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OMICS Group International is an amalgamation of Open Access publications and worldwide international science conferences and events. Established in the year 2007 with the sole aim of making the information on Sciences and technology 'Open Access', OMICS Group publishes 400 online open access scholarly journals in all aspects of Science, Engineering, Management and Technology journals. OMICS Group has been instrumental in taking the knowledge on Science & technology to the doorsteps of ordinary men and women. Research Scholars, Students, Libraries, Educational Institutions, Research centers and the industry are main stakeholders that benefitted greatly from this knowledge dissemination. OMICS Group also organizes 300 International conferences annually across the globe, where knowledge transfer takes place through debates, round table discussions, poster presentations, workshops, symposia and exhibitions.

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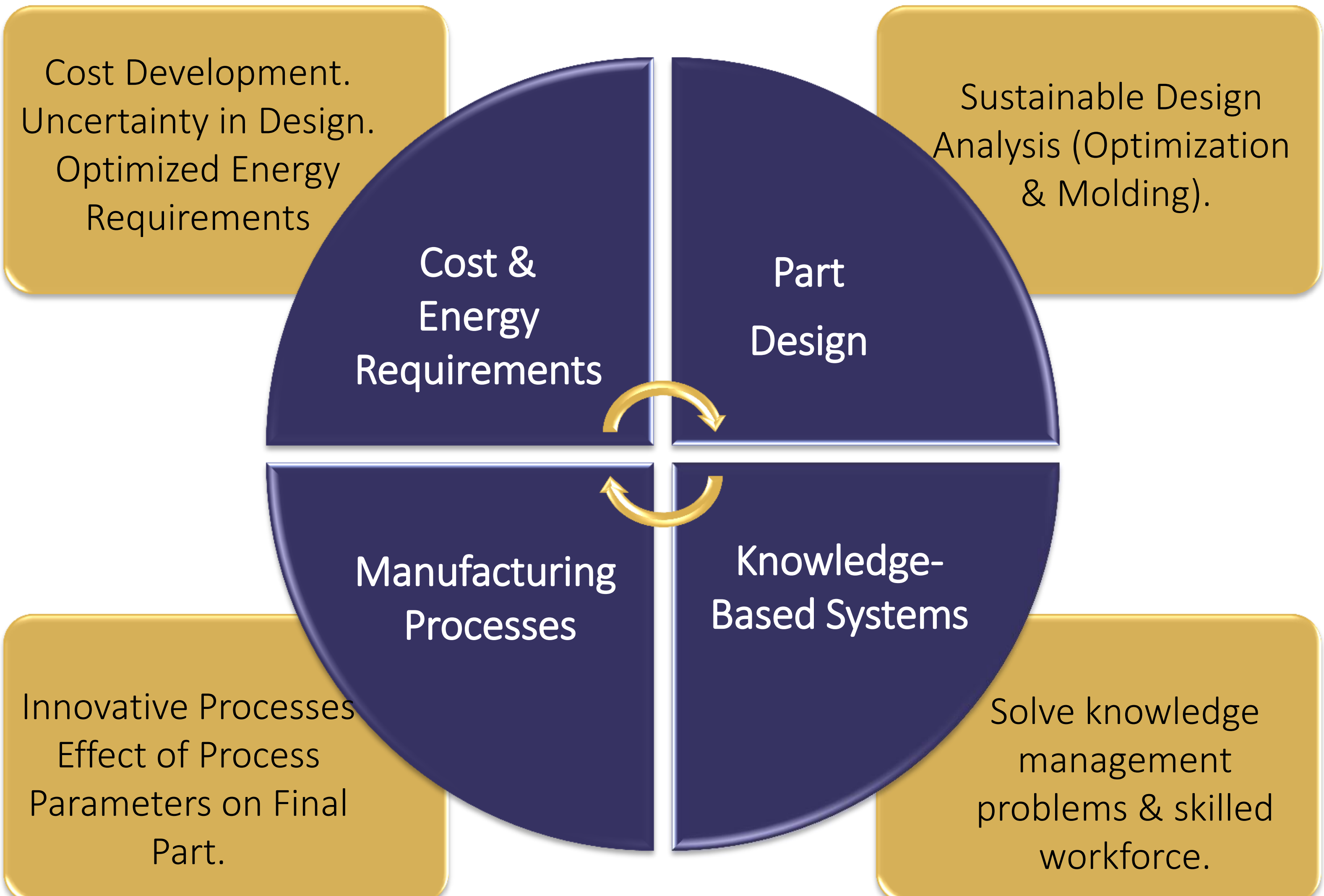
OMICS Group International is a pioneer and leading science event organizer, which publishes around 400 open access journals and conducts over 300 Medical, Clinical, Engineering, Life Sciences, Pharma scientific conferences all over the globe annually with the support of more than 1000 scientific associations and 30,000 editorial board members and 3.5 million followers to its credit.

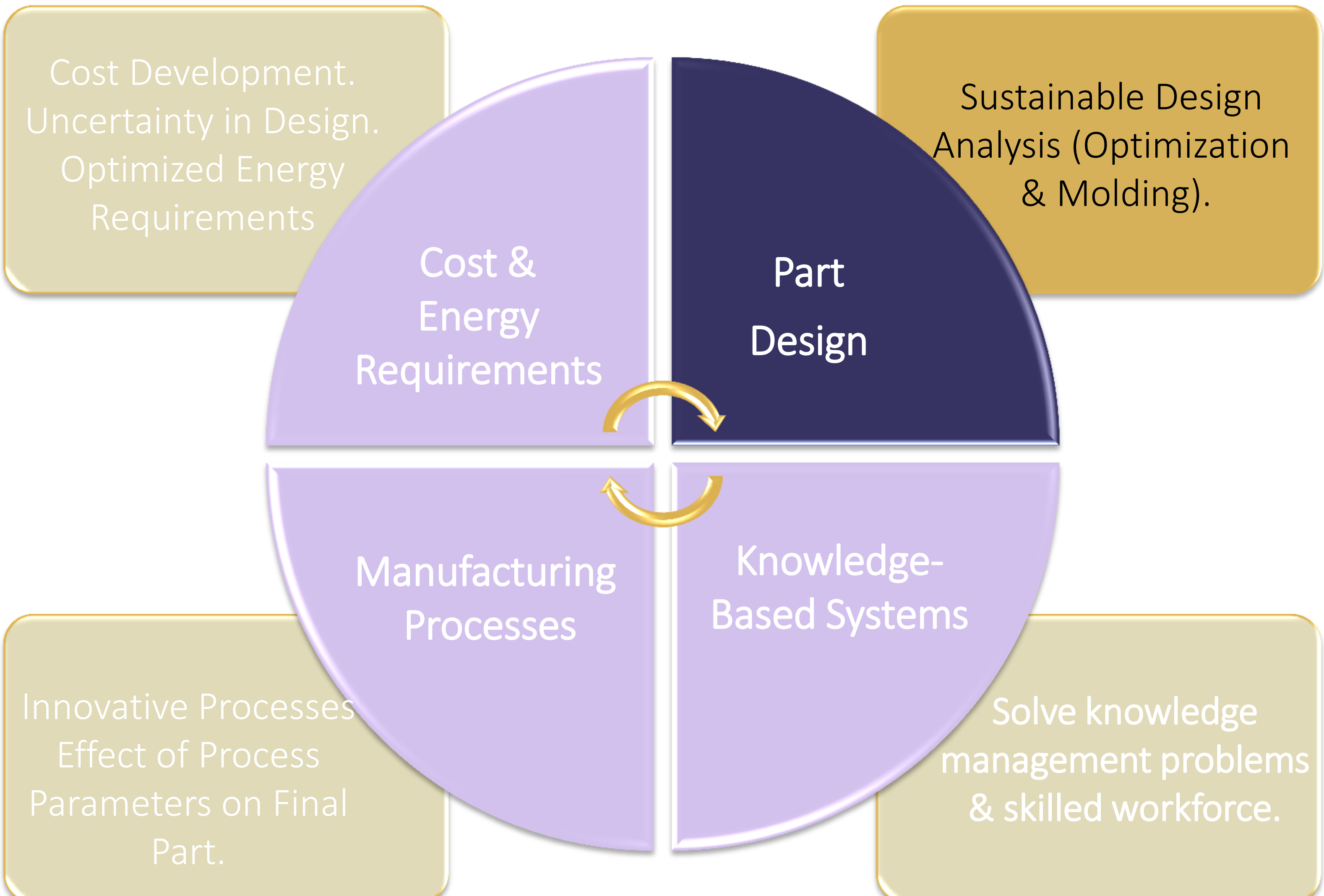
OMICS Group has organized 500 conferences, workshops and national symposiums across the major cities including San Francisco, Las Vegas, San Antonio, Omaha, Orlando, Raleigh, Santa Clara, Chicago, Philadelphia, Baltimore, United Kingdom, Valencia, Dubai, Beijing, Hyderabad, Bengaluru and Mumbai.

Optimization of Innovative Manufacturing Techniques to Enhance the Mechanical Properties of Parts

Ala Qattawi
Assistant Professor
Mechanical Engineering, University of California, Merced

UCMERCED


Cost Development.
Uncertainty in Design.
Optimized Energy
Requirements
Sustainable Design
Analysis (Optimization
& Molding).
Cost &
Energy
Requirements
Part
Design
Manufacturing
Processes
Knowledge-
Based Systems
Innovative Processes
Effect of Process
Parameters on Final
Part.
Solve knowledge
management
problems & skilled
workforce.


Cost Development. Uncertainty in Design. Optimized Energy Requirements
Sustainable Design Analysis (Optimization & Molding).
Cost & Energy Requirements
Part Design
Manufacturing Processes
Knowledge-Based Systems
Innovative Processes Effect of Process Parameters on Final Part.
Solve knowledge management problems & skilled workforce.

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Today Design & Manufacturing Sectors Faces Challenges

Market

High demand for individualization.

Decrease in product life cycle.

Production

Maximizing economies of scale

Massive long-term investments in technologies, tools and equipment

Product

Fragmented: large numbers of models and product derivatives.

Enormous complexity is a hindrance.

Results

Inability to execute quickly

Limited to no on-the-fly flexibility for innovations

Less is more is the Opportunity

Less Complexity

More Desirability & Capability

Less Investment

More Choice

Less Mass Production

More Individualism

What is Origami-Based Folding?

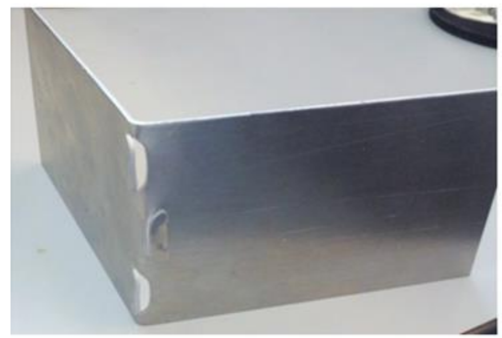
Image Courtesy: industrial Origami

What is Origami-Based Folding?

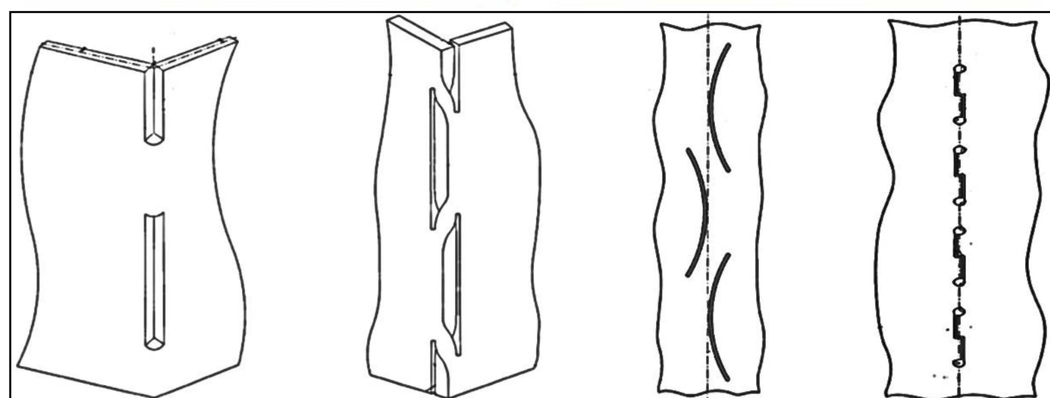
Vehicle interior structure made by origami-based folding process

What is Origami-Based Folding (Cont.)

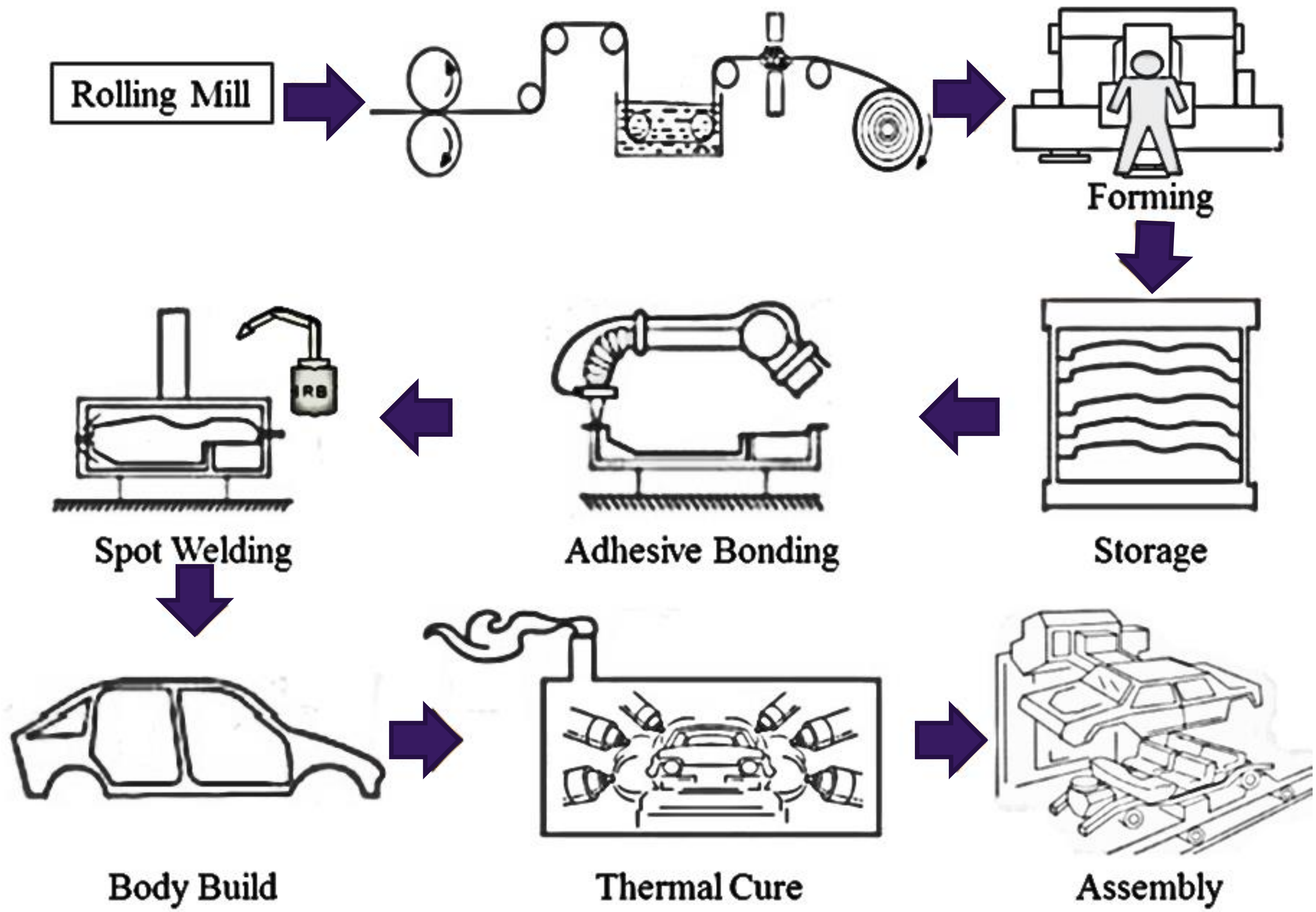
Depends on features (materials discontinuities) added on bend line to improve process capabilities and final part's properties.



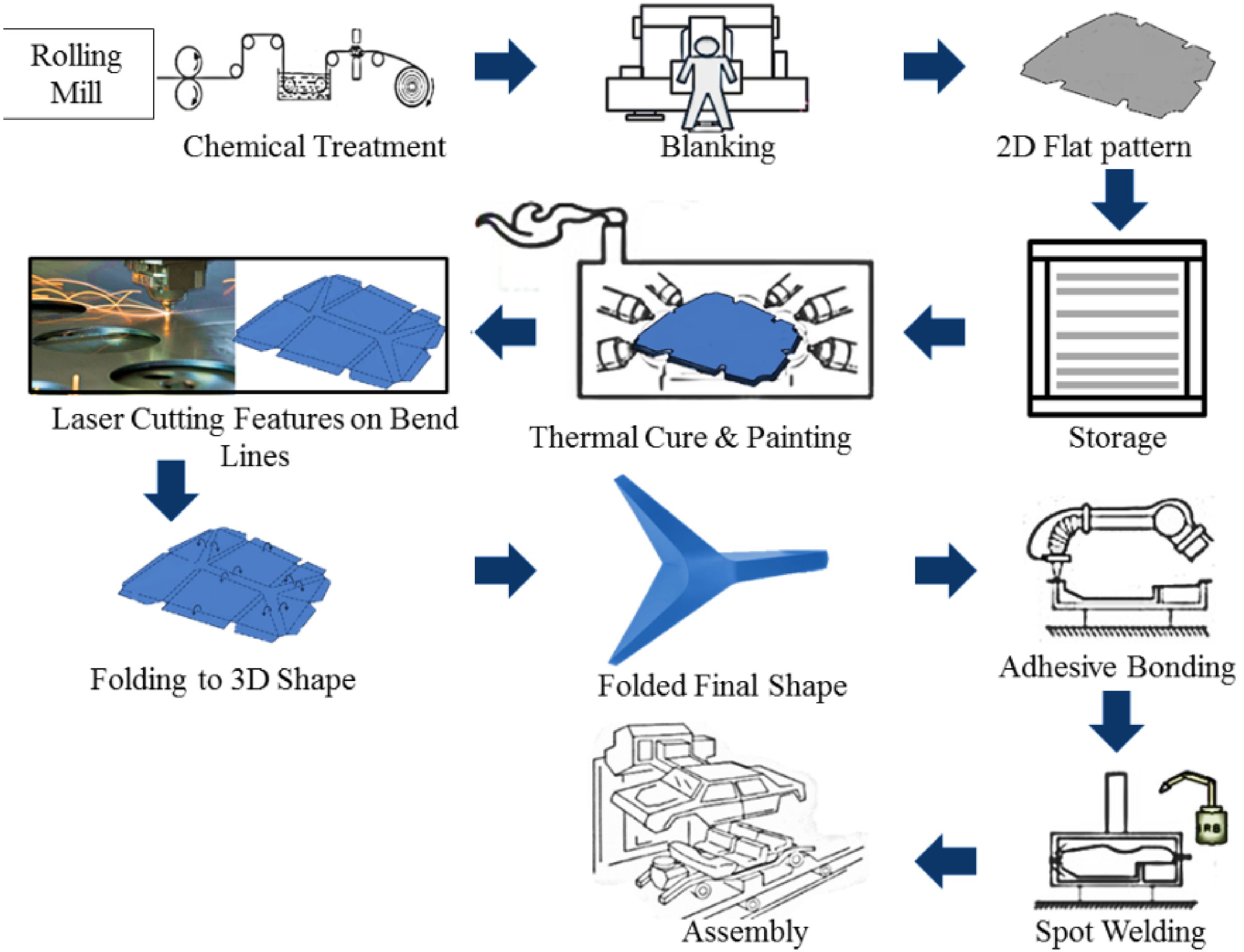
Examples of possible shapes for features.



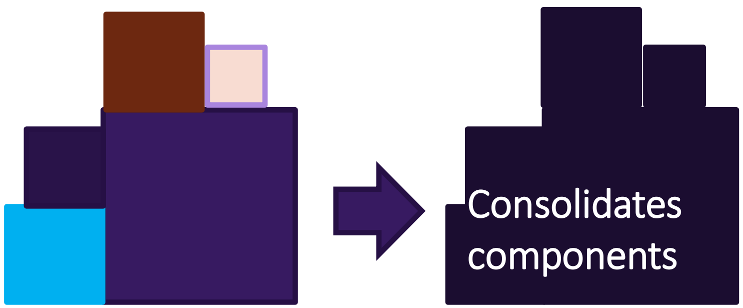
Origami-Based Folding Compared to Traditional Stamping

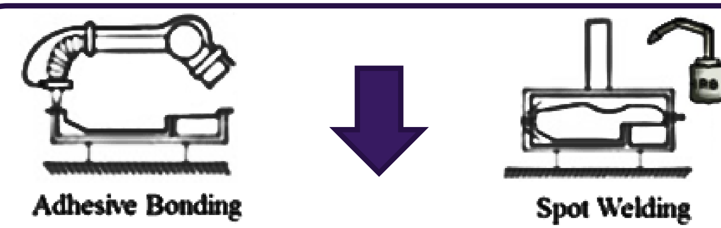


Origami-Based Folding Compared to Traditional Stamping



Origami-Based Folding Potential

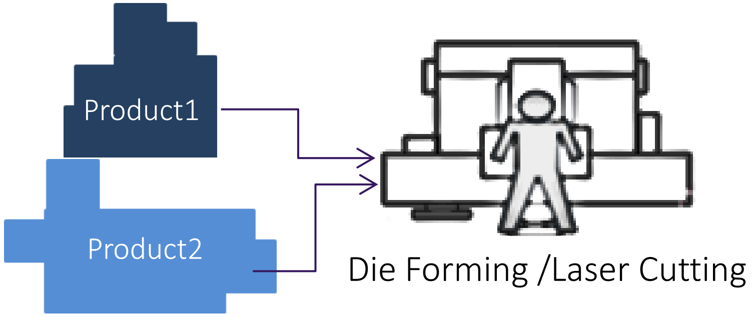




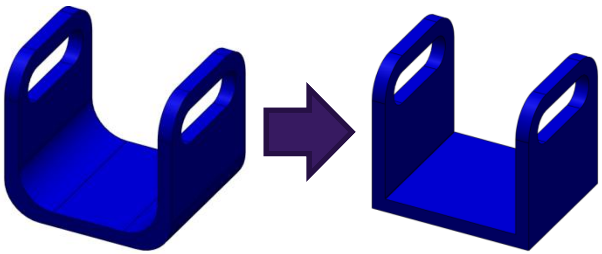
less joining and processing operations

Enables better flexibility in the process sequence and the material flow; supports one-piece flow production.

Origami-Based Folding Potential (Cont.)

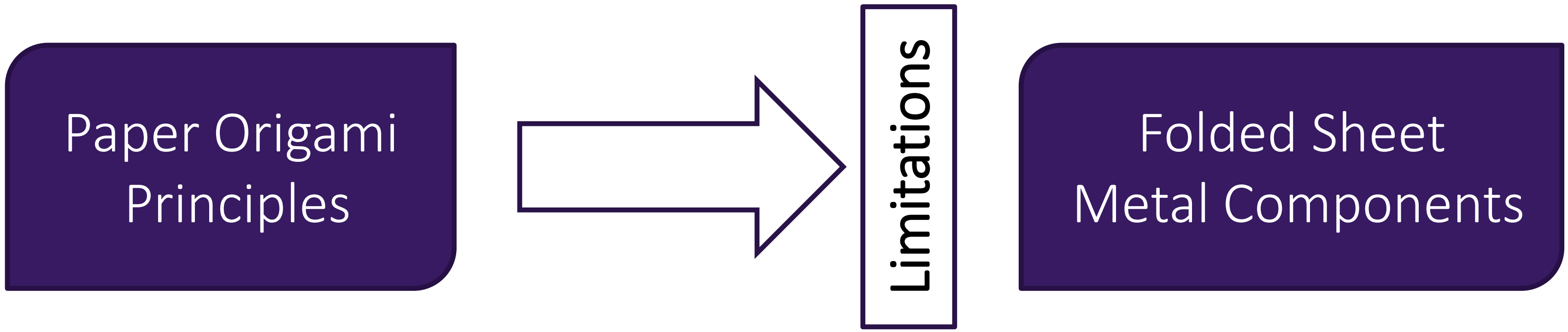


Eliminates the need for rigid tooling dedicated for each product. Enable low cost investment.



Features at the bend lines affect the bending force, remove the limitations on bending radius, minimize occurrence of tears and cracks, and reduce the punch displacement analysis.

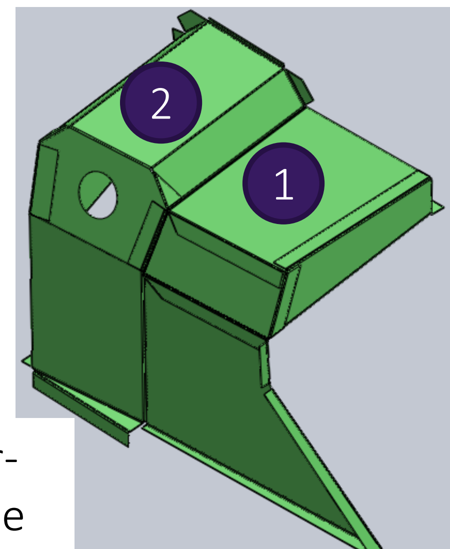
Current Limitations for Origami –Based Folding Adaptation



- Design 2-D transformation to 3-D and vise versa.
- Mechanical properties & performance.
- Origami-based folding rank among exiting fabricating processes.

Topological Analysis of Components

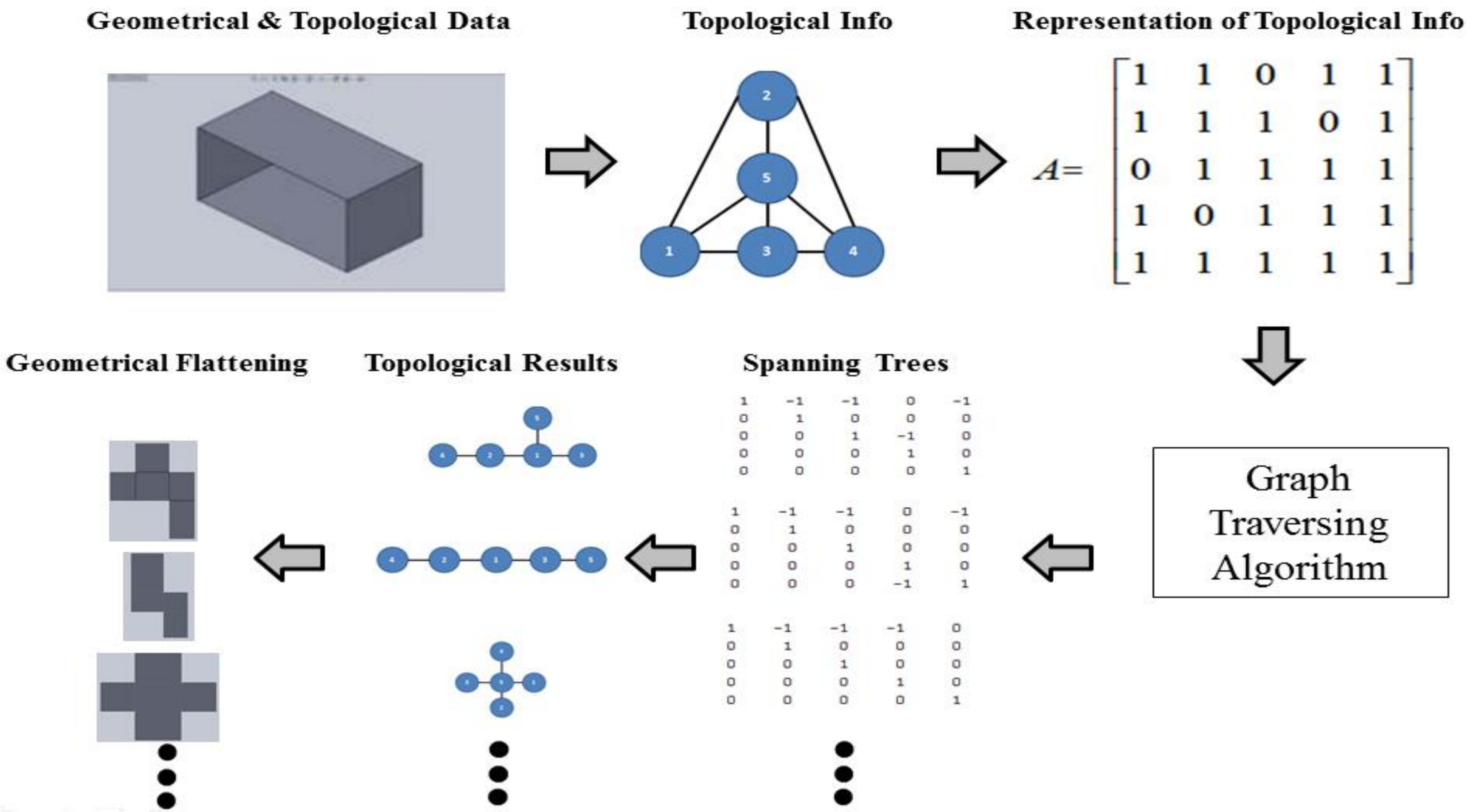
Flat Pattern Analysis (FPA) tool : number and design of possible layouts, bend lines location and number, effect of initial 3-D geometry type on resulted flat pattern, and the conditions to determine validity of flat pattern.



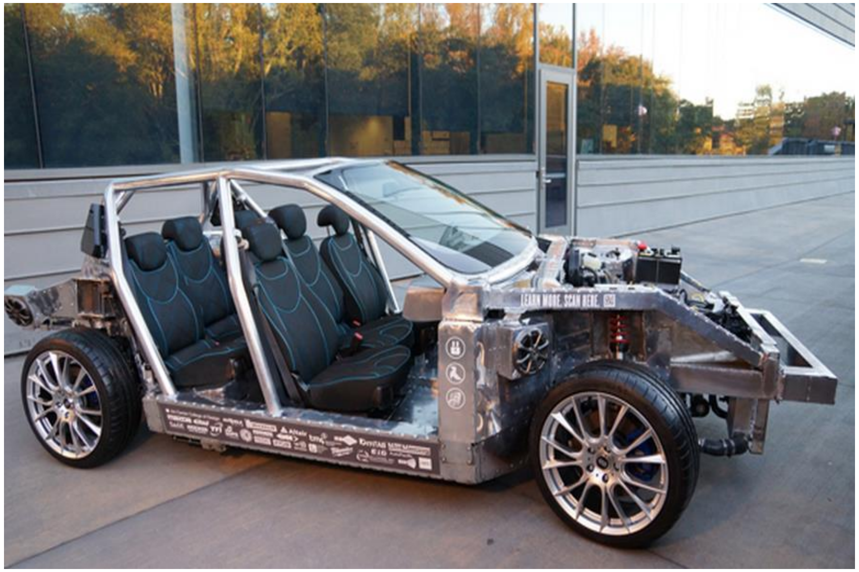
Crash Tower-
Front Module
(Deep Orange 3)

29 Flat Patterns Possible to fold Part 1

Final Step of Flat Pattern Generation



Qattawi, A., Mayyas, A., Thiruvengadam, H., Kumar,V., Dongori, S., Omar, A., “Design Considerations of Flat Patterns Analysis Techniques when Applied for Folding 3-D Sheet Metal Geometries”, Journal of Intelligent Manufacturing , DOI: 10.1007/s 10845-012-0679-9 , (2012).



Front underbody can be made of Origami-based sheet metal folding.
However, the mechanical properties need to be investigated.

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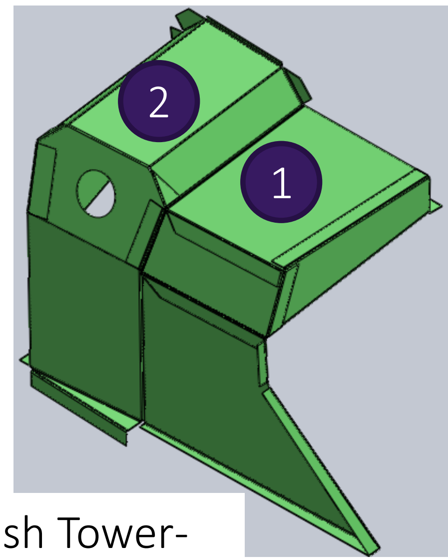
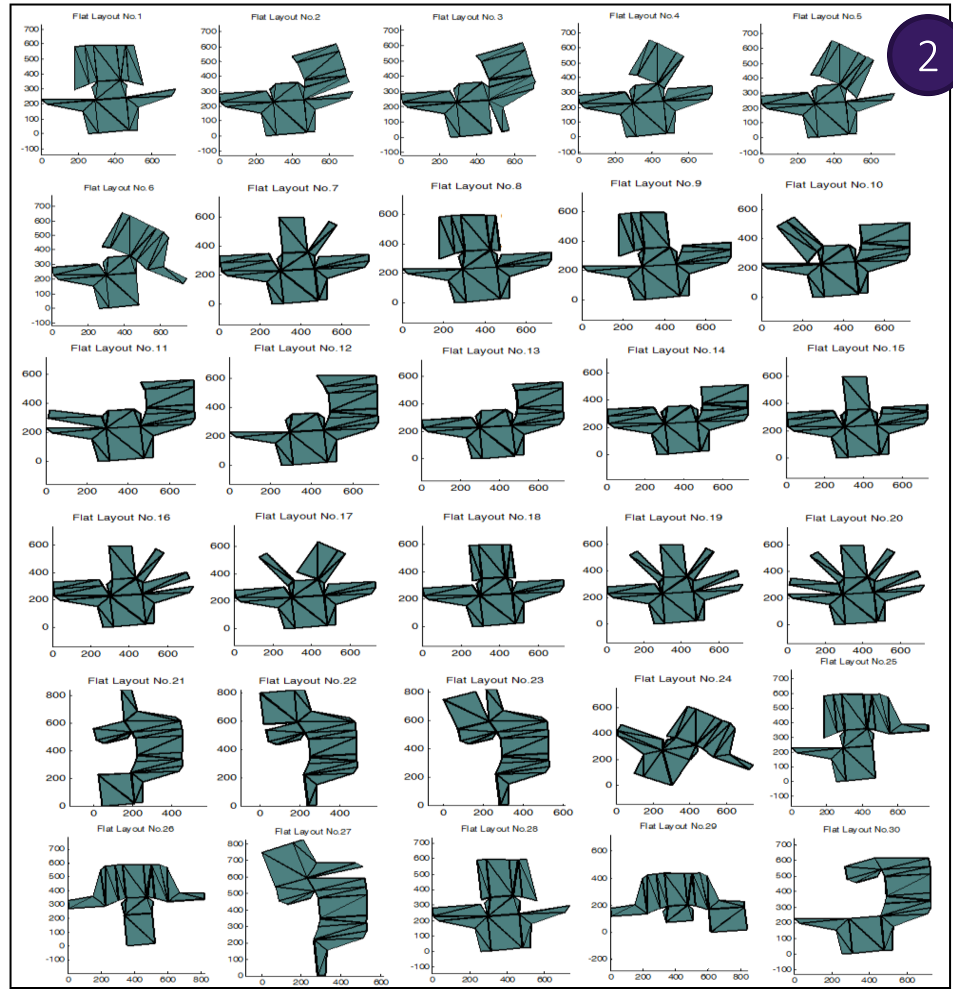
Which Flat Pattern is Best?

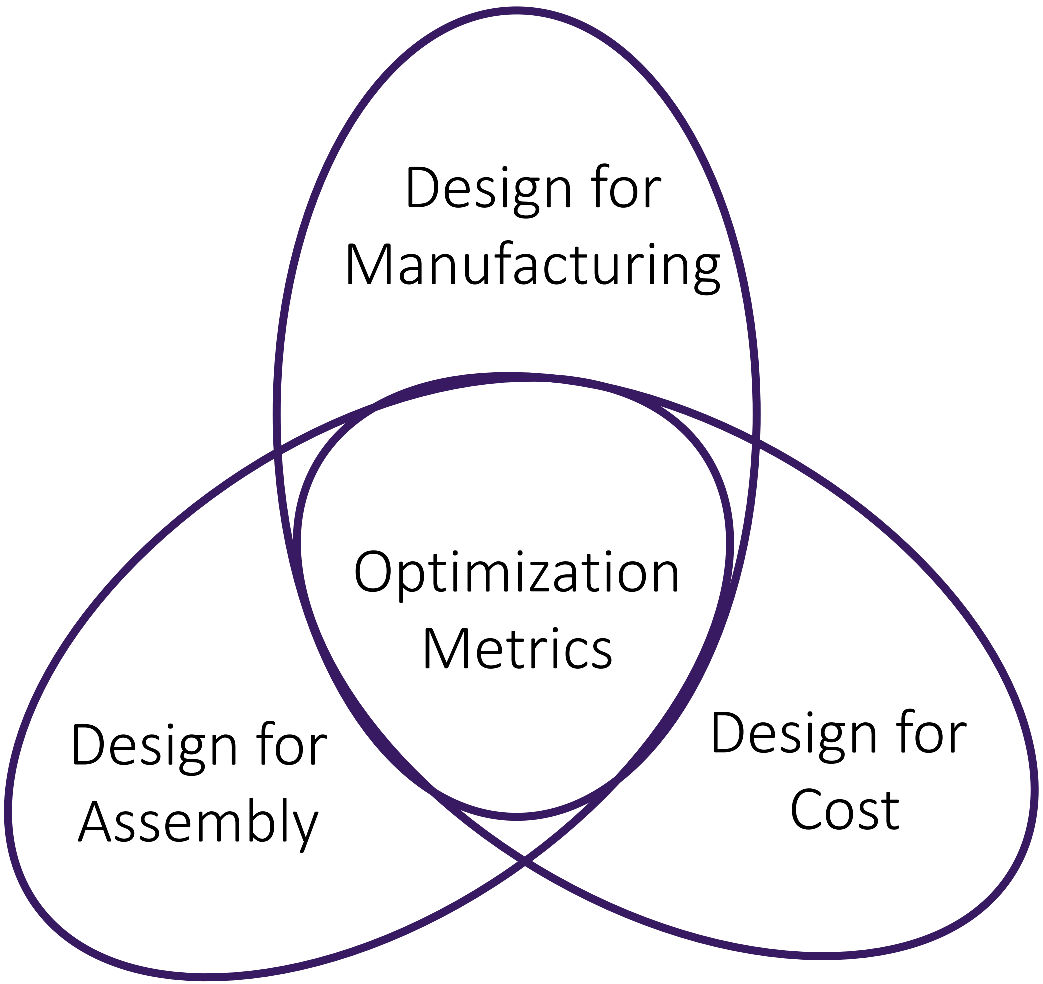


Crash Tower-
Front Module
(Deep Orange 3)



Qattawi, A., Abdelhamid, M., Mayyas, A., Omar, M., "Design Analysis for Origami-Based Folded Sheet Metal Parts" SAE International Journal of Materials and Manufacturing, 2014-01-9098 (2014).

Optimization Objectives



Optimality Based on Compactness

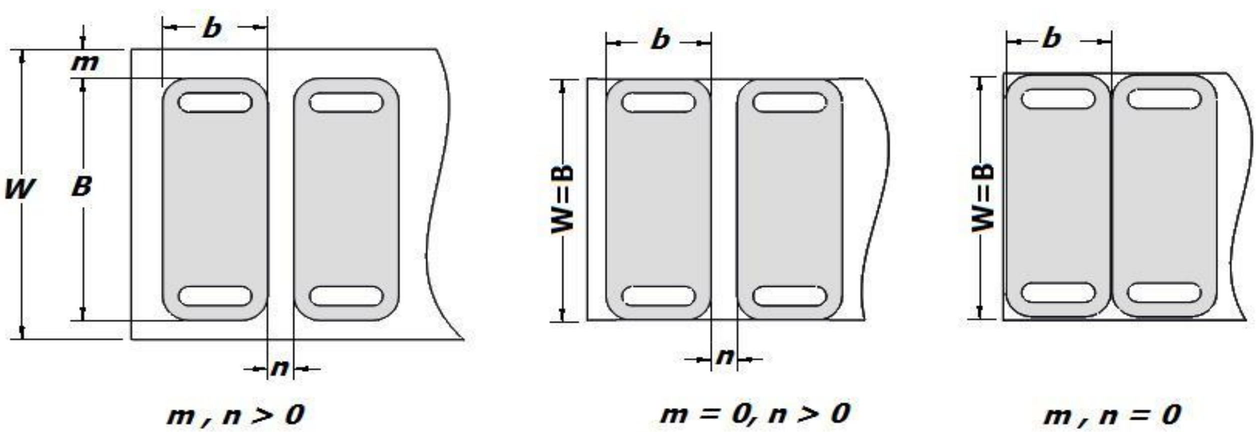
Compactness Metric (CM) is a main metric for optimized flat layout, it can be defined in terms of different aspects serving different design requirements

- $CM_{Geometric} = \frac{\mathrm{A}}{\mathrm{p}^2}$ → Total length of cut edges
- $CM_{Min.Overall\ Extent} = \max[(x_i - x_0), (y_i - y_0)]$ → Largest extent in x/y direction
- $CM_{Min.Enclosing\ Area} = (x_i - x_0)(y_i - y_0)$ → Utilized Material as prescribed out of a rectangle
- $CM_{Area\ Condensation} = \frac{A}{(x_i - x_0)(y_i - y_0)}$ → Utilized Material as percentage of used area to prescribed area out of a rectangle

A is the area of a flat layout, p is the perimeter of the flat layout, xi, y_i, x_0 and y_0 are the largest x-coordinate, largest y-coordinate, smallest x-coordinate, and smallest y-coordinate of all vertices in a single flat layout, respectively

Optimality Based on Nesting Efficiency

- Nesting Efficiency Metric (NEM) utilizes the compactness measures as initial inputs for further investigation with respect to nested material utilization percentage.
- A nesting efficiency of 70% to 80% (i.e. material utilization) is set as indication of good nesting.*
- $NEM = \frac{nA}{LW}$. Where, A is the surface area of a flat layout, n is the number of flat layouts cut from the strip, W is strip width, L is the total length of strip used to produce the flat layouts.



Strip scrap model parameters; Strip width *W*, Layout width *B*, Layout length *b*, Distance from the edge of the layout to the side of the strip *m*, Distance between the layouts *n.*

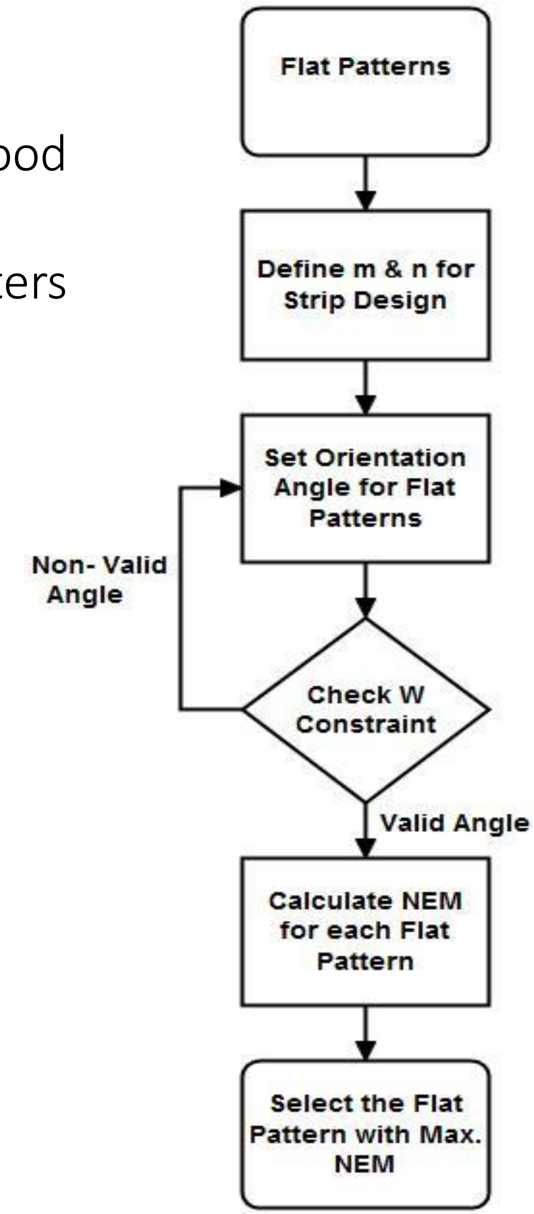
*Boljanovic, V. (2004), Sheet metal forming process and die design. New York: Industrial Press.

Optimality Based on Nesting Efficiency (Cont.)

- A heuristic approach is followed to determine a good nesting arrangement for multiples of each flat pattern.
- Constraints on strip width *W* and nesting model parameters *n* & *m* are set before analysis.

The values of *m* and *n* in strip design model for each strip thickness and width.

Strip Thickness (T) mm	Strip Width (W) mm	Value of (m) mm	Value of (n) mm
$T \leq 0.6$	$W \leq 75$	2.0	2.0
	$76 \leq W \leq 100$	3.0	3.0
	$101 \leq W \leq 150$	3.5	3.5
	$151 \leq W$	4.0	4.0
$0.61 \leq T \leq 0.8$	Any value of W	$m = T + 0.015\,B$	3.5
$0.81 \leq T \leq 1.25$			4.3
$1.26 \leq T \leq 2.5$			5.5
$2.6 \leq T \leq 4.0$			6.0
$4.1 \leq T \leq 6.0$			7.0

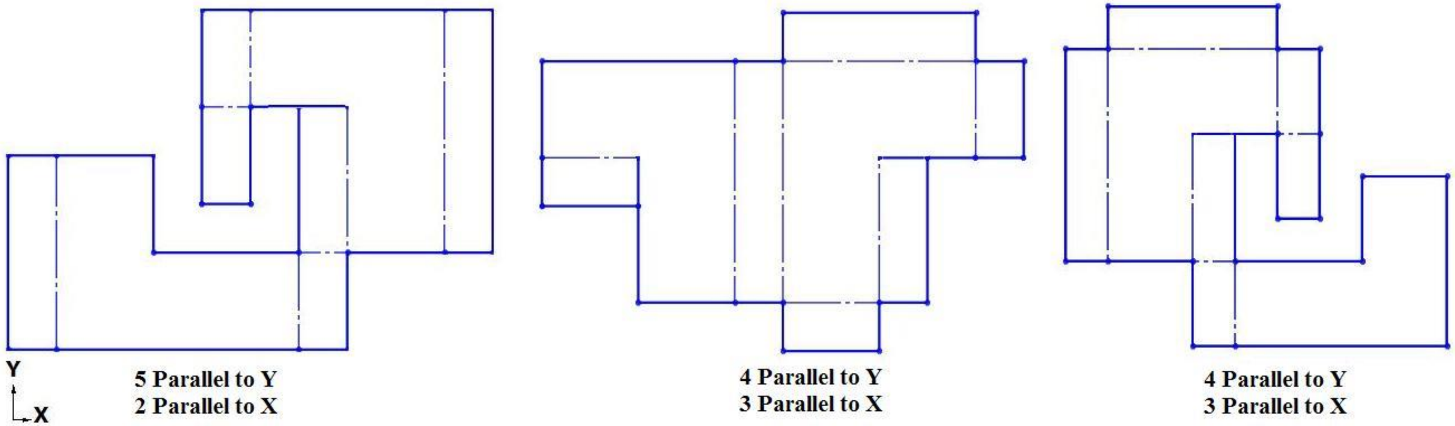


Optimality Based on Bend Lines Orientation

- For sheet metal applications, robotic arms can be utilized to fold the part over the bend lines in a sequential manner; process sequence and precedence must be considered when designing a flat pattern for a folded part.
- Bend lines with minimum orientations accommodate the process capabilities – in terms of equipment and time constraints.
- Orientation of Bends Metric $(OBM)_{axis} = \max\left(n_x, n_y\right)$.

Where, n_x is number of bend lines parallel to the x direction.

n_y is number of bend lines parallel to the y direction.



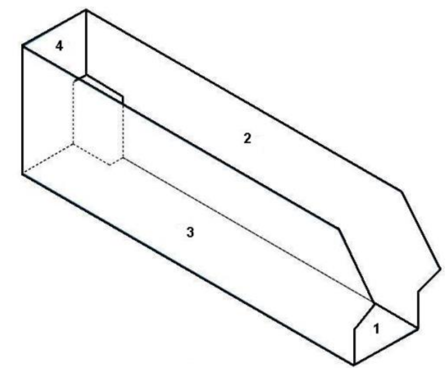
Effect of bend lines orientation on flat pattern designs

Optimality Based on Welding Cost

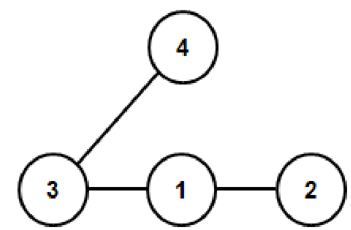
- Welding Cost Metric (WCM): Selects the flat layout with minimum welding cost based on edges length.
- If all the long edges for flat pattern are produced by folding, the cost to weld such a structure will be minimum compared to other patterns where most of the long edges are set as weld lines.
- Minimum Spanning Tree (MST) algorithm (Prim's Algorithm), conducted during topological analysis.
- $WCM = \sum_{1}^{k} W_{i\,(MST)}$

*Where, **W**$_{i(MST)}$ the weight assigned for edge i in the minimum spanning tree. **k** is the total number of edges in a spanning tree.*

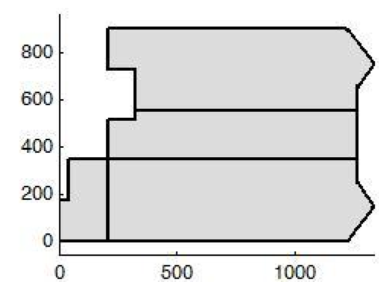
3-D Sheet Metal Enclosure



Spanning Tree 5 (MST)



Flat Pattern 5



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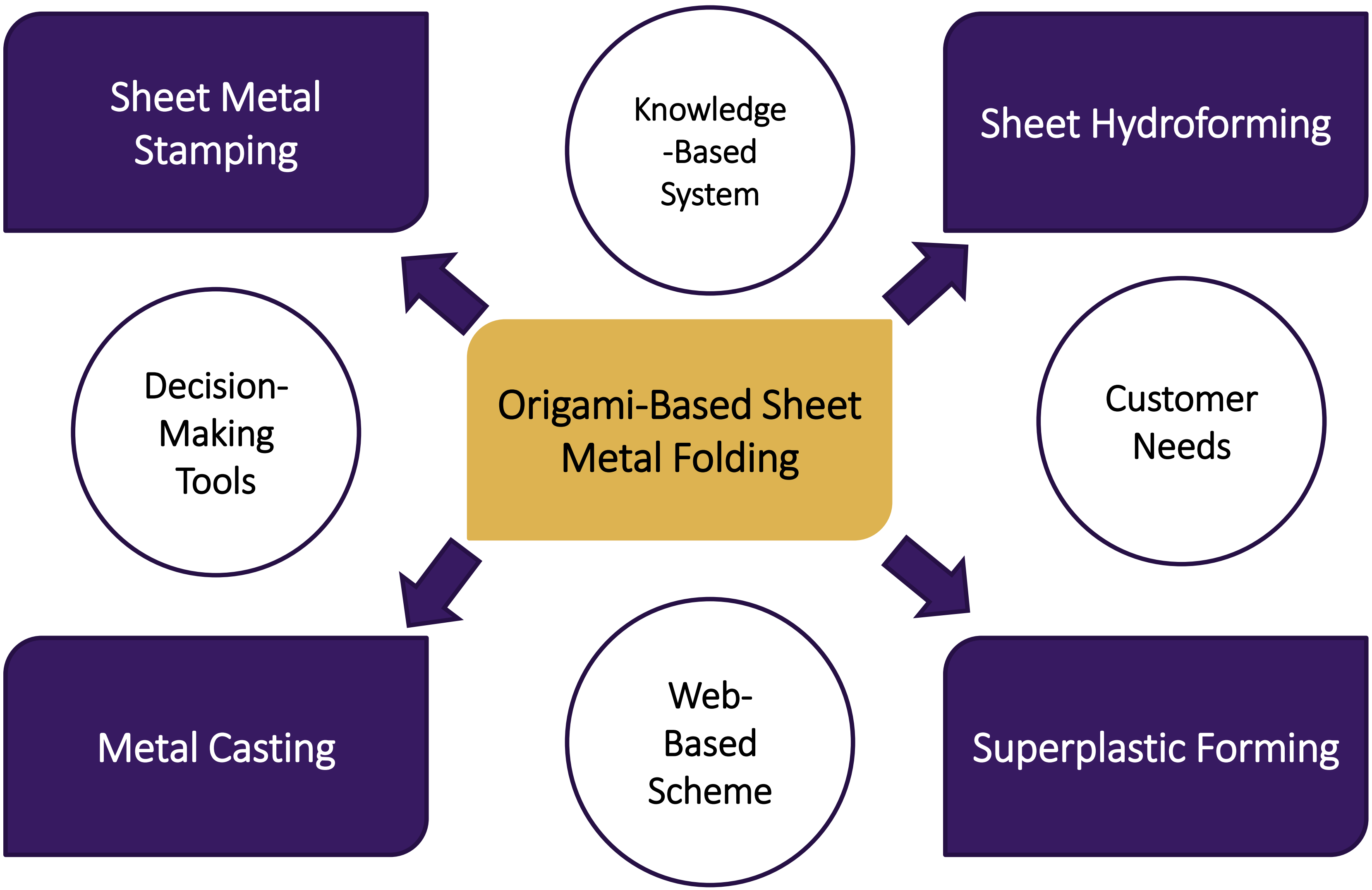
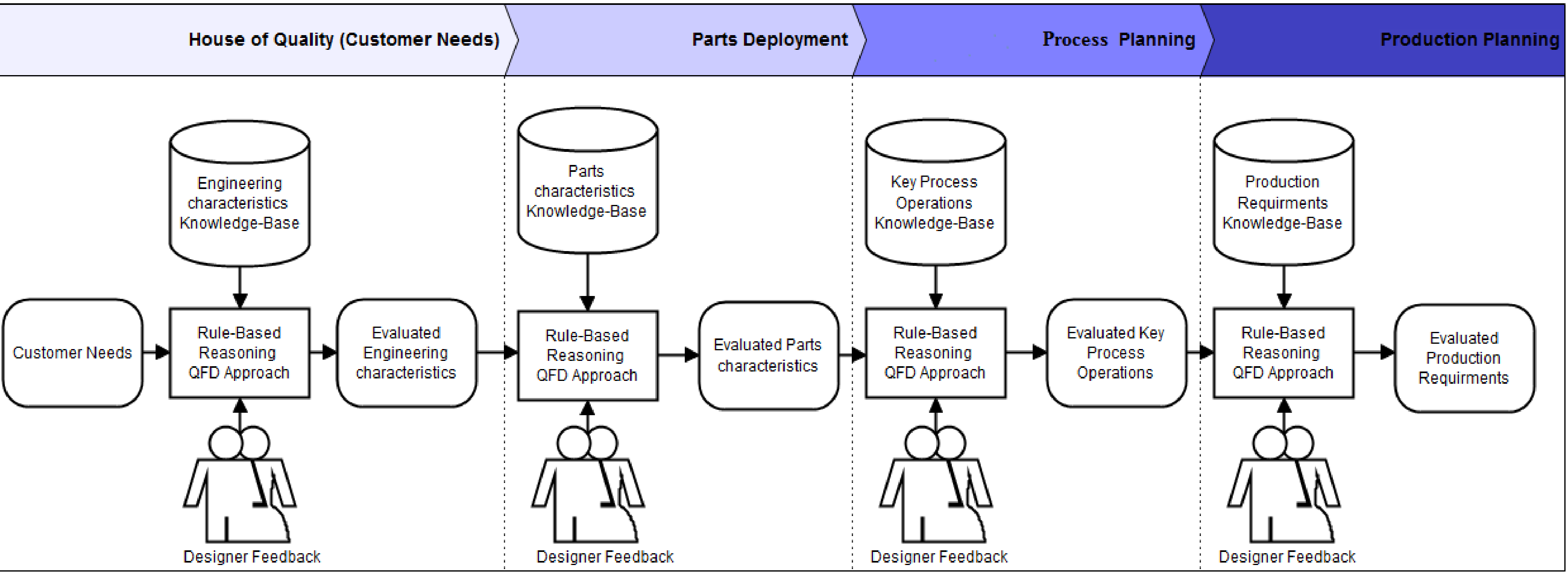
Comparative Analysis for Origami-Based Folding Process



Deriving Production Line Requirements from Customer Needs



Qattawi, A., Mayyas, A.T., Abdelhamid, M., Omar, M., "Intelligent Automotive System Design Using Quality Function Deployment and Analytical Hierarchy Process", International Journal of Computer Integrated Manufacturing, DOI:10.1080/0951192X.2013.799780, (2013).

Production Requirements

- Number of Components
- Variability in Dimensions
- Usage of Common Platform
- Change Over Time
- Consolidation of Components
- Open Architecture Control
- Uniformity in Material Selection
- Intricate Shapes
- Nesting Optimization
- Intra-cell & inter-cell distance

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Can Origami-Based Folding be the Natural Process to Produce Sheet Metal?

Research

Mechanical Behavior Under Loading	Effect of Material Discontinuities	Optimized Process Sequence

Research Pillars

Investigating the merits of Origami-based sheet metals for load bearing components

Material Type	Design
Mechanical Proprieties	Energy & Time Requirements