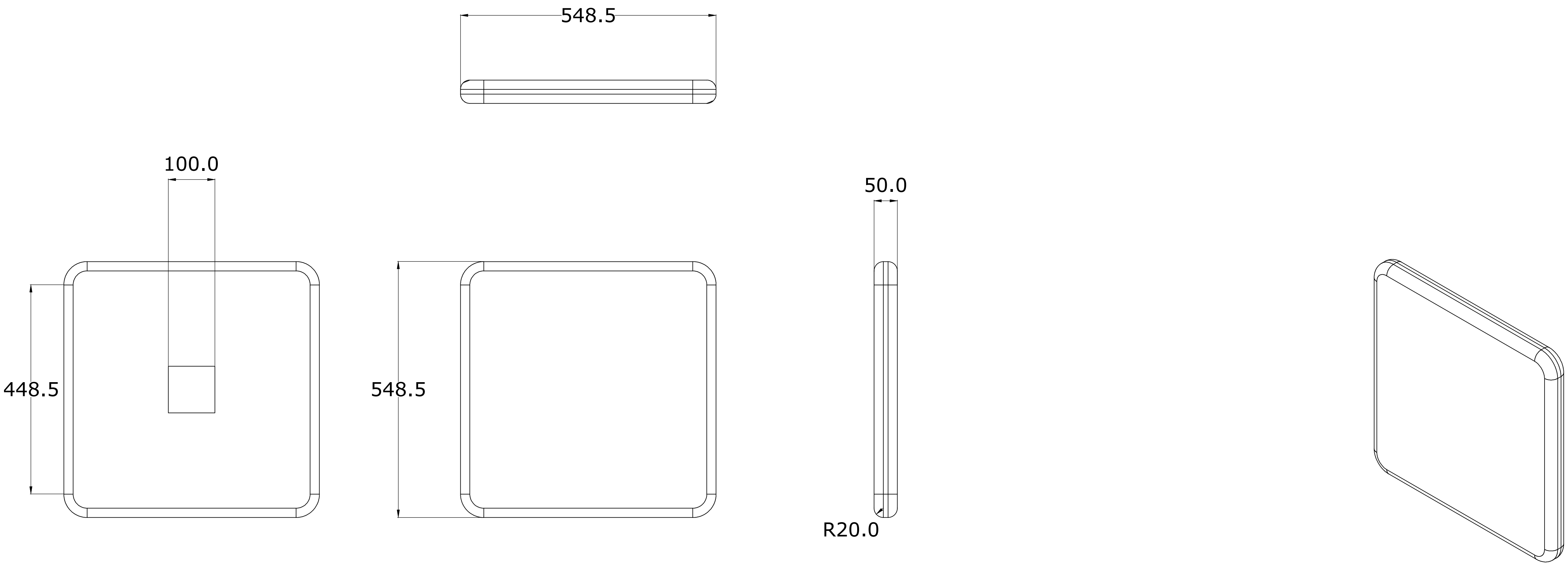
SP01H	4	Panel acústico-Hoja	Poliéster reciclado	Corte y moldeo con calor
Clave	Cant.	Nombre	Material	Proceso

GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES PANEL HOJA		Cotas: mm	10/16



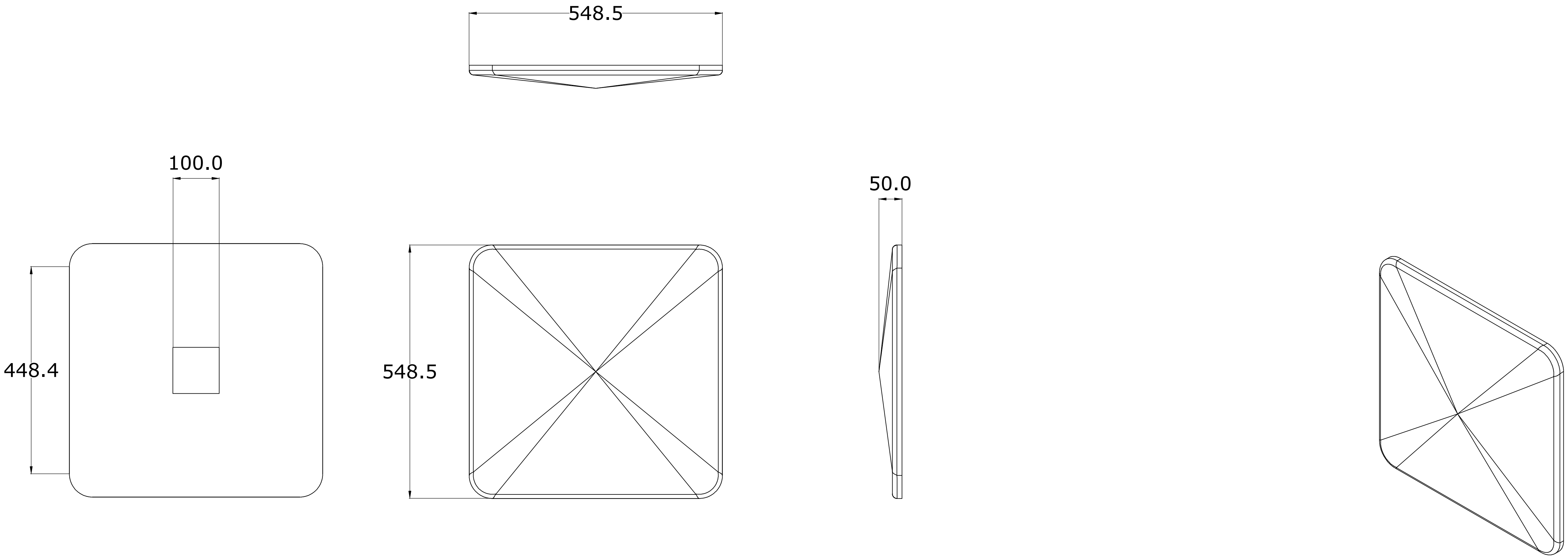
SP01C	4	Panel acústico-Círculo	Poliéster reciclado	Corte y moldeo con calor
Clave	Cant.	Nombre	Material	Proceso

GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES PANEL CÍRCULO		Cotas: mm	11/16



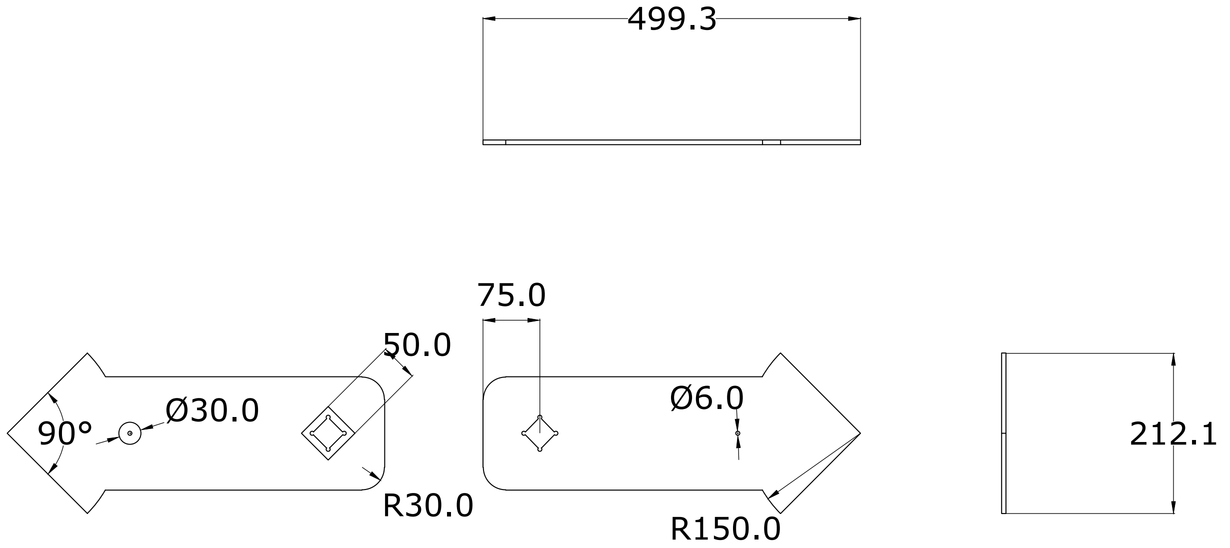
SP01CU	4	Panel acústico-Cuadrado	Poliéster reciclado	Corte y moldeo con calor
Clave	Cant.	Nombre	Material	Proceso

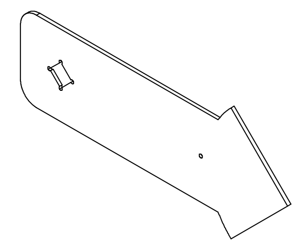
GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES PANEL CUADRADO		Cotas: mm	12/16



SP01P	4	Panel acústico-Pirámide	Poliéster reciclado	Corte y moldeo con calor
Clave	Cant.	Nombre	Material	Proceso

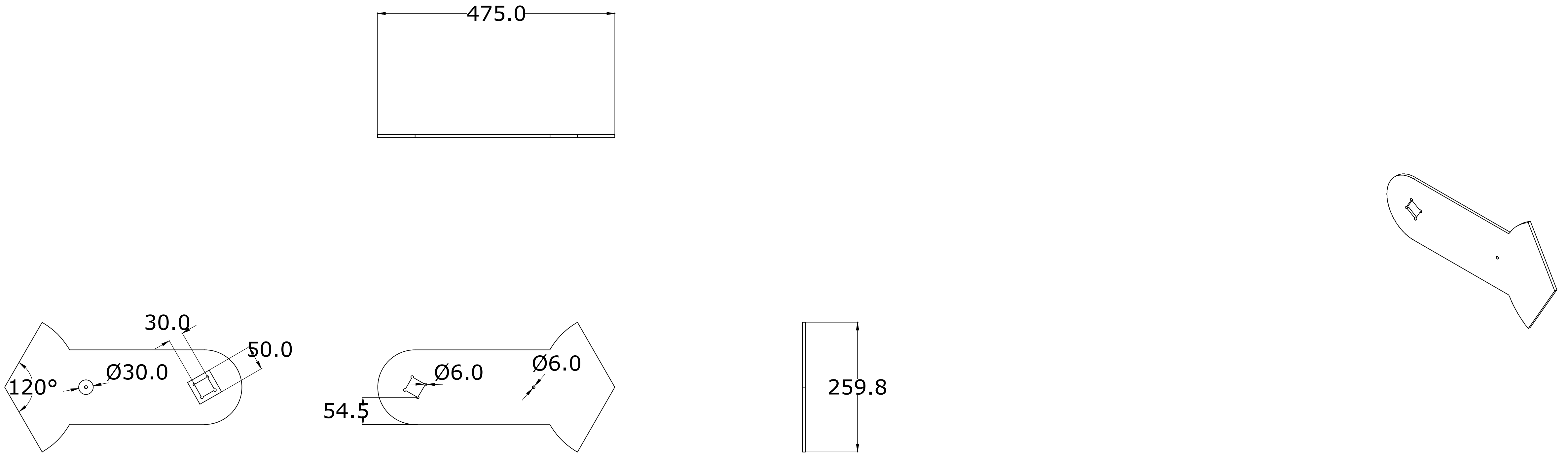
GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES PANEL PIRÁMIDE		Cotas: mm	13/16





SB03H	4	Brazo Base-Hoja	MDF 6 mm	Corte CNC
Clave	Cant.	Nombre	Material	Proceso

GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES BRAZO BASE-HOJA		Cotas: mm	14/16

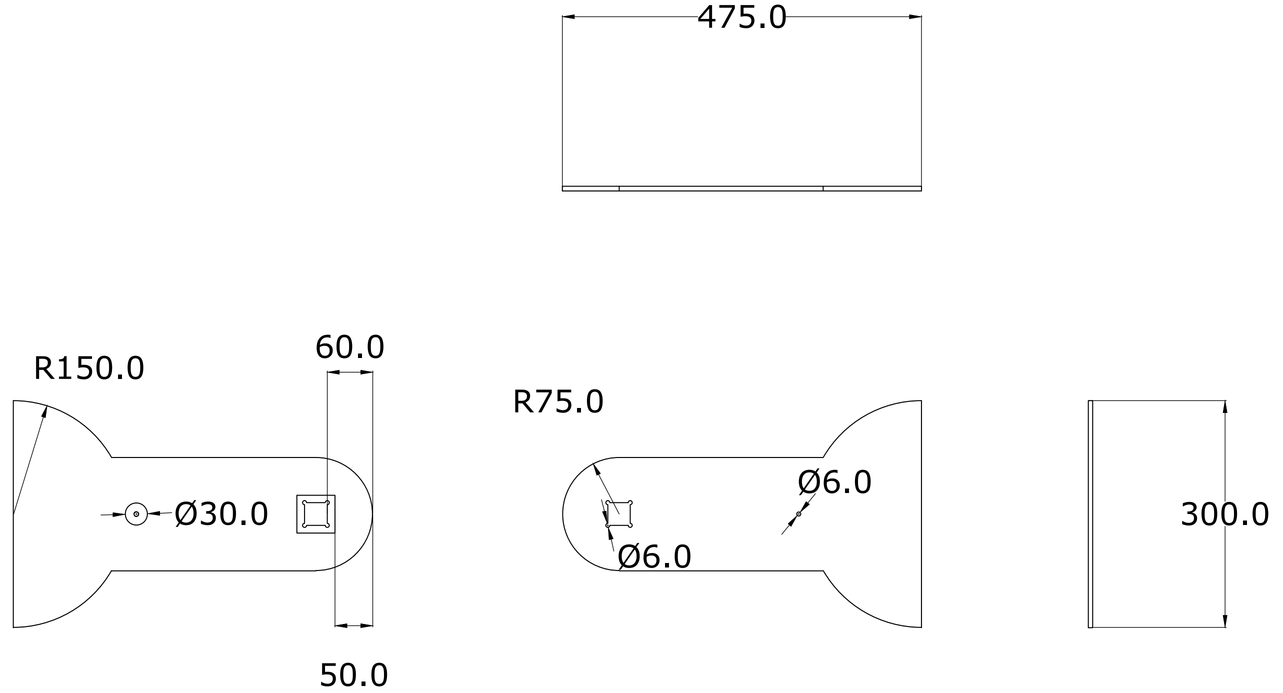


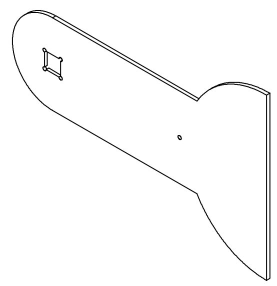
SB03T	3	Brazo Base-Trébol	MDF 6 mm	Corte CNC
Clave	Cant.	Nombre	Material	Proceso

GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES BRAZO BASE-TRÉBOL		Cotas: mm	15/16

1 2 3 4 5 6

A B C D





SB03C	2	Brazo Base-Círculo	MDF 6 mm	Corte CNC
Clave	Cant.	Nombre	Material	Proceso

GABRIEL JUAREZ	CIDI-UNAM	Fecha: 05/02/20	esc: 1:20
PANELES ACUSTICOS KINNARPS		A3	
VISTAS GENERALES BRAZO BASE-CÍRCULO		Cotas: mm	16/16