Vehicledesign to reduce weight material and CO2

Public report

Project within FFI
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Content

FFI in short

FFI, Strategic Vehicle Research and Innovation, is a joint program between the state and the automotive industry running since 2009. FFI promotes and finances research and innovation to sustainable road transport.

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1. Summary

This project evaluated the potential of **STILFOLD's manufacturing technology** compared to conventional stamping and welding methods traditionally used for automotive component production.

Conventional manufacturing methods are characterized by high investments in stamping dies and jigs, complex multi-step production processes, significant levels of material waste, and high carbon emissions. In contrast, STILFOLD's patented curve-folding technology offers a **tool-less, digitally driven production process**, significantly reducing the need for expensive tooling, minimizing part counts and welding operations, and improving material utilization.

The selected demonstrator for this study was a **front subframe** for Volvo Cars. By applying STILFOLD technology, the number of components was reduced from 58 to 27 simplified folded parts. Material waste was cut dramatically, from approximately 40% scrap down to below 10%, and the number of welds required was substantially decreased thanks to integrated, folded geometries.

Tooling investment was reduced by more than 90%, from approximately EUR 5.75 million to about EUR 0.5 million, providing a strong financial argument for STILFOLD's adoption. Furthermore, the development timeline was compressed significantly: while conventional stamped solutions require around 60 weeks from tool freeze to material validation, STILFOLD reduced this to approximately 20 weeks, enabling much faster innovation and market adaptation.

Testing and validation of the final design confirmed these performance advantages. The STILFOLD2 prototypes demonstrated substantial weight reductions and performance gains:

- The traditional subframe weighed **24.89 kg**.
- The STILFOLD2 (1.5 mm sheet) prototype reduced this to **23.81 kg**.
- The STILFOLD2 (1.0 mm sheet) achieved a weight of just **17.15 kg**, a **31% reduction** compared to traditional designs.

  Torsional stiffness was also significantly improved. While the baseline Volvo Cars design had a torsional stiffness of **6.9 Nmm/deg**, the

STILFOLD2 (1.5 mm) variant achieved a **+49% increase** in torsional stiffness despite being lighter.

Beyond mechanical performance, the environmental benefits of STILFOLD technology were clearly demonstrated.

Material savings alone (~7 kg per vehicle) equate to **700,000 kg of material saved** across 100,000 vehicles. Scrap reduction adds another **699,000 kg** in raw material savings. Combined, the total CO_2 emissions avoided are estimated at approximately **2,658 tonnes**, driven by both reduced material use and the elimination of energy-intensive stamping and welding operations.

In addition, STILFOLD's digital-first, tool-less manufacturing enables localized, decentralized production models that further support environmental and supply chain resilience goals.

The project demonstrated how **core innovation principles** — tool-less manufacturing, efficiency by design, resilience through digital flexibility, and circular design thinking — can translate into real-world automotive manufacturing improvements.

Specifically, STILFOLD enables efficient geometric optimization, substantial cost savings through eliminated tooling, significant weight and emission reductions, and a faster, more agile development process.

2. Sammanfattning på svenska

Detta projekt har utvärderat potentialen i STILFOLD-tillverkningstekniken genom en jämförelse med traditionella stansnings- och svetsningsmetoder som används vid produktion av fordonskomponenter. Traditionella metoder innebär ofta höga investeringar i pressverktyg och fixturer, komplexa och resursintensiva processer i flera steg, betydande mängder materialspill samt ett högt koldioxidavtryck. STILFOLD-tekniken representerar ett nytt angreppssätt där en verktygsfri och digitalt styrd vikningsprocess används för att kraftigt reducera behovet av dyra verktyg, minska antalet komponenter och svetsfogar samt förbättra materialutnyttjandet.

I projektet valdes en främre subframe från Volvo Cars som demonstrator. Genom att tillämpa STILFOLD-tekniken kunde antalet komponenter minskas från 58 till 27, samtidigt som materialspillet reducerades från cirka 40 procent till under 10 procent. Integrerade vikningslösningar minskade även behovet av svetsning avsevärt. Investeringen i verktyg kunde reduceras med över 90 procent, från cirka 5,75 miljoner euro till omkring 0,5 miljoner euro, vilket innebär en väsentlig kapitalkostnadsbesparing. Projektet visar också att utvecklingstiden från designfrysning till validerat material kan kortas från cirka 60 veckor till ungefär 20 veckor, vilket stärker möjligheten till snabbare innovation.

Testresultaten från den slutliga designen bekräftade de förväntade förbättringarna. Vridstyvheten ökade markant och viktminskningar på upp till 31 procent kunde uppnås, där vikten reducerades från 24,89 kg i traditionella konstruktioner till 17,15 kg med STILFOLD2-tekniken. Samtidigt kunde en betydande minskning av koldioxidutsläpp påvisas, med totalt cirka 2 658 ton undvikna utsläpp över en produktionsvolym om 100 000 enheter, genom kombinationen av lägre materialförbrukning och minskat spill.

Miljöfördelarna är tydliga och omfattar minskad råmaterialförbrukning, reducerad energianvändning genom eliminering av energikrävande stansning och svetsning samt möjligheten till lokal och flexibel produktion med lägre klimatpåverkan. Den digitala, verktygsfria tillverkningsprocessen gör det dessutom möjligt att enkelt anpassa produkter och tillverka olika varianter utan ökade verktygskostnader, vilket ytterligare stärker hållbarhetsprofilen.

STILFOLD-tekniken har genom projektet visat sig vara en hållbar och kostnadseffektiv tillverkningsmetod, särskilt lämpad för fordonsindustrin och sektorn för batterielektriska fordon (BEV), där låg vikt, hållbarhet och produktionsflexibilitet är centrala krav.

3. Background

The objective of this project is to redesign a complex structural chassies component, starting from a flat sheet and applying STILFOLD’s origami-inspired folding technology to achieve a highly competitive solution in terms of **cost efficiency**, **structural stiffness**, and **weight optimization**.

Specifically, the project will focus on adapting the design of a **subframe** — a key part of the front wheel suspension system — to STILFOLD’s advanced manufacturing methodology.

Traditionally, subframes are manufactured either from:

- **Cast or extruded aluminum**, assembled by welding, or
- **Stamped sheet metal parts**, joined through welding, or
- **Single-piece aluminum castings** created with large molds.

Each traditional approach presents clear trade-offs:

- **Steel sheet metal** solutions offer relatively low part costs but require significant investments in expensive stamping tooling.
- **Aluminum solutions**, conversely, present lower tooling costs but much higher per-part manufacturing costs.

In the case of **stamped steel subframes**, production involves welding together multiple smaller stamped parts. However, this method is material-inefficient: stamping operations generate substantial scrap material. **Typical material utilization rates are below 60%**, meaning that **over 40% of the input steel is wasted** during production.

By contrast, **STILFOLD technology** offers the potential to dramatically improve the manufacturing process by:

- **Reducing the number of individual parts** required,
- **Increasing material utilization** through precise cutting and folding,
- **Eliminating the need for costly stamping tools**, and
- **Lowering the environmental footprint** by minimizing scrap.

The project will validate whether adapting the subframe design to the STILFOLD process can deliver superior performance across critical dimensions of cost, sustainability, and structural integrity — thereby offering a compelling alternative to conventional manufacturing methods.

4. Purpose, research questions and method

Volvo Cars, in collaboration with STILFOLD, aims to explore the application of **STILFOLD's advanced curve-folding technology** within the automotive sector to achieve **significant reductions in component weight, material usage, manufacturing cost, and associated carbon emissions**.

Given the automotive industry's increasing focus on **cost efficiency**, **environmental sustainability**, and **manufacturing resilience**, this initiative is directly aligned with Volvo Cars' strategic objectives to innovate toward a greener and more agile production system.

The project will focus on the **redesign of a critical automotive component — the front subframe** — which is traditionally produced from multiple stamped or cast parts requiring extensive welding and assembly steps. By rethinking the subframe through STILFOLD's technology, the project seeks to validate opportunities for a **simpler, more sustainable, and cost-effective manufacturing approach**.

Research Questions

The investigation will be guided by the following key research questions:

- **Weight Reduction:** To what extent can STILFOLD technology reduce component weight compared to traditional multi-part manufacturing methods?
- **Material Utilization:** What improvements in raw material utilization can be achieved through STILFOLD's optimized cutting and folding techniques?
- **Carbon Footprint Reduction:** How significantly can STILFOLD simplify manufacturing processes and reduce associated carbon emissions compared to conventional stamping and welding methods?
- **Process Agility:** In what ways can a tool-less, flexible manufacturing approach accelerate time-to-market and enable decentralized, regional production strategies?
- **Cost Efficiency:** What potential cost advantages — both in tooling investments and per-unit production — can be realized through the adoption of STILFOLD manufacturing principles?

Methodology

The project will adopt a **simulation-driven and prototype-based research methodology**, comprising the following stages:

- **Computational Design Optimization:**

Advanced simulation and optimization tools, combined with STILFOLD's proprietary software and expertise, will be used to adapt the subframe geometry to maximize the benefits of folding-based manufacturing.

- **Iterative Physical Prototyping:**

  Prototypes will be fabricated through STILFOLD's proprietary flexible manufacturing process, enabling rapid iteration, validation of formability, and assessment of structural integrity.

- **Sustainability and Cost Analysis:**

  Each iteration will be systematically evaluated for improvements in **sustainability metrics** (material utilization, carbon footprint) and **economic performance** (tooling costs, part costs, production time).

By applying a combined **digital-first and agile prototyping approach**, the project seeks to deliver concrete, measurable evidence of the strategic advantages STILFOLD technology can offer in next-generation automotive manufacturing.

5. Objective

The primary objective of this project is to **leverage STILFOLD's curve-folding technology** to design, develop, and validate an **improved automotive chassie**. The component selected for this study is the **front subframe**, which, in traditional manufacturing, is constructed from multiple stamped steel sheets welded together through a resource-intensive process.

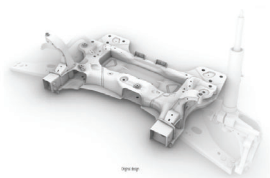
Through the application of **STILFOLD's industrial origami manufacturing methodology**, the project seeks to:

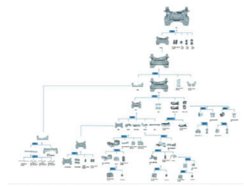
- **Minimize material usage** through optimized sheet folding patterns,
- **Reduce energy consumption** across the production process,
- **Substantially lower manufacturing costs** by eliminating expensive tooling and simplifying assembly,
- **Decrease the environmental impact** by improving material utilization and reducing emissions.

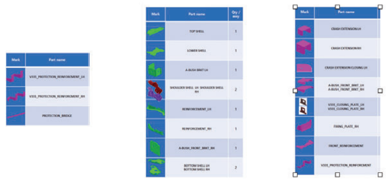
The project will deliver **measurable, validated evidence** of these advantages through the **design, fabrication, and rigorous testing** of a full-scale prototype subframe.

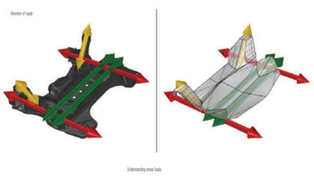
6. Results and deliverables

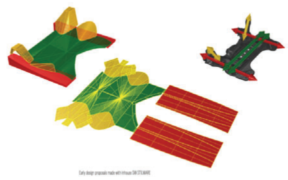
The project delivered a set of robust, evidence-based results that collectively demonstrate the **technical feasibility**, **economic advantage**, and **sustainability benefits** of applying STILFOLD technology to automotive component manufacturing. Key deliverables and findings are summarized below.

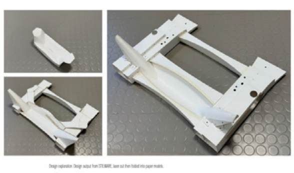


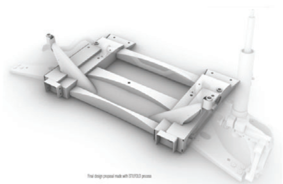












Technical Report

Documentation of the collaboration between Volvo Cars and STILFOLD, covering:

- **Requirement exchange and feedback**
  - Volvo Cars: Provided initial technical plans, CAD data, packaging constraints, and stiffness requirements.
  - STILFOLD: Supplied iterative updates, development feedback, and feasibility analysis.
- **Preparation Phase**
  - STILFOLD assessed and adapted its manufacturing methodology to the specific design requirements of the Volvo front subframe.
- **Technology Familiarization Visit**
  - Joint site visit where Volvo engineers evaluated early-stage manufacturing progress and assessed the benefits and limitations of the STILFOLD process.
- **Concept Development**
  - Design of a subframe tailored to Volvo-specific hardpoint layouts, proving the compatibility of STILFOLD manufacturing principles.
- **Prototype Fabrication**
  - Development of the first full-scale prototype matching the surrounding wheel suspension interfaces.
- **Demonstrator Integration and Communication**
  - Assembly and public presentation of a Volvo demonstrator vehicle integrating the STILFOLD-manufactured subframe.
- **CAD Drawings and Engineering Data**
  - Complete digital models and structural analyses supporting prototype validation and further optimization.

Comparative Manufacturing Analysis

Aspect	**Traditional Stamped/Welded Steel**	**STILFOLD Process**
Material Utilization	~55–60%	>90%
Scrap Rate	~40–45%	<10%
Tooling Investment	~EUR 5.75M	~EUR 0.5M
Prototype Development Timeline	~40 weeks	~12 weeks
Total Lead Time to Production Readiness	~60 weeks	~20 weeks
Welded Parts	~23 distinct parts	6 folded parts + 21 bent/machined parts

Aspect	Traditional Stamped/Welded Steel	STILFOLD Process
Weight Reduction	Baseline	~30%
Complexity	High (multi-step)	Low (integrated)

Key Performance Outcomes

Weight and Material Optimization

- **31% Weight Reduction** achieved through geometric optimization enabled by curve folding.
- **Use of high-strength steels** made feasible by non-stamping manufacturing, allowing thinner gauges without compromising performance.
- **7 kg material savings per vehicle**, scaling to:
    - **700,000 kg total material saved** over 100,000 vehicles.
    - **1,330 tonnes CO_2 emissions avoided** from material weight reduction alone.

Manufacturing Cost and Flexibility

- **Tooling CAPEX reduced by ~90%** (from EUR 5.75M to ~EUR 0.5M).
- **Elimination of stamping and welding energy loads**, resulting in major operational cost savings.
- **Simplified assembly** due to fewer parts and reduced welding operations.

Environmental Sustainability

- **Scrap Reduction:**
    - Scrap decreased from ~40% to <10%, saving an additional **1,328 tonnes of CO_2**.
- **Total CO_2 Savings:**
    - Combined impact (material + scrap reduction) of approximately **2,658 tonnes CO_2 avoided** over 100,000 units.
- **Energy Efficiency:**
    - Elimination of high-energy stamping and welding processes leading to major reductions in energy consumption per unit.

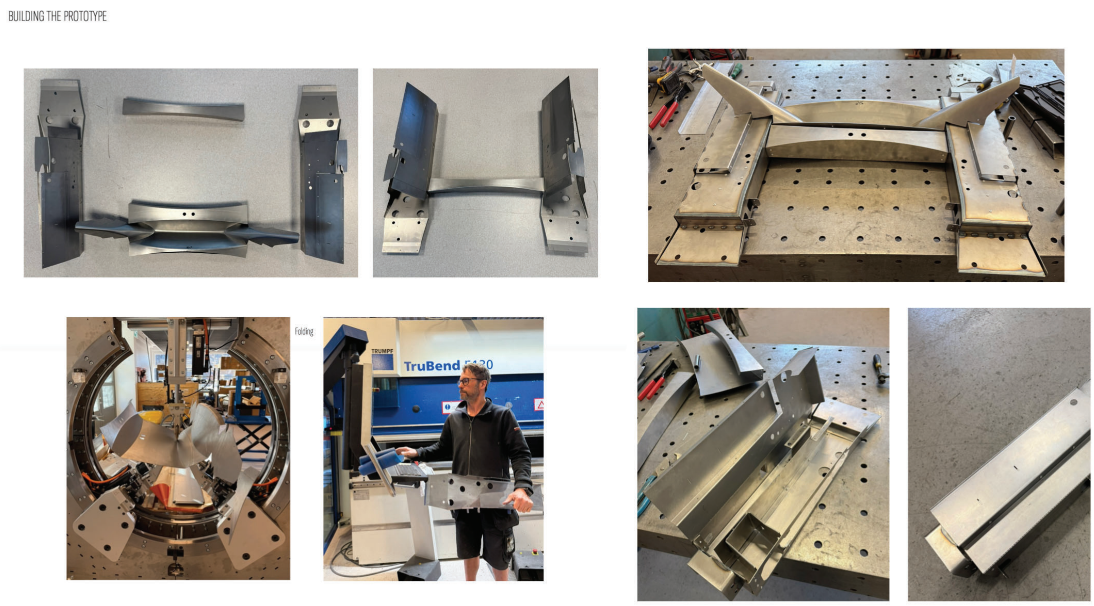
Prototype Testing and Validation

Performance Testing

- **Torsional Stiffness:**
  - The STILFOLD2 1.5 mm prototype demonstrated a **49% increase** in stiffness compared to the reference traditional design.
- **Weight Reduction:**
  - 1.0 mm STILFOLD2 prototype:
    - Weight reduced to **17.15 kg**, ~**31% lighter** than traditional designs.

Demonstrator Build and Integration

- Successful assembly of the subframe into a **full front wheel suspension system** of a Volvo vehicle.
- **On-vehicle testing and evaluation** demonstrated compatibility with existing architectures and torsional stiffness performance.



Strategic Outcomes

- The first STILFOLD iteration showed torsional stiffness on par with VCC original design with 1Kg decrease in weight.
- The last iteration STILFOLD design showed a weight decrease of about 7Kg with kept torsional stiffness.
- **Over 2,600 tonnes of CO_2 emissions could be avoided** through material and scrap savings.
- **Significant advancement of Volvo's sustainable manufacturing strategy** by proving a flexible, low-carbon production method.
- **Demonstration of accelerated development timelines** supporting agile vehicle programs and future regionalized production models.

7. Dissemination and publications

7.1 Dissemination

How are the project results planned to be used and disseminated?	Mark with X	Comment
Increase knowledge in the field	X	

Be passed on to other advanced technological development projects	X	
Be passed on to product development projects	X	
Introduced on the market	X	
Used in investigations / regulatory / licensing / political decisions	X	

7.2 Publications

https://www.dagensinfrastruktur.se/2024/11/25/stilfold-samarbetar-med-volvo-cars-for-att-framja-hallbar-fordonsproduktion/

https://svenskverkstad.se/affarer/STILFOLD_i_samarbete_med_Volvo_Cars_/9y5u

https://www.di.se/nyheter/deras-plat-origami-kan-forandra-volvo-cars-bilar/

https://www.dn.se/motor/deras-plat-origami-kan-forandra-volvo-cars-bilar/

8. Conclusions and future research

Project Conclusions

The project successfully delivered on its initial objectives:

- **STILFOLD technology** demonstrated strong potential to enhance automotive manufacturing by:
  - Reducing mass and weight
  - Reducing tooling investment requirements,
  - Minimizing the number of parts,
  - Substantially decreasing welding operations,
  - Significantly improving material utilization.
- **Performance exceeded expectations**, with weight reductions combined with increased torsional stiffness and structural robustness.
- **Strategic collaborations strengthened**, particularly with Volvo Cars, creating a strong foundation for ongoing integration of STILFOLD technologies into future platforms.

Additional Key Outcomes

➔ Up to 31% mass reduction, directly contributing to lower vehicle energy consumption and lifecycle emissions.

➔ Elimination of stamping and welding steps results in significant energy savings per manufactured unit, contributing to greener production and lower scrap rates

➔ Reduced resource-intensive tooling requirements, lowering emissions associated with tool production and maintenance.

➔ Faster innovation cycles enable more agile adoption of lightweight, low-emission vehicle architectures.

Extension of STILFOLD's applicability beyond subframes to **body structures**, **battery housings**, and **closure systems**.

Core Innovation Principles Validated

- **Tool-less Manufacturing:**

  Agile, digital-first processes replace stamping and welding, dramatically cutting costs and time-to-market and securing resilience and regional production.

- **Efficiency by Design:**

  Geometric optimization reduces part count, fasteners, and material waste.

- **Resilience and Localization:**

  Digital manufacturing methods enable decentralized, scalable, and flexible production strategies.

- **Digital Variant Flexibility:**

  Variant design adjustments without new tooling investments.

- **Circular Manufacturing Principles:**

  Designs optimized for disassembly, reuse, and full recyclability.

Key Strategic Insights

- **Mass Reduction Achieved:**
  - Traditional VCC subframe mass: **24.89 kg**
  - STILFOLD2 (1.5 mm sheet) mass: **21.03 kg**
  - STILFOLD2 (1.0 mm sheet) mass: **17.15 kg**

    ➔ **Result:** Up to **31% mass reduction**, directly contributing to lower vehicle energy consumption and lifecycle emissions.

- **Torsional Stiffness Improvement:**
  - Traditional VCC: **6.9 Nmm/deg**
  - STILFOLD2 (1.0 mm): **6.39 Nmm/deg**
  - STILFOLD2 (1.5 mm): **+49% greater stiffness** compared to baseline

    ➔ **Result:** Improved crashworthiness and performance while enabling lightweighting strategies for enhanced sustainability.

- **Tooling Cost Reduction:**
  - Traditional tooling investment: **~EUR 5.75M**
  - STILFOLD tooling investment: **~EUR 0.5M** (~**90% reduction**)

    ➔ **Result:** Reduced resource-intensive tooling requirements, lowering embodied emissions associated with tool production and maintenance.

- **Development Time Acceleration:**
  - Traditional development timeline: **~60 weeks** to validated material readiness
  - STILFOLD development timeline: **~20 weeks**

    ➔ **Result:** Faster innovation cycles enable more agile adoption of lightweight, low-emission vehicle architectures.

- **Environmental Benefits:**
  - **Material Savings:**

    ➔ ~7 kg material saved per vehicle, translating to **700,000 kg** over 100,000 units.

- **Scrap Reduction:**

  ➔ Scrap rate reduced from ~40% to <10%, saving nearly **699,000 kg** of material.

- **CO_2 Emissions Avoided:**

  ➔ **~2,658 tonnes of CO_2** saved through combined mass reduction and scrap minimization.

- **Energy Efficiency:**

  ➔ Elimination of stamping and welding steps results in significant **energy savings per manufactured unit**, contributing to greener production processes.

Strategic Recommendations

- **Embed STILFOLD Design Criteria Early:**

  Integrate folding optimization into the early development phases of future chassie parts.

- **Target High-Stiffness, Weight-Sensitive Components:**

  Prioritize adoption for subframes, body structures, closures, and battery housings.

- **Explore High-Strength Materials:**

  Investigate folding-optimized use of advanced high-strength steels to enable further material and weight reductions.

- **Develop Full TCO Models:**

  Include tooling, energy consumption, carbon footprint, and lead time savings in total cost analyses.

- **Scale Broadly Across Automotive Applications:**

Expand the use of STILFOLD technology beyond front subframes into comprehensive body-in-white systems and EV architectures.

Future project potential: CAR CANVAS

There are clear synergies and links to other internal and external projects, notably the STILFOLD CAR CANVAS project. The CAR CANVAS – Body-in-White Demonstrator aims to revolutionize vehicle manufacturing by shifting from traditional, tool-dependent methods to a digital, tool-less process.

Using STILFOLD's patented sheet metal folding technology combined with additive manufacturing and roboforming techniques, the project seeks to eliminate costly and inflexible tooling, enabling sustainable, adaptable, and localized production of advanced automotive structures.

9. Participating parties and contact persons

Project management and project participants

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