Chapter 16
Integrated Approach for Sustainable Flooring Product Development

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Abstract This chapter is to illustrate the integrated approach for sustainable product development with a case study of a raised access flooring product which consists of a floor panel made of sheet moulding compound material, a support stringer and pedestals. The product development process presented in this chapter focuses on the sustainable production process, including elaboration of product design specification, conceptual design, detail design, prototyping and testing, and manufacture. The other phases of the product life cycle, such as product in service, and the end-of-life product treatment are also considered in the product life cycle assessment. Various sustainable methods, such as life cycle analysis and eco-manufacture, and tools, such as life cycle impact assessment and finite element analysis, are integrated in the production process.

Keywords Life cycle assessment · Raised access floor product · Sustainable design · Product design · Finite element analysis

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16.1 The Integrated Approach

The integrated approach for sustainable product development is presented in Chap. 1. This chapter is to illustrate the approach with a raised access flooring product (for introduction of this type of product, please see Chap. 14).

As shown in Fig. 16.1, this case study focus on the total production, which includes the elaboration of product design specification, conceptual design, detail design, prototyping and testing, and manufacture. The other phases of the product life cycle, such as product in service, and the end-of-life product treatment (recycle, reuse, and disposal) will be considered in the life cycle assessment.

As stated in Chap. 1, where the detailed description of the integrated approach is given, the tools and methods to be integrated into the product development process are not expected to be all the same in different applications, but could be various subject to the nature of particular applications. This case study utilises the methods and tools related to sustainable production.

Sustainable Production Methods The methods include LCIA methods which are detailed in Chap. 3, three-tier methods which is detailed in Chap. 1, as well as common methods such as finite element analysis and modular design. In particular, they include

- Elaboration of product design specifications (PDS) with sustainability constraints, such as reduction of product carbon footprints, energy/material consumption, waste, and contribution to climate change.

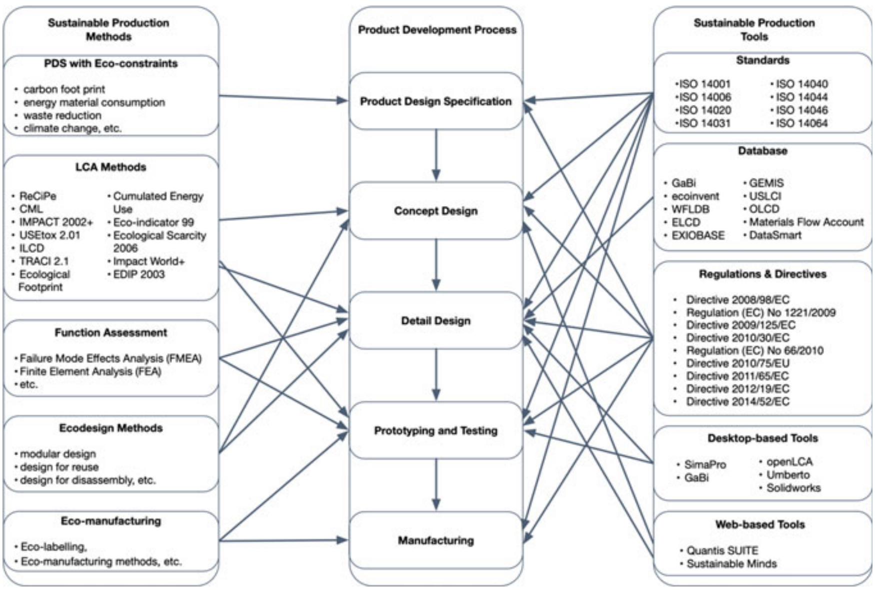

Fig. 16.1 Framework of the integrated approach for sustainable product development

- Product lifecycle impact assessment methods, such as ReCiPe, CML.
- Product failure analyses, such as failure mode and effect analysis (FMEA), and finite element analysis (FEA).
- Ecodesign methods, such as modular design, design for re-use, design for recycling.
- Eco-manufacturing, eco-labelling.

Sustainable Production Tools The tools involved include regulations, directives and standards which are detailed in Chap. 2; databases which are detailed in Chap. 3; LCIA tools, including desk top software packages and Web-based tools, which are detailed in Chap. 4, as well as other existing common tools. In particular, the tools include:

- Standards are requirements related to the production activities and quality of products characteristics.
- Regulations and directives are regulatory rules related to ecodesign, recycling of wastes, pollutant emissions and reporting at voluntary and legislative level.
- Databases are data sources to support LCA and environmental performance reporting.
- Software tools (desktop based) are used to select sustainable materials and conduct comprehensive LCA.
- Software tools (web based) are used to conduct screening level sustainable design, environmental materials selection, and simple LCA.

16.2 Elaboration of Product Design Specifications

The sustainable flooring system is manufactured with Sheet Moulding Compound (SMC) and metal, and this case study introduces the process of developing this product system with the proposed integration framework and state-of-the-art tools.

The following sustainable constraints are elaborated during the PDS phase:

- The product needs to use the least number of components possible, whilst maintaining the required quality.
- Extending the product lifespan. The product should be durable and components should have easy access for installation and repair.
- Application of eco-design methods, such as modular design, design for easy repair and upgrade, design for disassembly, design for reuse.
- Designing the product system that facilitates components' recovery for reuse, re-manufacture and recycle.
- Using the minimum type of materials, which facilitates the sorting of components for reuse and recycling when the product reaches its end of service life.
- Using low environmental impact materials and manufacturing processes.
- Avoiding the use of special tools for disassembly, non-detachable joints (welded or glued joints), and toxic materials.

- The weight of a floor panel should not be more than 11 kg, in order to reduce the total load for transportation and, hence, reduce the energy consumption in transportation, as well as to reduce the load on the building.

The above PDS are derived from relevant directives, regulations and standards related to sustainable production in the EU. For example, the Environmental Impact Assessment Directive demands the companies to implement environmental impact assessment towards product life cycle, and to report the pollutant emissions related to manufacturing (European Commission 2014). Derived from this directive, the 'Use low environmental impact materials and manufacturing processes' is listed in the PDS.

16.3 Conceptual Design

In the conceptual design phase, the product concept was developed as shown in Fig. 16.1, in compliance with the sustainable PDS and regulations, directives, and standards that are directly linked with the flooring product quality and regulatory requirements, which are presented in Table 16.1.

Software SolidWorks is adopted to design the raised access floor system as it offers both the modelling function and the screening-level life cycle assessment. In addition, the BS EN 12825 requires the strength test (BSI 2001), once the modelling of the raised access floor system is completed, FEA can be conducted in the SolidWorks to examine the system's strength performance.

SMC materials are selected for the floor panels in this project, because of its strong performance in mechanical properties, fire resistance, and stiffness. Its physical properties are presented in Table 16.2.

The modelling of the raised access floor system involves the design of a floor panel, a pedestal, and a pedestal cover, which are shown in Fig. 16.2. The dimensions of the pedestal unit and the floor panel are introduced in Table 16.2, which meet the criteria of the British Standard 12825 and PSA raised access floors performance specification. The pedestal design prevents excessive movement of the panel, by which the stability of the raised access floor system is strengthened.

The standard size for raised access floor panels is adopted to design the floor panel in this project, and its dimensions are also presented in Table 16.2. The weight of the floor panel is 25.92 kg, which is obtained by calculating the design dimensions and SMC density. This violates the weight constraint ($\leq$ 11 kg) defined in the PDS, and action has to be taken to reduce the weight to meet the constrain.

CML and TRACI are methodologies offered by the LCA package of SolidWorks (for further information, see Chap. 4). The CML method is adopted in this phase, and the screening-level results show that the materials contribute major negative impacts in the four environmental impact categories: 84% in Carbon Footprint, 91% in Total

Table 16.1 The sustainable PDS, regulations, directives, and standards for the sustainable flooring product

Compliance with the sustainable PDS	
PDS	*Design features*
• Use fewer components and low environmental impact materials • Using the minimum type of materials • Facilitating components' recovery for re-use, re-manufacture and recycle	The floor system consists of one panel, one stringer and four pedestals, which are the minimum number of components for the system. The glass fibre filled polymer is used to produce the floor panel, because it not only has high performance in strength, cost and fire resistance properties, be also can be recycled to make cement. The material of the pedestal unit and stringer is steel, and it can be re-used or recycled
Increase product lifespan	Several strategies have been implemented to increase the flooring product lifespan: (1) increase the reliability of the product, (2) design the product for easy disassembly, (3) long warranty, (4) design a scheme to encourage the recycling of components
Easy to install the product	The flooring product system consists of a pedestal and a pedestal cover. The cover is placed on the top of the pedestal circular plate, which supports the accurate installation for the floor panel
Using the minimum type of materials	Only two types of materials used: SMC enforced with glass fibre for the floor pane and steel for stringer and pedestal
Avoiding the use of special tools for disassembly, non-detachable joints, and toxic materials.	The flooring system can be installed and disassembled using simple standard tools such as spanners. No toxic materials are used
Compliance with the sustainable regulations, directives, standards	
Regulations, directives, and standards	*Compliance*
EU waste framework directive	Information is provided to the user about the routs to recycle the product when it reaches the end-of-life stage
EU industrial emissions directive and environmental impact assessment directive	The manufacturer is to assess and report environmental performance related to manufacturing process and product life cycle. For this purpose, the detailed LCA is conducted at the end of the design
BS 476-Part 6 and 7—fire tests on building materials and structures	BS 476 Part 6 requires the floor panel to achieve Class O on fire propagation performance (BSI 1989), and BS 476 Part 7 requires the floor panel to achieve Class 1 on performance of resisting surface spread of flame (BSI 1997). Hence, the panel material selected must meet this fire resistance requirement
BS EN 12825—raised access floors	It states that the floor system must pass the work load test by measuring the deflection/deformation values, and the limited value is rated as Class A (2.5 mm), Class B (3.0 mm), Class C (4.0 mm) (BSI 2001). Hence the design of the floor system has to meet the requirement

Table 16.2 Dimensions in conceptual design and the SMC physical properties

Items	Values
Component dimensions in conceptual design	
Height of pedestal	100 mm
Square base plate	100 mm × 100 mm
Diameter of circular plate at the top	90 mm
Size of the floor panel	600 mm × 600 mm × 40 mm
Weight of the floor panel	25.92 kg
Physical properties of SMC	
Density of the selected SMC	1800 kg/m^3
Flexural modules	1.3 GPa
Poisson’s ratio	0.3
Yield strength	250 MPa
Tensile strength	150 MPa

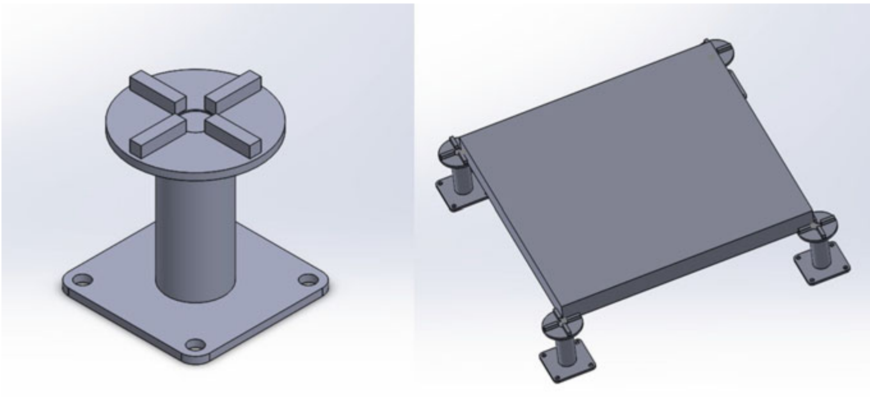

Fig. 16.2 Conceptual design for the pedestal unit and the raised access floor system

Energy Consumed, 73% in Air Acidification, and 66% in Water Eutrophication. The pie charts of the LCA analysis results are shown in Fig. 16.3. However, the results only show the total negative impacts in the limited environmental impact categories, and the breakdowns of each impacts are not described, therefore user cannot identify the specific elements of the composites, or production processes causing high negative impacts. Consequently, the targets for design optimization and manufacturing improvement are not clearly shown.

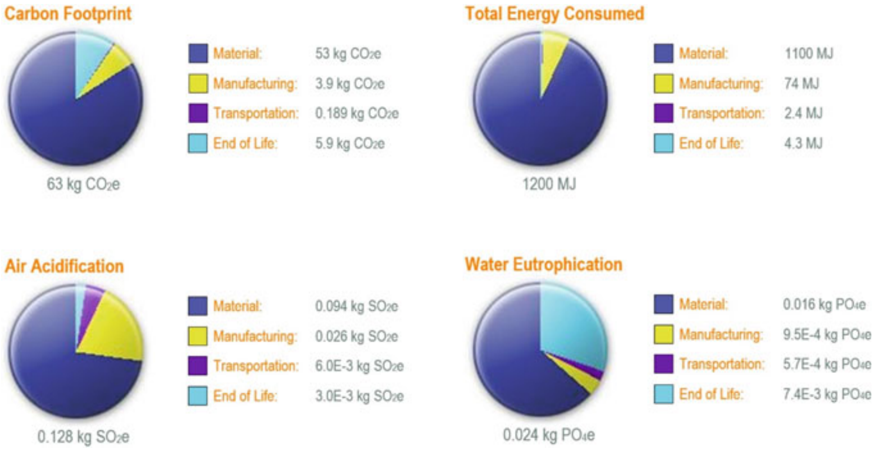

Fig. 16.3 The LCA results by adopting CML methodology in SolidWorks 2015

16.4 Detail Design

A key objective in the detail design phase is to mitigate the constraints identified in the concept design phase. Therefore, reducing the weight of the floor panel is the prioritized task in this phrase. In addition, multiple advanced tools are utilized to perform detail design for the prototype and carry out a delicate LCA.

16.4.1 Refinement of the Raised Access Floor System

In order to achieve an effective design, the floor panel requires strong outer edges with the side of the panels connected by ribs, and, hence, the strategy of designing ribs for the floor panel is adopted. The optimum design of the floor panel has same size squares with 3 mm ribs between them. The layout and dimensions of these rectangles are shown in Fig. 16.4 and Table 16.3 respectively. The thickness of the floor panel is cut from 40 mm to 30 mm in the design comprising squares' size and ribs' thickness, therefore the strength performance of the floor panel is reduced. The solution of placing a steel stringer under the floor panel is adopted, as this design not only sustains the strength performance of the floor system, but also provides the facility of recycle or reuse for the steel stringer. The stringer design is shown in Fig. 16.4, and its dimensions are shown in Table 16.3.

With this optimum design, the total weight of this raised access floor system has been reduced to 8.06 kg, which is lighter than the average weight of a raised access flooring product. Figure 16.4 shows the raised access floor system after the refinement.

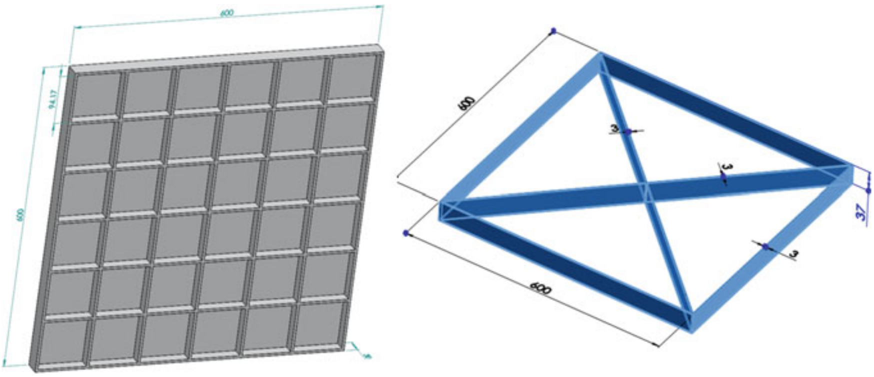

Fig. 16.4 The design of the floor panel and stringer

Table 16.3 Main components' dimensions and weight in detail design phrase

Item	Value
Component dimensions and weight in detail design	
Square	94.7 mm × 94.7 mm × 94.7 mm
Thickness of ribs	3 mm
Thickness of the floor panel	30 mm
Size of the stringer	600 mm × 600 mm × 37 mm
Thickness of the string edge and beam	3 mm
Component weight for detailed design	
Floor panel	3.52 kg
Stringer	3.55 kg
Pedestal unit	0.99 kg
Total mass	8.06 kg

16.4.2 LCA of the Raised Access Floor System

According to the regulatory requirements, environmental performances of the raised access floor system are required to report, as mentioned in Table 16.1. In addition, the materials and manufacturing processes with high negative impacts through the product life cycle should be identified, with the aim to configure the optimization strategies for design iterations and production processes.

The environmental impact assessment of the raised access floor system is implemented by using the SimaPro with the ecoinvent database. ReCiPe methodology are adopted to conduct LCIA under the Cradle-to-Grave scenario towards the raised access floor system in this research (for further information, see Chap. 4 for SimaPro and Chap. 3 for ReCiPe and ecoinvent).

Table 16.4 Percentages of recyclable materials in the waste scenario of England

Material	Waste treatment	Percentages
Glass	Recycling glass/RER U	46.5
Steel	Recycling steel and iron/RER U	46.6
Plastics	Recycling mixed plastics/RER U	2.7
Wood	Recycling/recovery in the England	42.3
PVC	Recycling PVC/RER U	2.7

16.4.2.1 Life Cycle Modelling

Considering the available data and objectives of this research, the examined life cycle processes of the raised access floor system include: Materials, Production, Distribution and End of Life, which are described as follows:

Materials: The main ingredients of SMC are glass fibre and polymers. The pedestal unit and stringer are manufactured with normal steel. The floor panel is packaged with wood pallets and PVC films.

Production: The examined processes of producing SMC include: heating of resin, and moulding which follows the information of the SMC product specification (Menzolit 2016). The examined processes of producing the floor panel include: heating, cutting ribs and edges. The examined processes of producing the pedestal unit and stringer include: extrusion of steel and steel turning.

Distribution: The examined distribution scenarios are from manufacturing site to retailers or construction sites in England, and this distance is an average of 200 km (suggested by the floor panel prototype manufacturer). The neglected distribution scenarios are the delivery of SMC ingredients from suppliers to manufacturers, and the delivery of packaging materials from suppliers to flooring product manufactures.

End of Life: This study refers for the waste treatment and management figures in England that are provided by the UK DEFRA (DEFRA 2015), and these statistics are compiled to comply with EC Waste Framework Directive (2008/98/EC). In this study, the waste treatment involves glass, steel, plastics, wood and PVC, and the percentages of recyclable materials are presented in Table 16.4. This means that the environmental impact evaluation of this scenario adopts the recycling percentages of each type of materials that are used in the product system. Hence, based on the descriptions presented above, the core activities and boundaries involved with the raised access floor system life cycle are mapped in Fig. 16.5.

16.4.2.2 Life Cycle Inventory Building

SMC ingredients' masses are obtained according to the material percentage revealed in the SMC production specification. The values of delivery distance, packaging weight, and machine energy consumption are provided by the manufacturer. Missing data is supplied by the ecoinvent 3.2 database, for example, LCI of pedestal unit, emissions of lorry transportation, electricity voltage for production in the England.

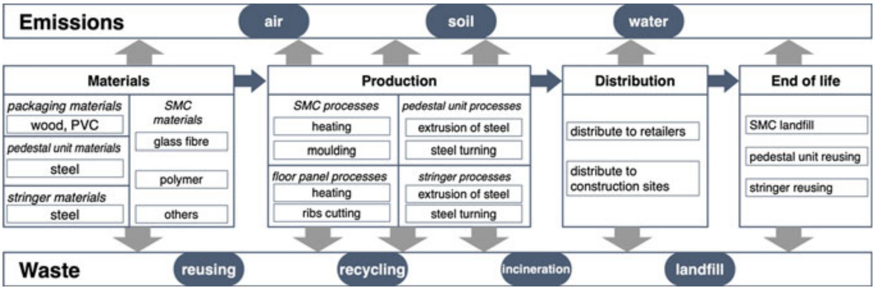

Fig. 16.5 Life cycle modelling of the raised access floor system

Table 16.5 LCI values of the raised access floor system

Materials/processes	Values	Units
Glass fibre	1.87	kg
Polymer	4.35	kg
Stringer	3.55	kg
Pedestal unit (steel)	0.993	kg
Packaging (wood pallet)	0.2	piece
Packaging (film)	0.47	kg
Transport distance	200	km
Transport weight	10	kg
Heating	2.1	kWh
Cutting	0.3	kg

The functional unit adopted in this study is one piece of raised access floor system, and the values of the inventories are presented in Table 16.5.

16.4.2.3 Life Cycle Impact Assessment

The network of analytical results is shown in Fig. 16.6, where a 2.4% cut-off is applied, i.e., any impacts with percentage <2.4% is not shown in the network diagram. Figure 16.7 only shows the partial network diagram to highlight the key flows of materials and processes, as the original completed diagram is too large for this paper layout. Each box in the network shows the name, weight, and percentage of the process/material in the whole life cycle, and all the numerical information is indicated by the thermometer within the box.

As Fig. 16.7 shows, within the total impacts, the major negative impacts are generated by the Materials (56.13%), and the Production (24.53%), Packaging (18.4%), and End of Life (3.52%) share 46.45% impacts in total. The distribution impacts are only shown (0.33%) with at least a 1.3% cut-off criteria.

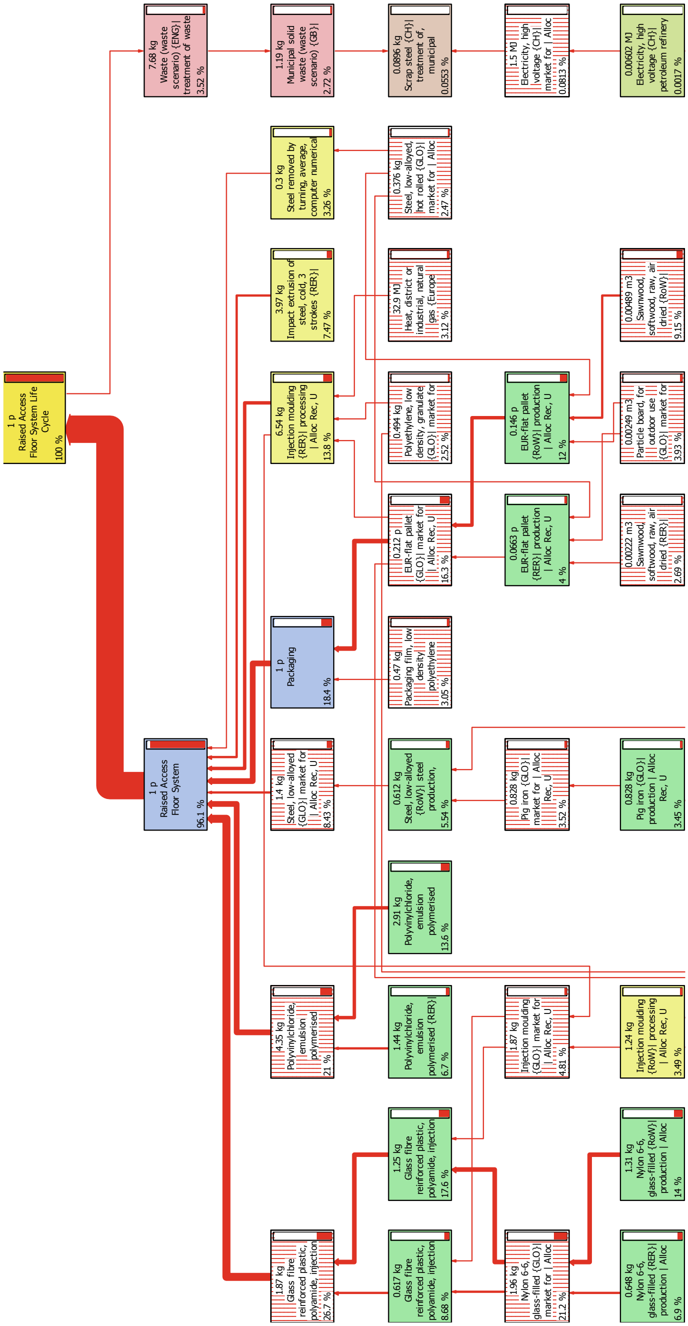

Fig. 16.6 Network diagram of the LCIA results with a 2.4% cut-off criteria

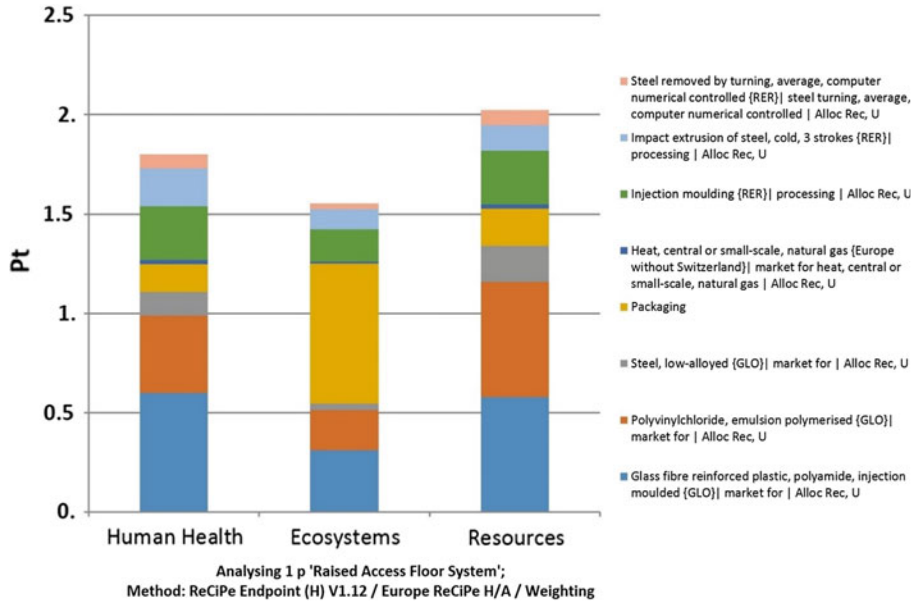

Fig. 16.7 Weighting results in ReCiPe endpoint impacts for the raised access floor system

Within the Materials, glass fibre, polyvinylchloride, and steel contribute 26.7%, 21%, and 8.43% impacts respectively. It means the two components, the floor panel and pedestal unit, are allocated 47.7 and 8.43% impacts. Furthermore, among the materials producing the floor panel, the main impacts are caused by Nylon 6-6 (21.2%), which is also the main ingredient for producing the glass fibre.

Focusing on the Production, the SMC moulding (13.8%) and steel extrusion (7.47%) and turning (3.26%) have the highest environmental impacts. Within impacts caused by the packaging, the wood pallet and PVC film share 16.3% and 3.05% respectively. As the wood pallet is reusable, the negative impacts related to it are linked to its production stage (16%).

In terms of the End of Life for the raised access floor system, the environmental impact (3.52%) is not remarkable compared with the impacts that occur in Materials, Production, and Packaging, which shows that the adopted materials' recyclable performance is not remarkable.

Figure 16.7 shows the weighting results of the raised access floor system in endpoint impact categories, which include Human Health, Ecosystems and Resources. It shows that Resources category (about 2.02 Pt) has the highest negative impacts, and the steel, polyvinylchloride, and glass fibre reinforced plastic cause the top 3 negative impacts, which are also the top 3 impact sources for the Human Health category (about 1.8 Pt). The Ecosystems category (about 1.5 Pt) contributes relatively small negative impacts, and the top 3 impact sources are Packaging, glass fibre reinforced plastic, and polyvinylchloride.

16.4.2.4 Interpreting the Analysis Results

As the End of Life and Distribution share relatively small negative impacts (3.85%, 0.2155 Pt) in the life cycle of the raised access floor system, the target of design improvement should be placed at the Materials (56.13%, 3.13 Pt). The following strategies are proposed to achieve this objective through exploring the findings of the LCIA:

Table 16.6 shows the mass of negative impacts caused by the main flows within the three environmental impact categories, which could be used as benchmarking values in the next iterations of design. For example, in the case of investigating alternative main materials, the total mass (5.3787 Pt) of negative impacts can be used as the key benchmarking value to examine the potential material's environmental performance.

The Materials has the most negative impacts, and the Distribution stage has the smallest negative impacts, which is consistent with the analytical results offered by SolidWorks 2015 in the conceptual design phase. It shows the design improvement strategy on reducing the mass of materials is correct, and in order to achieve further design improvement, the design on the ribs and rectangles of floor panel could be elaborated, for example, reducing the thickness of ribs, or increasing the depth of each rectangles.

Glass fibre reinforced plastics have the most negative impacts among all the materials, therefore the alternative improvement strategy is to select the SMC composites

Table 16.6 Mass of main flows with high environmental impacts, expressing benchmarking values for optimum design and production

Flows	Unit	Human Health	Ecosystems	Resources	Total
Glass fibre reinforced plastic, polyamide, injection moulded {GLO}|market for|Alloc Rec, U	Pt	0.5997	0.3134	0.5779	1.491
Steel, low-alloyed {GLO}|market for|Alloc Rec, U	Pt	0.119	0.0337	0.1822	0.3348
Polyvinylchloride, emulsion polymerised {GLO}| market for|Alloc Rec, U	Pt	0.3909	0.2006	0.5814	1.1729
Packaging	Pt	0.1396	0.7033	0.1865	1.0294
Injection moulding {RER}| processing|Alloc Rec, U	Pt	0.2718	0.1613	0.268	0.7012
Impact extrusion of steel, cold, 3 strokes {RER}| processing|Alloc Rec, U	Pt	0.1888	0.101	0.1278	0.4177
Steel removed by turning, average, computer numerical controlled {RER}| steel turning, average, computer numerical controlled|Alloc Rec, U	Pt	0.0723	0.0302	0.0797	0.1822
Heat, central or small-scale, natural gas {Europe without Switzerland}|market for heat, central or small-scale, natural gas|Alloc Rec, U	Pt	0.0183	0.0102	0.021	0.0496
Total	Pt				5.3787

with low glass fibre and polyvinylchloride in the SMC formulation, or to reduce the percentages of Nylon 6-6 in the glass fibre formulation, which contributes the highest impacts (21.2%) as shown in Fig. 16.7.

The Injection moulding process causes the highest negative impacts among all the production processes, so an improvement strategy would be to cut the overall moulding cycle time, and improve the mould speed.

It will be necessary to evaluate the proposed design improvement strategies, in order to test whether they can be implemented without compromising the physical properties required by the PDS, regulations and standards (e.g. fire resistance, strength). For example, although the recycling performance of SMC is low, other possible alternative materials are required to meet the fire resistance requirements.

As part of the ongoing project, diverse materials with different structures have also been proposed to design the raised access floor system, for example, paper core encapsulated by composite materials, balsa chipboard encapsulated by composite materials, and foam core encapsulated by composite material. The LCA will be used to evaluate the environmental performance of all these design solutions, and the solution with the lowest environmental performance would be commercialised in the European market.

16.5 Prototyping and Testing

In this phase, the prototype of the raised access floor system was tested and analysed to confirm that the final real product could meet the PDS, and pass all the tests identified in the conceptual and detail design phases, which include fire and strength tests. The prototype of the raised access floor system is shown in Fig. 16.8. The fire safety test must be conducted under controlled conditions, and by an external fire safety test company, which is not reported in this paper.

Fig. 16.8 The prototype of the raised access floor product system (left) and the back of the floor panel (right)

16.5.1 Finite Element Analysis (FEA)

Finite Element Analysis is a well developed and widely accepted method to examine the strength performance of products or components. Therefore, FEA is utilised in this research to validate the flooring product of this project, and the FEA module of SolidWorks is used to assess the strengthen performance of the product in this phrase. The finite element methods used for examining the raised access floor system is a static and a linear system so that the linearity of relationship between the force and deflection of the floor system can be identified. The finite element method worked by breaking the computer model of the raised access floor system into smaller elements through the use of nodes and elements. Physical and geometric properties are allocated to the elements, and loads and displacements are applied to the nodes.

Two key indicators of FEA strength simulation are max yielding stress and max deformation. In terms of the 'Maximum yielding stress criterion', also called 'Maximum distortion energy theory', a flooring product starts to yield at a location when the maximum yielding stress becomes equal to the yielding strength, which is used as the stress limit. For the flooring product developed in this project, the yielding strength is obtained according to the physical properties of the floor panel and stringer. The maximum yielding stresses of the panel and stringer are required to be <94 MPa and 250 MPa, respectively, while the maximum deformation of the panel and stringer should be lower than 2.5 mm. According to the requirements of British Standards BSEN 12825:2001 (BSI 2001) and Platform Floors (Raised Access Floors) Performance Specification (PSA Specialist Services 1990), 3000 and 6000 N working loads are required to place on the central and edge of the floor system.

As shown in Figs. 16.9, 16.10, 16.11, 16.12 and 16.13, all the deformation values are <2.5 mm with 3000 N loading forces on the central and edge of the panel and stringer, which satisfy the flooring product's deformation criteria of Class A, as defined by the British Standard requirements. Therefore, under 300 N of working

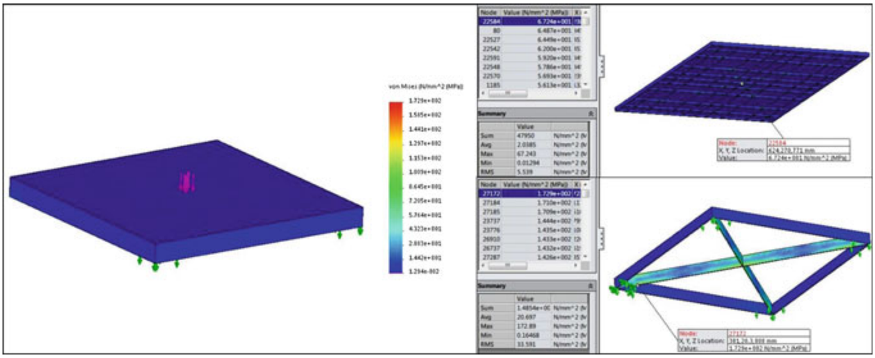

Fig. 16.9 Max yielding stress for the floor panel and stringer with loading 3000 N force at the central panel

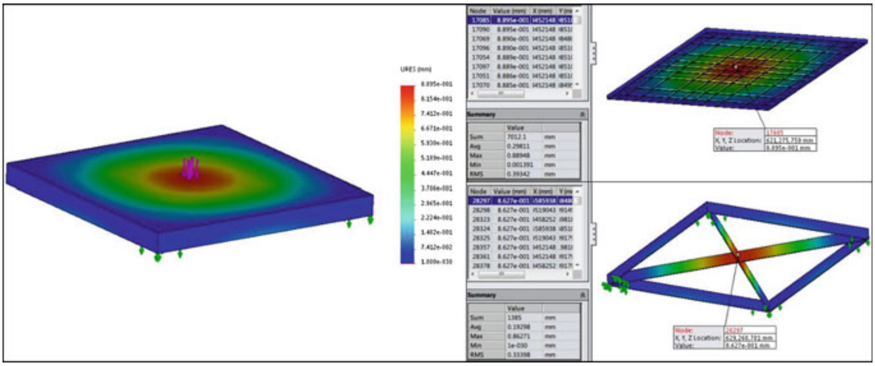

Fig. 16.10 Max deformation for the floor panel and stringer with loading 3000 N force at the centre panel

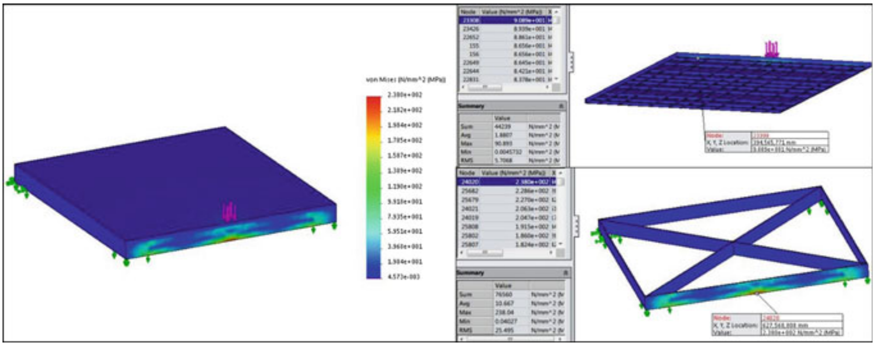

Fig. 16.11 Max yielding stress for the floor panel and stringer with loading 3000 N force at the outer edge of panel

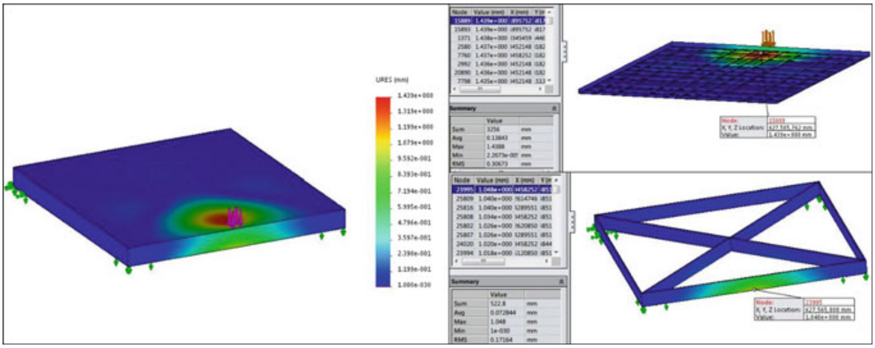

Fig. 16.12 Max deformation for the floor panel and stringer with loading 3000 N force at the outer edge of panel

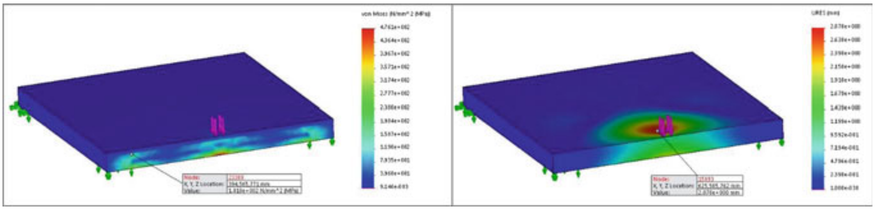

Fig. 16.13 Max yielding stress and deformation for the floor panel and stringer with loading 6000 N force at the outer edge of panel

load, the designed flooring product is able to work properly within the scope of elastic deformation.

As Fig. 16.13 shows, under 6000 N of ultimate working load, the maximum yielding stress and maximum deformation of the panel and string exceed the criteria of strength and deformation for the flooring products, therefore the floor panel will be broken down.

16.6 Strategies for Supporting Sustainable Manufacture

With the results obtained from the LCA, prototyping, test and FEA, it can be confirmed that the design of the raised access floor system meets the regulations, standards and PDS that have been incorporated in the conceptual and detailed design phases. Therefore, the flooring product will be produced by the industrial partner of the project. In order to achieve the sustainable production, the following are proposed:

- Avoid unnecessary heating time.
- Simplify the manufacturing process and use fewer processes, in order to reduce energy consumption and waste.
- Establish the recycle system for pedestal units and stringer, and provide information about how and where to dispose of the product.
- Increase the reuse rate of the wood pallet during the transportation of the product.
- Use local suppliers in order to reduce the impacts caused by the distribution of the product.
- Implement a long-term warranty.
- Register with an Environmental Management System (EMAS or ISO 14001) to improve environmental performance of the company's main activities.

16.7 Concluding Remarks

This chapter illustrates the integrated approach for sustainable product development using a raised access flooring product. This illustration is focused on elaboration of product design specification, conceptual design, detail design, prototyping and testing, and manufacture. The other phases of the product life cycle, such as product in service, and the end-of-life product treatment are considered in the LCA.

As a novelty of this research, it utilises the LCA analytical results as benchmarking values to examine environmental performance in the design iterations, and distilling LCA findings into methods and strategies to reduce the negative environmental impacts and improve resource efficiency in the production process.

This methodology's feasibility and functionality are approved via the case study. The new floor panel designed has achieved 44% weight reduction in comparison with the traditional raised access floor panel. The prototype passed the strength test and met environmental requirements stipulated by the regulations and standards on manufacturing floor products in the EU and UK market. ReCiPe methodology is adopted to evaluate the life cycle environmental performance of the flooring product, the results of which also identified the major negative impacts, which are related to the SMC material and moulding process.

The LCA results shows that the materials contribute significant impacts in the four environmental impact categories: 84% in carbon footprint, 91% in total energy consumed, 73% in air acidification, and 66% in water eutrophication. The results not only clarify the optimized design targets, but also enable to benchmark values for design iterations.

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