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Concurrent Manufacturing Process Selection for Natural Fiber Thermoplastic Composites

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Concurrent Manufacturing Process Selection

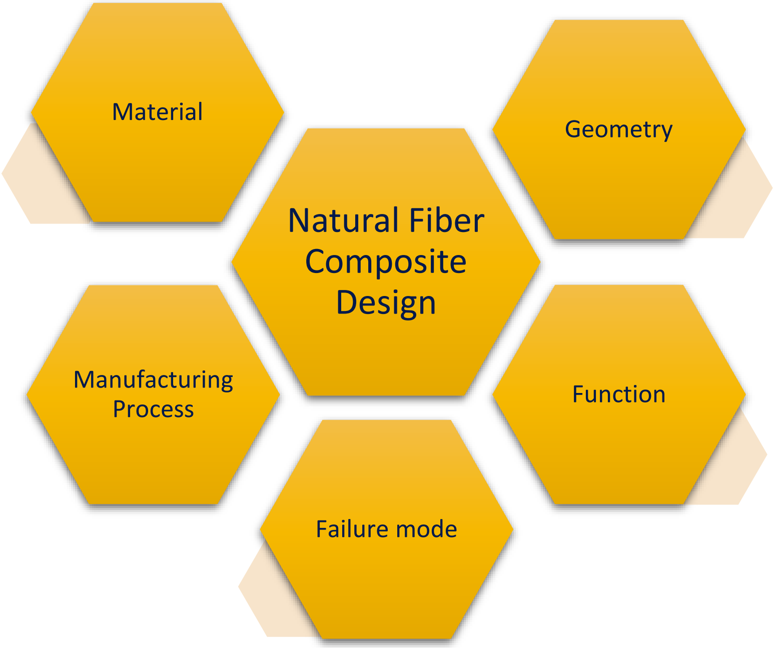


Fig. 1 Elements for natural fiber polymer reinforced composite design

Concurrent Manufacturing Process Selection

Stage 1: Identification of process path

- Determination of manufacturing requirements

Stage 2: Ranking the potential manufacturing processes using Analytic Hierarchy Process

- Sensitivity analysis is carried out to verify the evaluation

Fig. 2 **Flow chart of manufacturing process selection for natural fibre composite product**

Concurrent Manufacturing Process Selection

- Goal: Selecting the best manufacturing process
  - Level 2: Geometry limitation (L: .151)
    - Level 3: Complexity (L: .584)
    - Level 3: Mass (L: .135)
    - Level 3: Wall thickness (L: .281)
  - Level 2: Process Capability (L: .075)
    - Level 3: Surface finish (L: .250)
    - Level 3: Tolerance (L: .750)
  - Level 2: Cost control (L: .265)
    - Level 3: Capital cost (L: .637)
    - Level 3: Labor cost (L: .105)
    - Level 3: Tooling cost (L: .258)
  - Level 2: Process performance (L: .508)
    - Level 3: Production rate (L: .200)
    - Level 3: Production volume (L: .200)
    - Level 3: Processing time (L: .600)

Fig. 3Hierarchical framework for selecting the best manufacturing process for the automotive anti-roll bar with their weightage

General Requirements	Specific Requirements	Details
Geometry limitation	Complexity	Production of a complex shape would require a sophisticated manufacturing technique; either it should be integrated or require advanced equipment [47].
	Mass	Size of the design is measured by mass, where some large designs would require an additional process due to fundamental equipment mechanism restrictions [12].
	Wall thickness	The viscosity and fluid flow of the liquid materials would influenced by the thickness of the design [12]. Manufacturing tools are designed particularly to have a range of thicknesses to overcome the related concerns. Selection of a suitable manufacturing process would lower the cost and time.

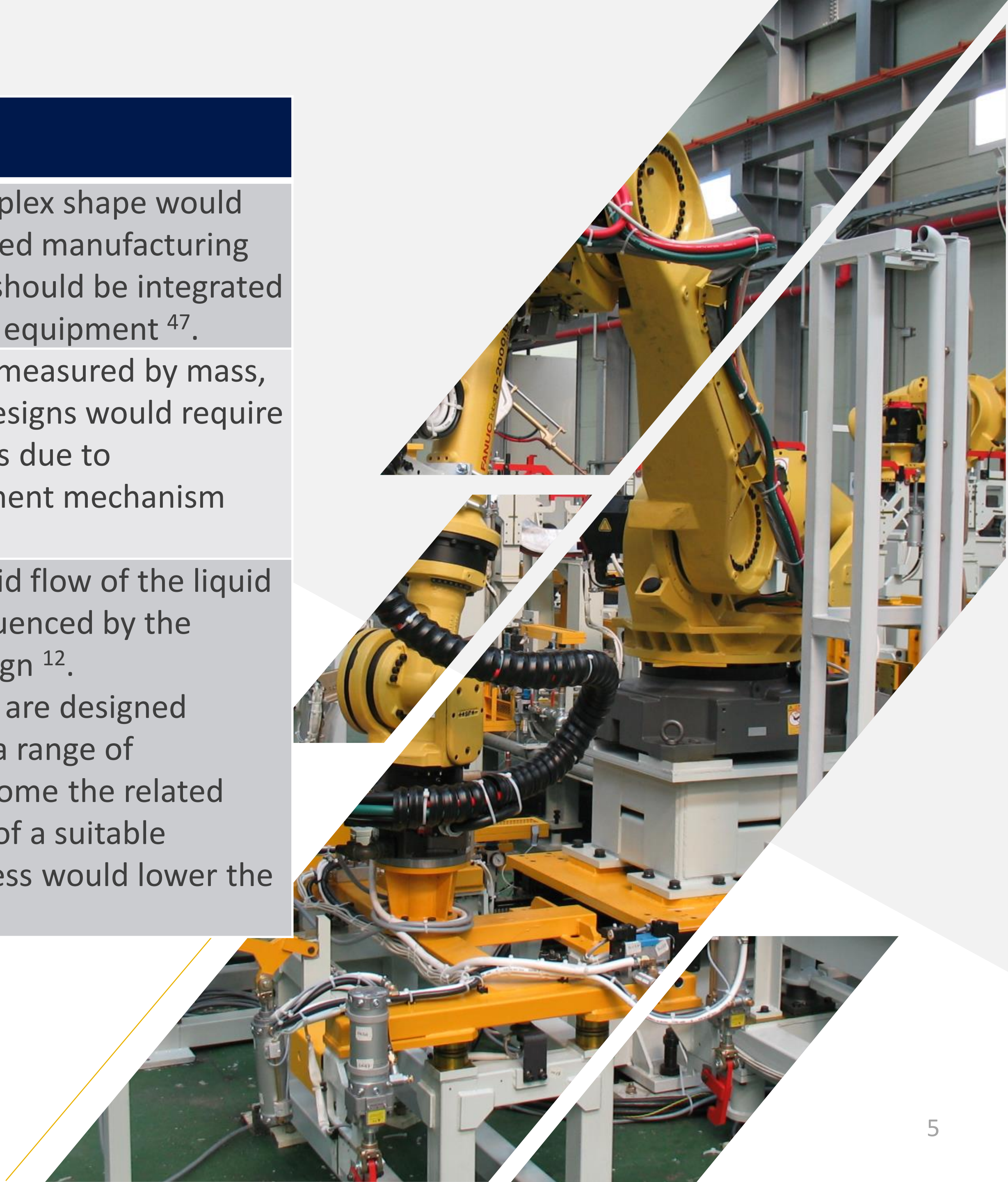


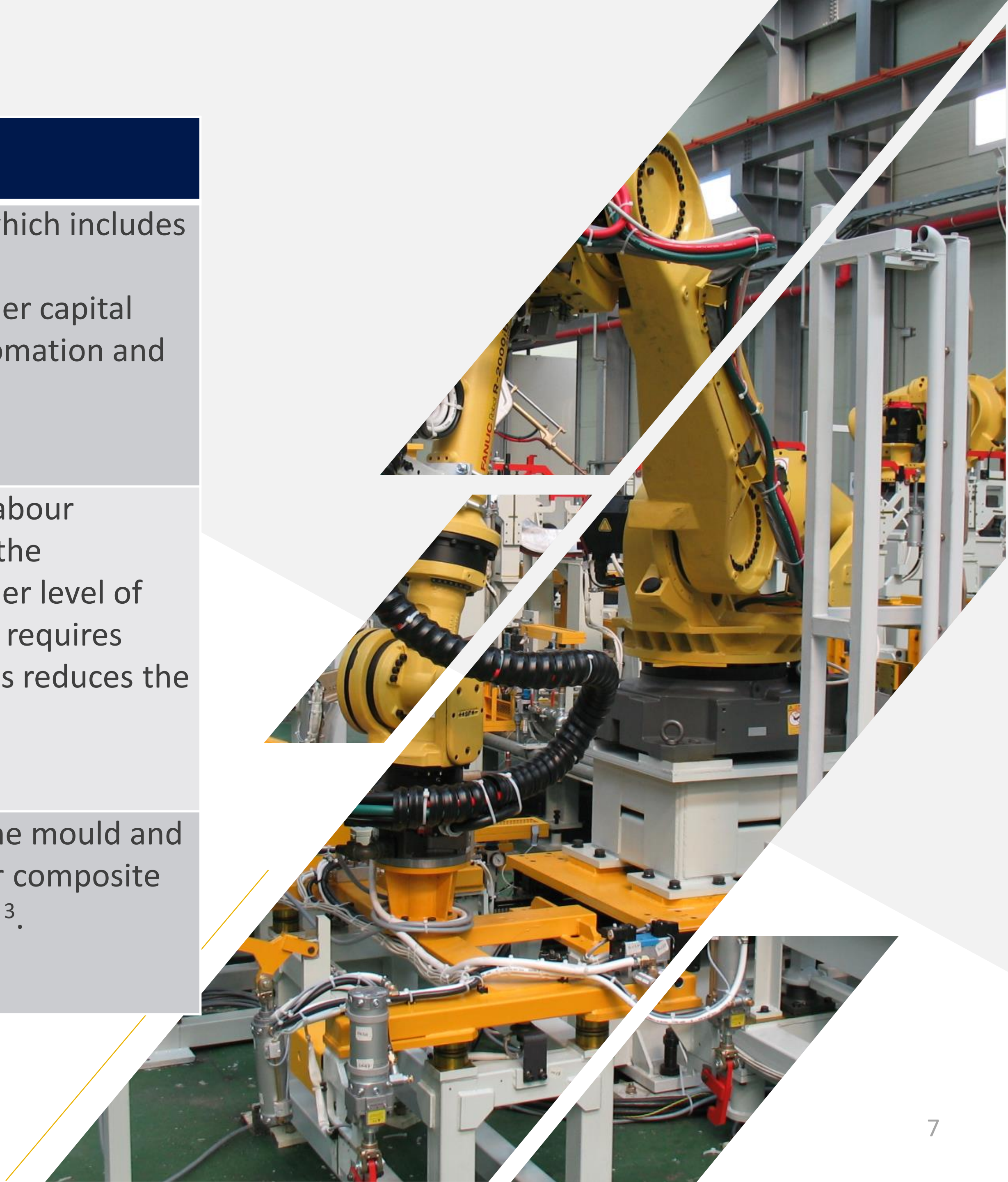
Table 1. Manufacturing requirements of the natural fibre composite automotive anti-roll bar

General Requirements	Specific Requirements	Details
Process capability	Surface finish	Surface finish measures the roughness and smoothness of the design surface after the manufacturing process. A good surface finish would not require secondary processes such as machining and grinding that add cost and time [12].
	Tolerance	Precision of the tools would imply the tolerances that would fit the design and the quality of the product [26].

Table 1. Manufacturing requirements of the natural fibre composite automotive anti-roll bar (continued)

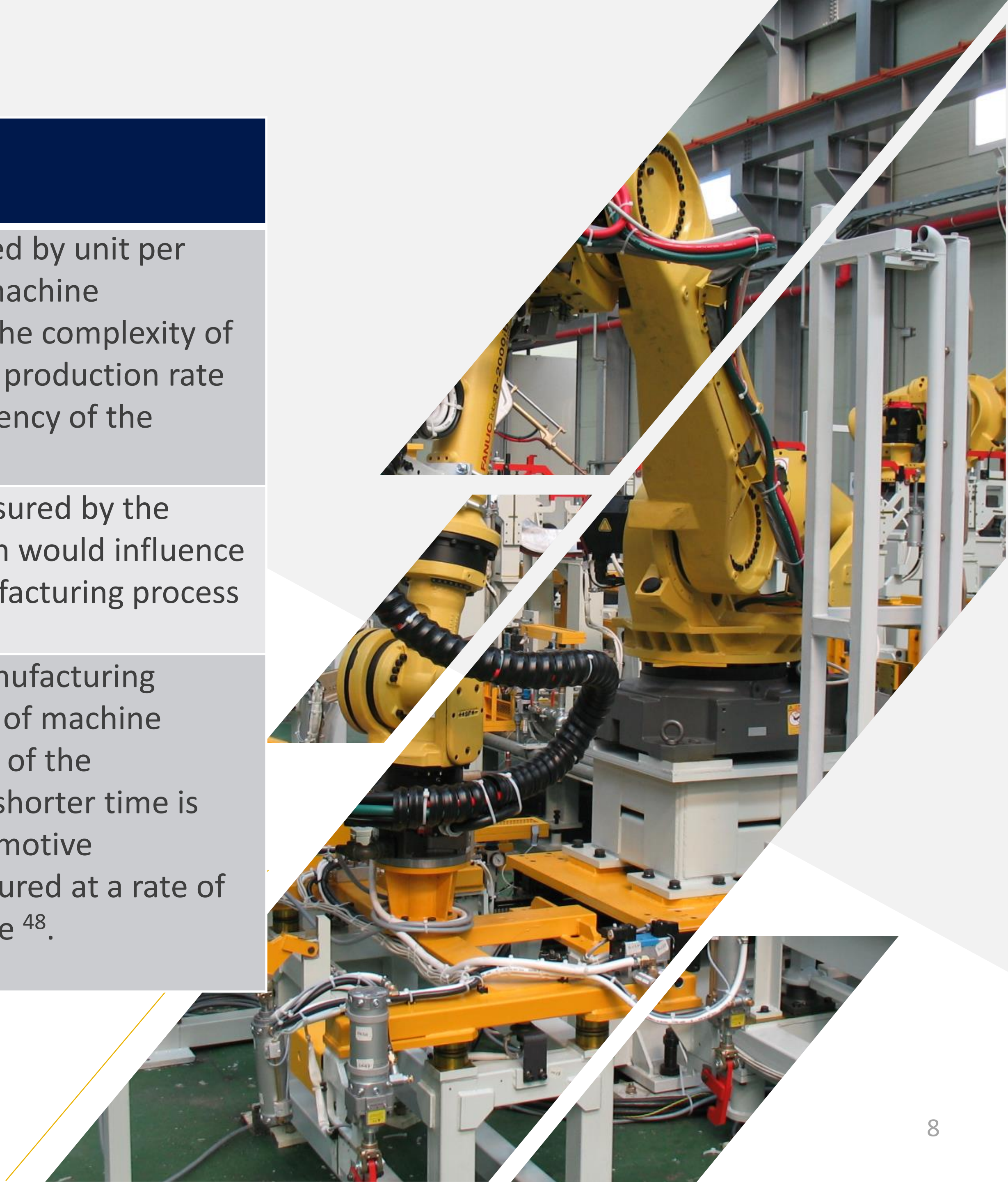
General Requirements	Specific Requirements	Details
Cost control	Capital cost	Capital cost is the total cost, which includes the equipment to perform the manufacturing process. A higher capital cost indicates the level of automation and size of the equipment [12].
	Labour cost	Labour cost would imply the labour intensity required to perform the manufacturing process. A higher level of automated equipment usually requires lower labour intensity and thus reduces the labour cost [12].
	Tooling cost	Tooling cost includes cost of the mould and its accessories for the polymer composite design manufacturing process [3].

Table 1. Manufacturing requirements of the natural fibre composite automotive anti-roll bar (continued)



General Requirements	Specific Requirements	Details
Process performance	Production rate	Production rate is measured by unit per hour as an output of the machine performance and implies the complexity of the process path. A higher production rate would also imply the efficiency of the manufacturing process [12].
	Production volume	Production volume is measured by the economic batch size, which would influence time and cost of the manufacturing process [12].
	Processing time	Processing time of the manufacturing process indicates the level of machine performance and intensity of the manufacturing process. A shorter time is desired, as generally automotive components are manufactured at a rate of one component per minute [48].

Table 1. Manufacturing requirements of the natural fibre composite automotive anti-roll bar (continued)



Properties	BMC moulding	Injection moulding (thermoplastics)	Resin transfer moulding	Reaction injection moulding	Polymer casting
Mass range (kg)	0.03 - 60	0.01 - 25	0.8 - 50	0.5 - 25	0.1 - 700
Range of section thickness (mm)	1.5 - 25	0.4 - 6.3	2-6	2-25	6.25 - 600
Tolerance (mm)	0.12 - 1	0.1 - 1	0.25 - 1	0.1 - 1	0.8 - 2
Roughness (µm)	0.1 - 1.6	0.2 - 1.6	0.1 - 1.6	0.2 - 1.6	0.5 - 1.6
Shape complexity	3	5	5	5	5
Production rate (units) (/hr)	12-60	60 - 3000	1-8	6-60	1-10
Economic batch size (units)	5000 - 1e6	10000 - 1e6	500 - 5000	100 - 10000	10 - 1000
Processing time	Medium	High	Low	Low	Low
Labour intensity	Medium	Low	High	Medium	Medium
Capital cost (USD)	66000 - 566000	37700 - 848000	9430 - 56600	18900 - 189000	566 - 5660
Tooling cost (USD)	9430 - 189000	3770 - 94300	943 - 3770	943 - 9430	94.3 - 3770

Table 2. Manufacturing process properties (Granta Design, 2013)

Concurrent Manufacturing Process Selection

Polymer Casting

Compare the relative importance with respect to: Level 2: Process performance \ Level 3: Processing time

Injection Molding

	BMC Moldi	Resin Tran	Reaction Ir	Polymer Ca	Injection M
BMC Molding		1.67	1.0	2.5	1.8
Resin Transfer Molding			1.67	1.5	3.0
Reaction Injection Molding				2.5	1.8
Polymer Casting					4.5
Injection Molding		Incon: 0.00			

Fig. 4Comparison on a pairwise basis of the manufacturing process with respect to processing time

Concurrent Manufacturing Process Selection

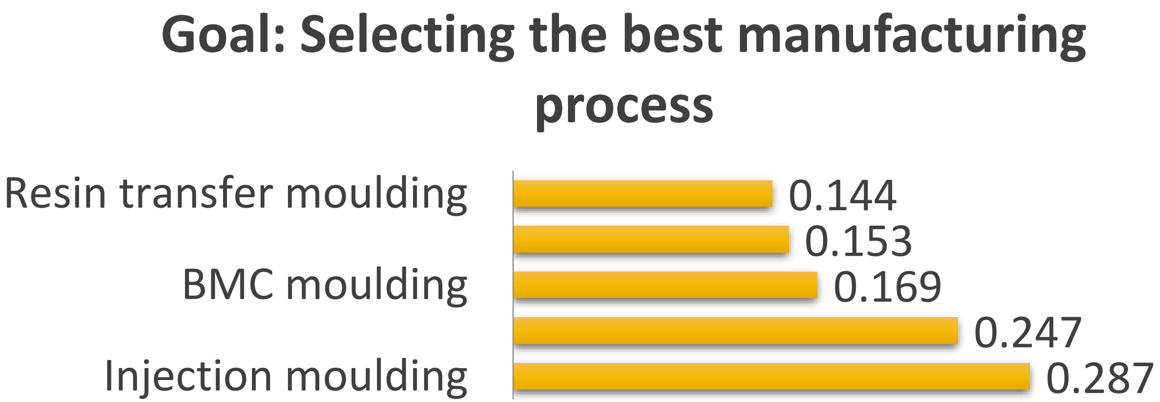


Fig. 5 Ranking of the manufacturing process

Concurrent Manufacturing Process Selection

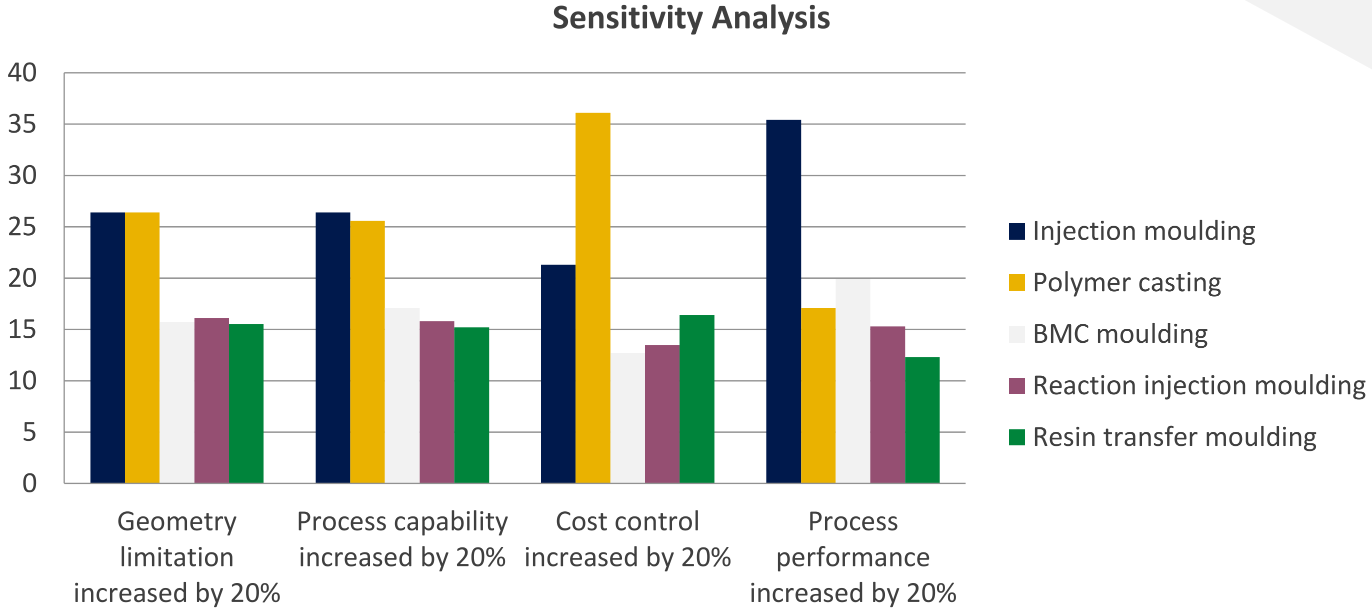


Fig. 6 **Graph of sensitivity analysis on judgement towards selecting the best manufacturing process**

Limitation

- Material selection and manufacturing process selection should be performed simultaneously as a new framework should be created.
- In this study, there is lack of information regarding on the selection of natural fibres.
- Moreover, design geometry or shape of the product also should be selected together in parallel of making decision for the suitable manufacturing process.

Conclusions

- In conclusion, the process of selecting a manufacturing process for a natural fibre composite-based product requires interaction between each of the design elements.
- Interaction in the design composition would imply the better quality and high performance of a design composite-based product where all the critical issues regarding the materials, function, failure mode, geometry and process are considered simultaneously.

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Thank You.

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